U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2017 Annual Merit Review, Vehicle Technologies Office

Results Report

October 2017

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Table of Contents

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Introduction

The 2017 U.S. Department of Energy (DOE) Hydrogen and Fuel Cells Program and Vehicle Technologies Office (VTO) Annual Merit Review and Peer Evaluation Meeting (AMR) was held June 5-9, 2017, in Washington, DC. The review encompassed work done by the Hydrogen and Fuel Cells Program and VTO: 263 individual activities were reviewed for VTO by 191 reviewers. Exactly 1,241 individual review responses were received for the VTO technical reviews.

The objective of the meeting was to review the accomplishments and plans for VTO over the previous 12 months, and provide an opportunity for industry, government, and academia to give inputs to DOE with a structured and formal methodology. The meeting also provided attendees with a forum for interaction and technology information transfer.

The peer review process followed the guidelines of the Peer Review Guide developed by the Office of Energy Efficiency and Renewable Energy (EERE). Each activity is reviewed every three years, at a minimum. However, VTO strives to have every activity reviewed every other year. The reviewers for the technical sessions were drawn from a wide variety of backgrounds, including current and former vehicle industry members, academia, government, and other expertise areas. Each reviewer was screened for conflicts of interest as prescribed by the Peer Review Guide. A complete list of the meeting participants is presented as Appendix A.

Evaluation Criteria—Research & Development Subprogram Projects

In the technical research and development (R&D) subprogram sessions, reviewers were asked to respond to a series of specific questions regarding the breadth, depth, and appropriateness of the VTO R&D activities. The technical questions are listed below, along with appropriate scoring metrics. These questions were used for all formal VTO R&D project reviews.

Question 1. Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve approach significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 2. Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress toward DOE goals. (Scoring weight for overall average = 40%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 3. Collaboration and coordination with other institutions. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (close, appropriate collaboration with other institutions; partners are full participants and well-coordinated)
- 3.5=Excellent (good collaboration; partners participate and are well-coordinated)
- 3.0=Good (collaboration exists; partners are fairly well-coordinated)
- 2.5=Satisfactory (some collaboration exists; coordination between partners could be significantly improved)
- 2.0=Fair (a little collaboration exists; coordination between partners could be significantly improved)
- 1.5=Poor (most work is done at the sponsoring organization with little outside collaboration; little or no apparent coordination with partners)
- 1.0=Unsatisfactory (no apparent coordination with partners).

Question 4. Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please select N/A. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)

- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 5. Relevance—does this project support the overall DOE objectives of petroleum displacement? (Scoring weight, not included with overall average = 20%)

- Yes
- No.

Question 6. Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

- Excessive
- Sufficient
- Insufficient.

Evaluation Criteria—Technology Integration Projects

Reviewers for the Technology Integration (TI) technical session answered questions tailored to TI's 2017 AMR focus on petroleum reduction technologies and practices, alternative fuels, infrastructure, and related efforts. These technical questions are listed below, along with appropriate scoring metrics.

Question 1. Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing the technical barriers identified in the 2016-2020 EERE Strategic Plan. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (project objectives are sharply focused on supporting DOE/VTO goals of reducing reliance on petroleum based fuels and reducing emissions; project has a direct and substantial impact upon addressing technical barriers; difficult to improve project objectives significantly)
- 3.5=Excellent (project objectives are effective; project addresses a significant number of technical barriers; effectively contributes to reducing reliance on petroleum based fuels and reducing emissions)
- 3.0=Good (project objectives are generally effective, but could be improved; project addresses some technical barriers; contributes to reducing reliance on petroleum based fuels and reducing emissions)
- 2.5=Satisfactory (project objectives have some weaknesses; project addresses some technical barriers; project may have some impact contributing to reducing reliance on petroleum based fuels and reducing emissions)

- 2.0=Fair (project objectives have significant weaknesses; project addresses few barriers; project may have a small impact contributing to reducing reliance on petroleum based fuels and reducing emissions)

- 1.5=Poor (project objectives are minimally responsive to DOE/VTO objectives; project does not address barriers; project is unlikely to contribute to reducing reliance on petroleum based fuels and reducing emissions)

- 1.0=Unsatisfactory (project objectives are not responsive to DOE/VTO objectives; project fails to address any barriers; project is highly unlikely to contribute to reducing reliance on petroleum based fuels or reducing emissions).

Question 2. Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (project approach is sharply focused on achieving project objectives; difficult to improve project approach significantly)

- 3.5=Excellent (effective; project approach contributes to achieving the majority of project objectives)

- 3.0-Good (generally effective but project approach could be improved; contributes to achieving some of the project objectives)

- 2.5=Satisfactory (has some weaknesses; project approach contributes to achieving some project objectives)

- 2.0=Fair (has significant weaknesses; project approach may have some impact on achieving project objectives)

- 1.5=Poor (minimally responsive to project objectives; project approach is unlikely to contribute to achieving project objectives)

- 1.0=Unsatisfactory (not responsive to project objectives; project approach is highly unlikely to contribute to achieving project objectives).

Question 3. Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals. (Scoring weight for Project Accomplishments = 40%)

- 4.0=Outstanding (project demonstrates significant accomplishments; strong progress toward achieving both project and DOE objectives; difficult to improve progress significantly)

- 3.5=Excellent (project demonstrates many accomplishments; very effective progress toward achieving overall project objectives and DOE goals)

- 3.0=Good (project accomplishments are generally effective; progress is on schedule to contribute to some project objectives and DOE goals)

- 2.5=Satisfactory (project has some accomplishments, but also displays some weaknesses; progress could be improved; contributes to some project objectives and DOE goals)
- 2.0=Fair (project has few accomplishments and demonstrates significant weaknesses; rate of progress is slow; minimal contribution to project objectives or DOE goals)
- 1.5=Poor (minimal demonstration of accomplishments; progress is significantly behind schedule; unlikely to contribute to project objectives or DOE goals)
- 1.0=Unsatisfactory (project demonstrates no accomplishments; limited or no demonstrated progress; not responsive to project objectives).

Question 4. Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners. (Scoring weight for Collaboration and Coordination = 10%)

- 4.0=Outstanding (sharply focused on collaboration among project team members; team is well-suited to effectively carry out the work of the project and have strong working relationships; no notable weaknesses)
- 3.5=Excellent (effective; team members meaningfully contribute to carrying out the work of the project, are well-suited to perform the work and have excellent working relationships)
- 3.0=Good (generally effective but could be improved; collaboration exists; team members are fairly well-suited to project work and have good working relationships)
- 2.5=Satisfactory (has some weaknesses; collaboration among team members is satisfactory for carrying out the work of the project; project partnerships, team members and working relationships could be improved)
- 2.0=Fair (has significant weaknesses; little collaboration exists and team could be improved)
- 1.5=Poor (minimally responsive; little collaboration exists and team lacks effective working relationships)
- 1.0=Unsatisfactory (little or no apparent collaboration between team members; project team is lacking critical expertise to effectively carry out the work of the project).

Question 5. Market Impact and sustainability—the degree to which the project has already contributed, as well as the potential to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies. (Scoring Weight for Market Impact=10%).

- 4.0=Outstanding (sharply focused on critical barriers and effective information products; clearly contributes to alternative fuel vehicle market expansion and/or petroleum/greenhouse gas reduction; difficult to improve significantly)

- 3.5=Excellent (effective; contributes to overcoming most barriers and informing appropriate audiences; contributes to alternative fuel vehicle market expansion and/or petroleum/greenhouse gas reduction)

- 3.0=Good (generally effective in overcoming barriers and providing information; has the potential to contribute to alternative fuel vehicle market expansion and/or petroleum/greenhouse gas reduction)

- 2.5=Satisfactory (has some weaknesses; may contribute to market improvements and/or petroleum/greenhouse gas reduction but needs better focus on overcoming some barriers and targeting appropriate audiences)

- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers and reducing petroleum consumption/greenhouse gas emissions)

- 1.5=Poor (minimally responsive; unlikely to advance an alternative fuel vehicle market or contribute to petroleum. reduction/greenhouse gas efforts)

- 1.0=Unsatisfactory (not responsive to eliminating barriers or providing information that will advance an alternative fuel vehicle market or lead to petroleum/greenhouse gas reductions).

Question 6. Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

- Yes

- Maybe

- No.

Project Scoring

R&D Subprogram Projects

For R&D subprogram sessions, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 4 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 4 were averaged to provide information on the project's question-by-question scoring. Scores for each of these four criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.40] +

[Question 3 Score x 0.10] + [Question 4 Score x 0.10]

Each reviewed activity has a corresponding bar chart representing that project's average scores for each of the four designated criteria. As demonstrated in Figure 1, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

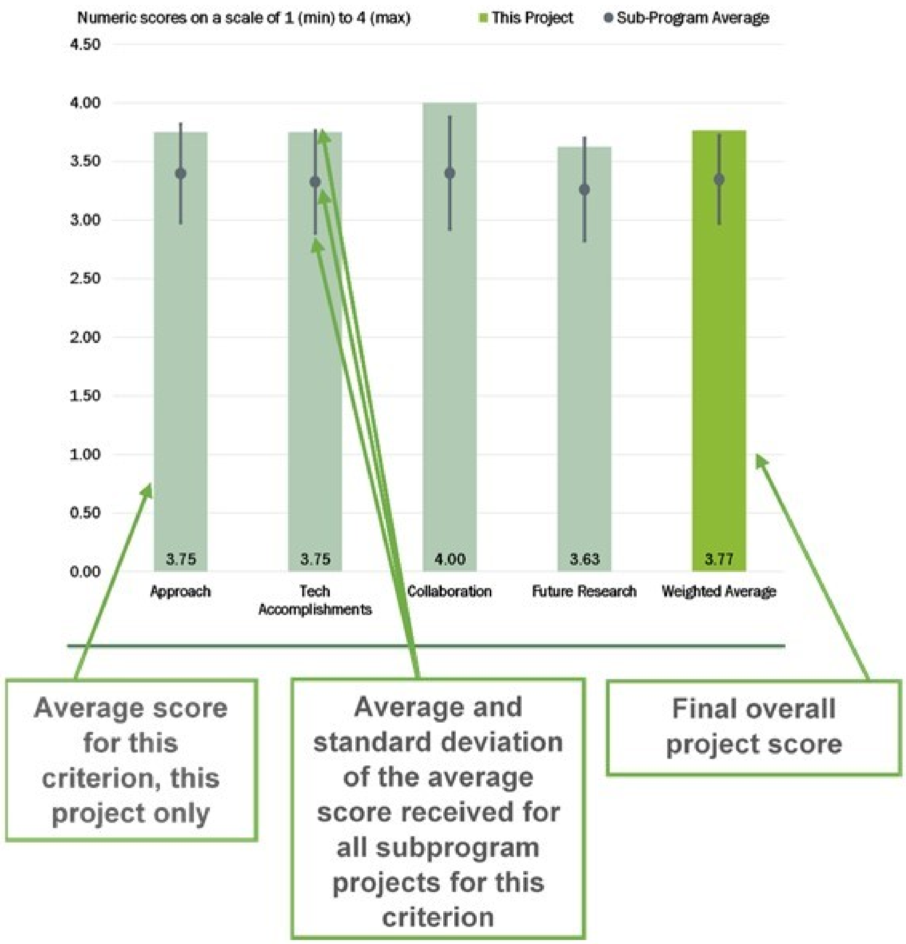

Figure 1. Sample Question 1 through Question score averages, standard deviations, and overall Weighted Average for an R&D project.

Reviewers were also asked to evaluate a given project's relevance and funding through Question 5 and Question 6, which were each scored on a different scale than Question 1 through Question 4. For the R&D subprogram sessions, while Question 1 through Question 4 were rated on a 1.0 to 4.0 scale in one-half point increments, Question 5 was rated on a yes or no scale, and Question 6 was rated on an excessive, sufficient, or insufficient scale. Consequently, Question 5 and Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible. As demonstrated in Figure 2, each reviewed activity has pie charts representing that project's population distributions for each reviewer rating associated with Question 5 and Question 6.

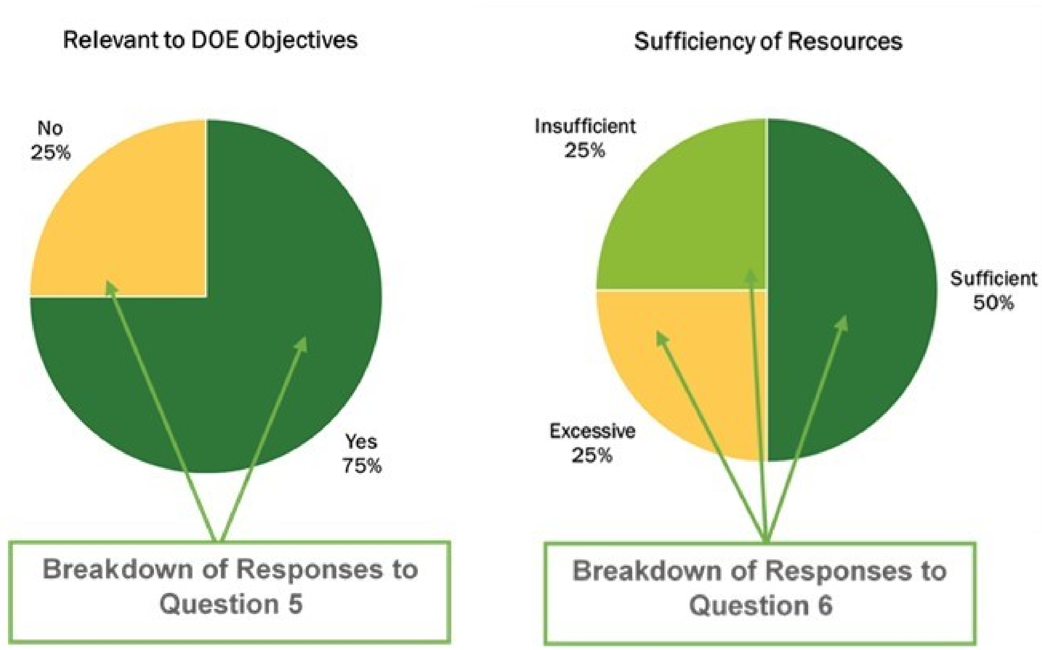

Figure 2. Sample Question 5 and Question 6 population distribution for R&D subprogram project.

TI Subprogram Projects

For the TI subprogram session, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 5 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 5 were averaged to provide information on the project's question-by-question scoring. Scores for each of these five criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.20] +

[Question 3 Score x 0.40] + [Question 4 Score x 0.10] + [Question 5 Score x 0.10]

Each reviewed TI activity has a corresponding bar chart representing that project's average scores for each of the five designated criteria. As demonstrated in Figure 3, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

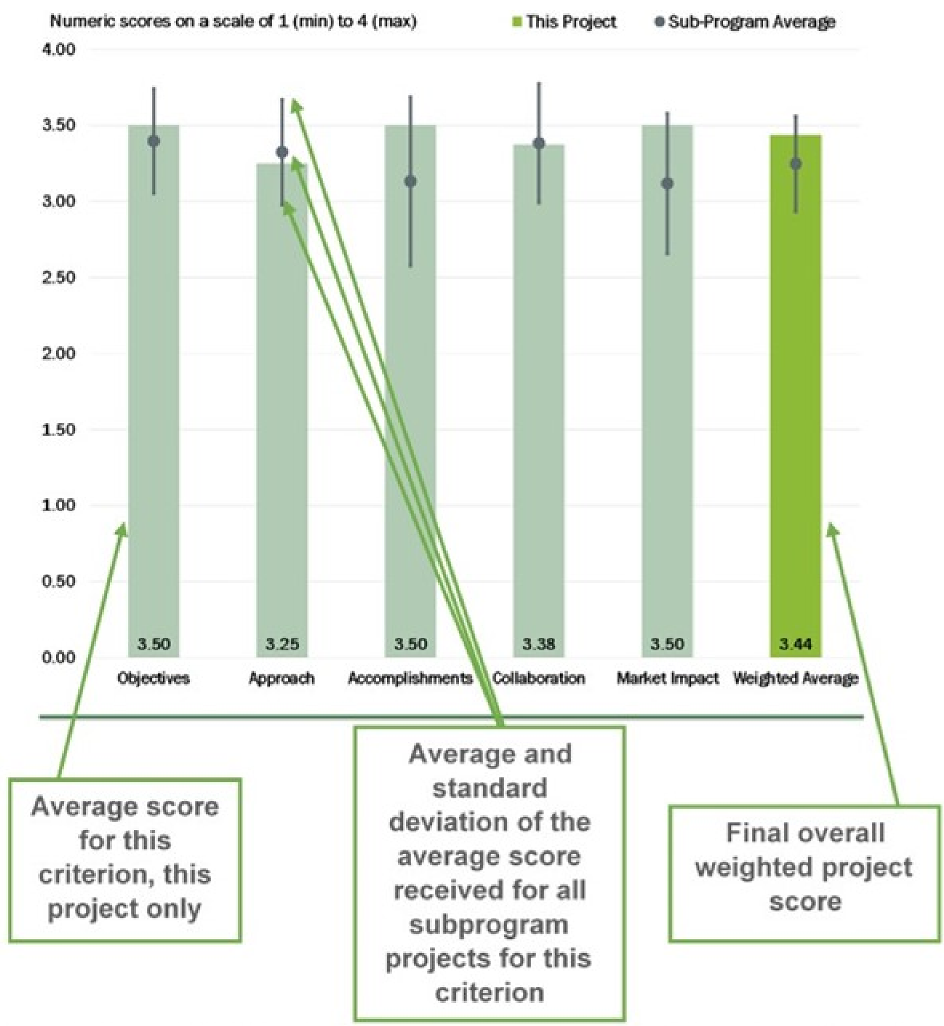

Figure 3. Sample Question 1 through Question 5 score averages, standard deviations, and overall Weighted Average for a TI subprogram project.

For TI projects, Question 1 through Question 5 were rated on a 1.0 to 4.0 scale in one-half point increments, whereas Question 6 was rated on a yes, maybe, or no scale. Consequently, Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible. As demonstrated in Figure 4, similar to the R&D subprograms, each reviewed activity for TI projects has a pie chart representing that project's population distributions for each reviewer rating associated with Question 6.

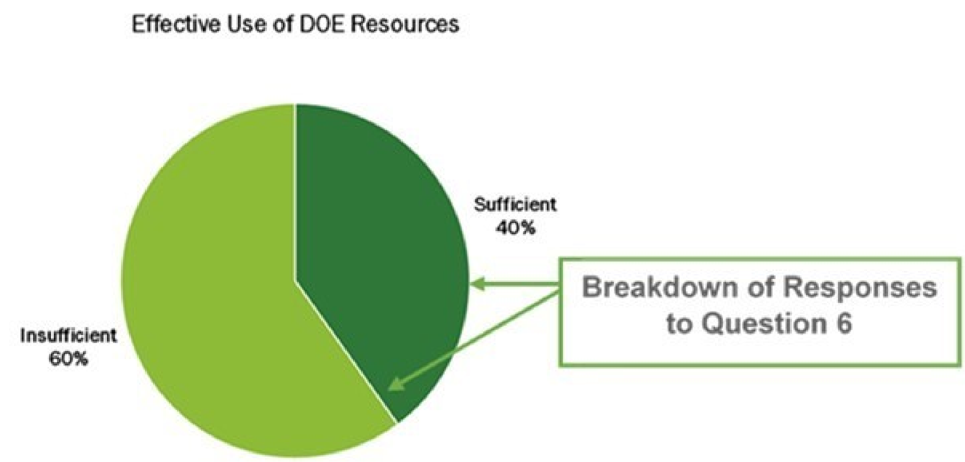

Figure 4. Sample Question 6 population distributions for TI Resources question.

Reviewer Responses

Text responses and numeric scores to the questions were submitted electronically through a web-based software application, PeerNet, operated by Oak Ridge Associated Universities (ORAU). Database outputs from this software application were analyzed and summarized to collate the multiple-choice, text comments, and numeric scoring responses and produce the summary report.

Responses to the questions are summarized in this report, with summaries of numeric scores for each technical session, as well as text and graphical summaries of the responses for each individual technical activity. For each project, the reviewer sample size is identified.

Each reviewed activity is identified by Presentation Number, followed by the Presentation Title, the Principal Investigator (PI), and the PI's organization. For each subprogram area, reviewed activities are ordered numerically by project number. Figure 5, below, provides an example project title.

Presentation Number: acs002
Presentation Title: Light-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

Figure 5. Sample project title with presentation ID, presentation title, PI, and PI organization.

For each project, in addition to the PI, the presenter at the AMR is identified, along with the reviewer sample size. For some projects, the presenter at the AMR was a project team member rather than the PI.

Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc.

Note that for each question the order of reviewer comments may be different; for example, for each specific project the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc. Not all reviewers provided a response to each question for a given project.

The report is organized by technical subprogram area. Each technical area section includes a summary of that subprogram, reviewer feedback received specific to the subprogram overview presentation(s) given by DOE, a subprogram activities score summary table (and page numbers), and project-specific reviewer evaluation comments with corresponding bar and pie charts

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1. Advanced Combustion Systems

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Advanced Combustion Systems (ACS) subprogram supports early-stage R&D to improve our understanding of, and ability to manipulate, combustion processes, generating knowledge and insight necessary for industry to develop the next generation of engines and fuels. The ACS subprogram utilizes unique facilities and capabilities at national laboratories to develop knowledge, new concepts and research tools that industry can use to develop advanced combustion engines. Facilities include the Combustion Research Facility at Sandia National Laboratories (SNL), the Advanced Photon Source at Argonne National Laboratory (ANL), the Institute for Integrated Catalysts at Pacific Northwest National Laboratory (PNNL), and the Spallation Neutron Source at Oak Ridge National Laboratory (ORNL). Major activities include: predictive modeling; experimental combustion including fuels and engines; and emission control. Predictive, high-fidelity models simulate the fundamental physics of fuel injection sprays, heat transfer, turbulence and combustion phenomena using high-performance computing resources. Experimental combustion processes develop data to establish quantitative relationships between fuel properties and efficiency improvement potential for engines operating in advanced compression ignition and multi-mode spark ignition/compression ignition regimes. Emission control experiments are conducted using high-resolution microscopy to understand chemical reactions at the atomic level on catalyst surfaces and within the catalysts that have the potential to reduce emissions at low exhaust temperatures.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: acs000 Presentation Title: Overview of the VTO Advanced Combustion Systems Program
Principal Investigator: Gurpreet Singh (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer said yes, that strategy, drivers, specific approaches, plans, challenges, and accomplishments were all covered.

Reviewer 2:
The reviewer stated that, yes, these topics were adequately covered.

Reviewer 3:
The reviewer believed that these topics were adequately covered.

Reviewer 4:
The reviewer remarked that the program area and strategy were well-covered. Background on fuel consumption was nicely presented. The three-pronged approach of fundamental combustion, aftertreatment, and cost reduction seemed reasonable to the reviewer. However, the reviewer pointed out several potential issues. The 2009 baseline presented was obsolete. The U.S. Environmental Protection Agency (EPA) is using 2015 in its Technical Assessment Report. On heavy-duty (HD) vehicles, this is a false baseline, as efficiency improved significantly when selective catalytic reduction (SCR) was added in 2010. The reviewer also questioned whether DOE should be concerned at this stage about costs. The reviewer suggested that DOE ought to keep costs in mind, but offer technical solutions and let industry cost reduce these options.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer commented that the role of DOE and the national laboratories R&D should primarily be focused on mid- and long-term R&D, while very near-term development and/or commercialization is the role of industry. The current program balance appeared, to the reviewer, to be consistent with this viewpoint.

Reviewer 2:
The reviewer said that it was well balanced.

Reviewer 3:
The reviewer stated that there appears to be appropriate balance. The reviewer also stated that the program would benefit from the integration of control technologies into being part of the program. This will be especially important for improving transient operations.

Reviewer 4:
The reviewer commented that project scopes seemed well-balanced. This reviewer argued there is little here for near-term (0 to 5 years) but that was acceptable. A zero to three-year timeframe “left the station.” A four to five-year timeframe would be CTS, some of the work at ANL on gasoline direct injection (GDI) particulate number (PN), lean burn, and fuel injector visualization and resolution. Medium term is most of the light-duty (LD) vehicle combustion work. Long term scopes would be all the collaboration with Basic Energy Sciences (BES), and the fundamental combustion work.

The reviewer further commented that given that plug-in electric vehicles (PEVs) are coming around the corner, it seems LD work ought to focus on the pre-2025 timeframe for implementation. For example, Japan is not doing internal combustion engine (ICE) research work after 2025.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer said that yes, the important issues and challenges were clearly identified for the various program areas (advanced combustion, emissions mitigation, and control systems, etc.).

Reviewer 2:
The reviewer stated that yes, the important issues and challenges were clearly identified.

Reviewer 3:
The reviewer commented that the important issues and challenges were identified. The program addressed the critical high-level challenges that need to be addressed for improving efficiency and reducing environmental impact. This project also realizes that the potential benefits are very large because the ICEs are predominant as power plants, and will be for decades to come.

Reviewer 4:
The reviewer reiterated that the issues identified are to maximize efficiency, work on aftertreatment gaps, and reduce cost. Emerging and future LD (and HD) powertrains will have some electrification. Given this, a missing challenge is calibrating for hybrid operation with advanced combustion regimes. It is fair to say that all LD will have some hybrid electric vehicle (HEV) operation in 2025 and beyond, so the reviewer questioned what these challenges would be.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer stated that yes, the plans for the various program areas were discussed.

Reviewer 2:
The reviewer said the plans were identified.

Reviewer 3:
The reviewer remarked that plans were presented at a very high level, which is appropriate for the scope of this presentation.

Reviewer 4:
The reviewer commented that the plans on fundamental low-temperature combustion (LTC) are impressive and yielded interesting results. The LD combustion projects cover the main opportunities. However, as suggested previously, the project ought to consider how hybridization fits in, as this may be complex and some of the combustion strategies might be enabled by it. Also, some of the aftertreatment projects might want to consider consolidation of functionality and synergies, such as zone coating and layering SCR (and diesel oxidation catalyst [DOC]) catalysts, and four-way catalyst (ANL was looking at coated gasoline particulate filters [GPF]). Also, the first layout of pre-turbo exhaust components was seen (Delphi gasoline direct compression ignition engine [GDCI]; Cummins). As DOC formulations seem to be hitting a wall when T90 is approximately 200°C, these components are a very attractive possibility. Much more fundamental work is needed on pre-turbo DOC, SCR, filters, and three-way catalyst (TWC).

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer said that yes, it was clearly benchmarked.

Reviewer 2:

The reviewer commented that progress was presented as a timeline chart covering multiple years of progress, which, for this level of presentation, is appropriate. It would be impractical to highlight individual project progress for the scope of this overview. The overall progress of this program is excellent.

Reviewer 3:

The reviewer remarked that some progress was mentioned, but not specifically over the previous year.

Reviewer 4:

The reviewer stated that it was difficult to assess this question from the presentation alone due to the many projects and progress on each. The 2050 fuel consumption projects show nominally a 25% cut due to these DOE programs versus the business as usual case, which is impressive. The chosen examples show progress, but much more is shown in the detailed presentations. The reviewer also stated that the start-up of the SuperTruck II Program is significant.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer said that yes, the projects were focused on improved engine and vehicle efficiency, reduced emissions through improved engine design and better aftertreatment systems, and cost reductions.

Reviewer 2:

The reviewer said that the projects were addressing the broad problems and barriers.

Reviewer 3:

The reviewer stated that, in general, there was a good mixture. Barriers are identified and projects are designed to address them.

Reviewer 4:

The reviewer remarked that the experimental projects were very adequate. However, the reviewer expressed that the computational projects were not so adequate.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer stated that the program area did appear to be focused, well-managed, and effective.

Reviewer 2:

The reviewer commented that yes, the programs were focused on existing VTO "needs". The reviewer, however questions whether those "needs" will be/are being re-defined to meet the new administration's priorities.

Reviewer 3:

The reviewer commented that the program area was focused. However, it was difficult to make an assessment of the level of management from an overview presentation. The reviewer's observations based on experiences outside of this review are that the program is very well managed.

Reviewer 4:

The reviewer stated that the funding seemed adequate. The programs have excellent collaboration and state-of-the-art investigations, with nothing even close to this elsewhere. As PEV costs come down and ICE costs go up, the ICE will still be used but with decreasing emphasis and impact. On the LD side, the reviewer remarked that the program needs to start shifting to this reality. Perhaps this can be accomplished by incorporating hybridization into each LD program; looking at smaller, less powerful engines (like range extenders); and looking at fundamentals of second-by-second power supplement by electric motors.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer considered a key strength to be the combined use of engine and vehicle testing and simulation and/or modeling work. No key weaknesses were given by the reviewer.

Reviewer 2:

The reviewer commented that the program brings together the fundamental capabilities of the national laboratories into conducting advanced research that industry no longer performs, yet couples the work with industry R&D efforts, who have the understanding of what is required for a technology to be incorporated in a product. There is not such a large interface with universities, unfortunately. Working groups, Memoranda of Understanding (MOUs), and research review meetings give ample opportunity for stakeholders to engage and offer input, and take important learning back to their respective R&D efforts.

Reviewer 3:

The reviewer suggested that the project needed more consideration of hybridization into the LD engine strategy, as discussed earlier. The fundamental combustion work is state-of-the-art and world-class. The reviewer did not really see much information on cost reduction, but as mentioned, this was acceptable as industry needs to choose the options offered by these DOE projects and reduce cost themselves.

Reviewer 4:

The reviewer listed a key strength as experimental diagnostics of advanced combustion engines. Several key weaknesses were listed. The computational efforts at the Sandia Combustion Research Facility (CRF) are adequate; however, the computational fluid dynamics (CFD) efforts led by ANL using the commercial code (i.e., the commercial CFD software CONVERGE) are not proper. The scientific merit and impacts of Argonne's CFD work by Sibendu Som are not up to the standard of a national laboratory. The ANL work is low-level CFD and can be easily accomplished by mediocre universities. In the meantime, the KIVA work at Los Alamos does not seem to have value or impact. Nowadays, every company, university, and national laboratory has its own in-house engine codes. The reviewer stated that it is unlikely that anyone will use the new KIVA in the future. Every institution has been migrated to Open Source Field Operation and Manipulation (OpenFOAM) for open-source code development. The inertia is too big to switch to the new KIVA. The reviewer considers it a waste of resources to continue the KIVA code development.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer stated that there seemed to be novel and innovative approaches to the barriers. The reviewer further highlighted the key value of the national laboratories is fundamental exploration of novel concepts.

Reviewer 2:

The reviewer said yes, the projects do represent novel and/or innovative ways to approach the barriers.

Reviewer 3:

The reviewer remarked that the projects are packed with creativity and novel approaches. DOE has shown flexibility and ability to adjust. One example is moving to gasoline on the Achates engine (not presented here). The reviewer suggested that scientists be given some general goals, given resources, and let them adjust to deliver results. The reviewer stated that it is acceptable to change goals, as long as the team is delivering good results.

Reviewer 4:
The reviewer noted that the experimental work is valuable, but the computational works by Argonne and Los Alamos are not novel or innovative.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer commented that excellent collaboration was obvious on all fronts. The reviewer was very impressed and stated that there were no concerns.

Reviewer 2:
The reviewer commented that appropriate partners were mentioned, such as the engine and vehicle manufacturers and energy companies in the Advanced Engine Combustion (AEC) MOU partnership; a catalyst company in the emissions catalyst R&D; and PPG for the improved tire materials.

Reviewer 3:
The reviewer said that yes, appropriate partners had been engaged.

Reviewer 4:
The reviewer said that yes, appropriate partners had been engaged.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer said yes, the program is collaborating effectively.

Reviewer 2:
The reviewer said yes, the program is collaborating effectively. This reviewer also suggested that this question should be incorporated into the previous one.

Reviewer 3:
The reviewer said yes, the program is collaborating effectively.

Reviewer 4:
The reviewer stated that good progress seemed to be made, but from the presentation material, it was not possible to determine the specific effectiveness and/or quality of the collaborations (i.e., it is theoretically possible that there is no significant collaboration with industry partners and all progress is being made by the national laboratories with minimal industry collaboration).

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer noted that it seemed that including more controls (for example, development of model based control approaches) will be an important area for improving transient performance. The reviewer asked if there fundamental barriers that need to be addressed to facilitate industry’s development of model based, proactive, and predictive control systems. It was the reviewer’s opinion that this will be an important enabler for using LTC approaches during transient operation.

Reviewer 2:
The reviewer stated that the portfolio does not have gaps. On the contrary, the reviewer commented that the work is a bit too extensive, and that computational work at ANL and Los Alamos was unnecessary.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer said that topics were being adequately addressed.

Reviewer 2:
The reviewer referenced previous comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewers either said that there were no other areas, or they reference answers to prior questions.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer stated that the program has innovative collaboration utilizing the R&D capabilities of the United States. No further recommendations were given.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer commented that the program appears to be well organized and doing effective work, maximizing the results and effectiveness within the budget that exists.

Reviewer 2:
The reviewer suggested that the Directions in Engine Efficiency and Emissions Research conference ought to be renewed. This is essential to communicating the results to industry. It was very-well attended and covered multiple areas very well. The reviewer asserted that this is a major gap and deficiency in the program.

Reviewer 3:
The reviewer commented that, regarding the computational efforts, the universities (rather than the national laboratories) should be allowed to develop advanced numerical models.

Reviewer 4:
The reviewer suggested marketing this review a little more to those organizations that can help deliver desired change (i.e., software/app developers, marketing people, leaders at the truck builders who integrate so many of these technologies, and fleets).

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 1-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs001	Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling	Mark Musculus (SNL)	1-15	3.50	3.75	3.63	3.50	**3.64**
acs002	Light-Duty Diesel Combustion	Stephen Busch (SNL)	1-18	3.00	3.13	3.00	3.00	**3.06**
acs004	Low-Temperature Gasoline Combustion (LTGC) Engine Research	John Dec (SNL)	1-22	2.75	2.88	3.50	3.13	**2.95**
acs005	Spray Combustion Cross-Cut Engine Research	Lyle Pickett (SNL)	1-25	3.40	3.30	3.60	3.30	**3.36**
acs006	Gasoline Combustion Fundamentals	Isaac Ekoto (SNL)	1-28	3.25	2.75	3.13	2.75	**2.92**
acs007	Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research	Joe Oefelein (SNL)	1-31	3.50	3.63	3.63	3.38	**3.56**
acs010	Fuel Injection and Spray Research Using X-Ray Diagnostics	Christopher Powell (ANL)	1-34	3.42	3.08	2.92	3.00	**3.14**
acs011	Advances in High-Efficiency Gasoline Compression Ignition	Steve Ciatti (ANL)	1-37	2.90	3.00	2.80	2.90	**2.94**
acs012	Model Development and Analysis of Clean & Efficient Engine Combustion	Russell Whitesides (LLNL)	1-40	3.75	3.50	3.25	3.38	**3.52**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs013	Chemical Kinetic Models for Advanced Engine Combustion	Bill Pitz (LLNL)	1-42	3.70	3.60	3.50	3.40	**3.59**
acs014	2016 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software	David Carrington (LANL)	1-46	2.90	3.00	2.60	2.90	**2.91**
acs015	Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Jim Szybist (ORNL)	1-52	3.38	3.38	2.88	2.75	**3.23**
acs016	High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines	Scott Curran (ORNL)	1-55	3.07	3.36	3.29	3.07	**3.24**
acs017	Accelerating Predictive Simulation of IC Engines with High Performance Computing	K. Dean Edwards (ORNL)	1-59	2.88	3.00	3.25	2.88	**2.98**
acs022	Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations Analysis and Coordination)	Josh Pihl (ORNL)	1-62	3.13	3.13	3.50	3.13	**3.17**
acs023	Cross-cut Lean Exhaust Emissions Reduction Simulation: Aftertreatment Modeling and Analysis	Yong Wang (PNNL)	1-66	3.10	3.20	3.40	2.90	**3.16**
acs024	Ash-Durable Catalyzed Filters for Gasoline Direct Injection (GDI) Engines	Hee Je Seong (ANL)	1-71	2.90	3.00	3.10	2.90	**2.98**
acs027	Next-Generation Selective Catalytic Reduction-Dosing System Investigation	Abhijeet Karkamkar (PNNL)	1-75	2.75	2.75	2.63	2.50	**2.70**
acs032	Cummins-ORNL Emissions CRADA: NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines	Bill Partridge (ORNL)	1-79	3.00	2.75	3.38	2.63	**2.88**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs033	Emissions Control for Lean Gasoline Engines	Jim Parks (ORNL)	1-83	3.38	3.25	3.63	3.25	**3.33**
acs052	Neutron Imaging of Advanced Transportation Technologies	Todd Toops (ORNL)	1-86	3.20	3.00	3.10	3.20	**3.09**
acs054	Rapid Compression Machine Studies to Enable Gasoline-Relevant Low-Temperature Combustion	Scott Goldsborough (ANL)	1-89	3.38	3.50	3.38	3.00	**3.39**
acs056	Fuel-Neutral Studies of Particulate Matter Transport Emissions	Mark Stewart (PNNL)	1-92	3.20	3.50	3.70	3.20	**3.41**
acs075	Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing Resources	Sibendu Som (ANL)	1-95	3.21	3.14	3.36	3.07	**3.18**
acs076	Improved Solvers for Advanced Engine Combustion Simulation	Matthew McNenly (LLNL)	1-101	3.75	3.63	3.38	3.50	**3.61**
acs084	Advanced Ignition Systems for Gasoline Direct Injection (GDI) Engines	Riccardo Scarcelli (ANL)	1-104	3.13	3.38	3.25	3.25	**3.28**
acs085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-107	3.60	3.50	3.10	3.40	**3.46**
acs092	High-Efficiency Variable Compression Ratio Engine with Variable Valve Actuation and New Supercharging Technology	Charles Mendler (Envera LLC)	1-110	2.79	2.86	2.93	2.79	**2.84**
acs093	Lean Miller Cycle System Development for Light-Duty Vehicles	David Sczomak (General Motors)	1-115	3.67	3.50	3.17	3.33	**3.48**
acs094	Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion	Keith Confer (Delphi Powertrain)	1-118	3.50	3.67	3.17	3.50	**3.54**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs095	Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation	Pu-Xian Gao (U. of Connecticut)	1-122	2.83	2.92	2.75	2.75	**2.85**
acs097	Affordable Rankine Cycle (ARC) Waste Heat Recovery for Heavy-Duty Trucks	Swami Subramanian (Eaton)	1-126	2.75	2.42	3.00	3.00	**2.33**
acs098	Cummins 55% Brake Thermal Efficiency Project	Lyle E. Kocher (Cummins)	1-130	3.43	3.29	2.36	3.00	**3.17**
acs099	Improved Fuel Efficiency through Adaptive Radio Frequency Controls and Diagnostics for Advanced Catalyst Systems	Alexander Sappok (Filter Sensing Technologies, Inc.)	1-135	3.58	3.33	3.58	3.42	**3.44**
acs100	Engine Improving Transportation Efficiency through Integrated Vehicle, and Powertrain Research SuperTruck II	Justin Yee (Daimler Trucks North America)	1-139	3.43	3.21	3.50	3.57	**3.35**
acs101	Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo)	1-144	3.58	3.33	3.58	3.33	**3.43**
acs102	Cummins/ Peterbilt SuperTruck II	Michael Ruth (Cummins)	1-149	3.79	3.43	3.57	3.64	**3.56**
acs103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer—SuperTruck	Russ Zukouski (Navistar)	1-154	3.14	3.29	3.07	3.14	**3.21**
acs104	Cavitation Within Fuel Injectors: Development and Multiscale Validation of Euler-Lagrange based Computational Methods for Modeling Cavitation within Fuel Injectors	Emily Ryan (Boston U.)	1-159	3.13	3.25	3.13	3.13	**3.19**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs105	Turbulent Spray Atomization Model for Diesel Engine Simulations	Caroline Genzale (Georgia Institute of Technology)	1-164	3.25	3.38	3.25	3.25	**3.31**
acs106	Multi-Component Fuel Vaporization and Flash Boiling	Chia-Fon Lee (U. of Illinois)	1-169	2.50	2.38	2.63	2.50	**2.45**
acs107	High-Pressure Supercritical Fuel Injection at Diesel Conditions	Ajay Agrawal (U. of Alabama)	1-174	3.00	3.00	3.17	2.83	**3.00**
acs108	Spray-Wall Interaction at High-Pressure and High-Temperature Conditions	Seung-Young Lee (Michigan Technological University)	1-177	3.25	2.88	3.25	3.00	**3.03**
acs109	Predictive Models for In-Cylinder Radiation and Heat Transfer	Dan Haworth (Penn State)	1-180	3.67	3.50	3.67	3.50	**3.56**
acs110	Engine Knock Prediction	Seung Hyun Kim (Ohio State U.)	1-183	3.00	3.13	3.25	2.88	**3.08**
acs111	Lagrangian Soot Model Considering Gas Kinetics and Surface Chemistry	Sage Kokjohn (U. of Wisconsin)	1-186	3.50	3.17	3.33	3.50	**3.31**
acs112	Integrated Boosting and Hybridization for Extreme Fuel Economy and Downsizing	Chinmaya Patil (Eaton)	1-189	3.25	3.38	2.75	3.38	**3.27**
acs113	DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics	Kambiz Salari (LLNL)	1-193	3.50	3.75	3.75	3.25	**3.63**
acs114	Improved Tire Efficiency through Elastomeric Polymers Enhanced with Carbon-Based Nanostructured Materials	Georgios Polyzos (ORNL)	1-198	3.25	3.38	2.88	3.00	**3.23**
acs115	Advanced Bus and Truck Radial Materials for Fuel Efficiency	Lucas Dos Santos Freire (PPG)	1-202	3.50	3.63	3.63	3.38	**3.56**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs116	Advanced Non-Tread Materials for Fuel-Efficient Tires	Tim Okel (PPG)	1-206	3.25	3.13	3.38	2.88	**3.16**
acs117†	HD Powertrain Optimization	Paul Chambon (ORNL)	1-210	3.33	3.50	3.33	3.33	**3.42**
acs118	Advanced Emission Control for High-Efficiency Engines	Janos Szanyi (PNNL)	1-213	3.10	3.10	3.40	3.00	**3.13**
acs119	Development and Optimization of a Multi-Functional SCR-DPF Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction	Ken Rappe (PNNL)	1-218	3.20	3.10	3.10	3.10	**3.13**
Overall Average				**3.24**	**3.21**	**3.22**	**3.12**	**3.20**

† Denotes a poster presentation.

Presentation Number: acs001
Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling
Principal Investigator: Mark Musculus (Sandia National Laboratories)

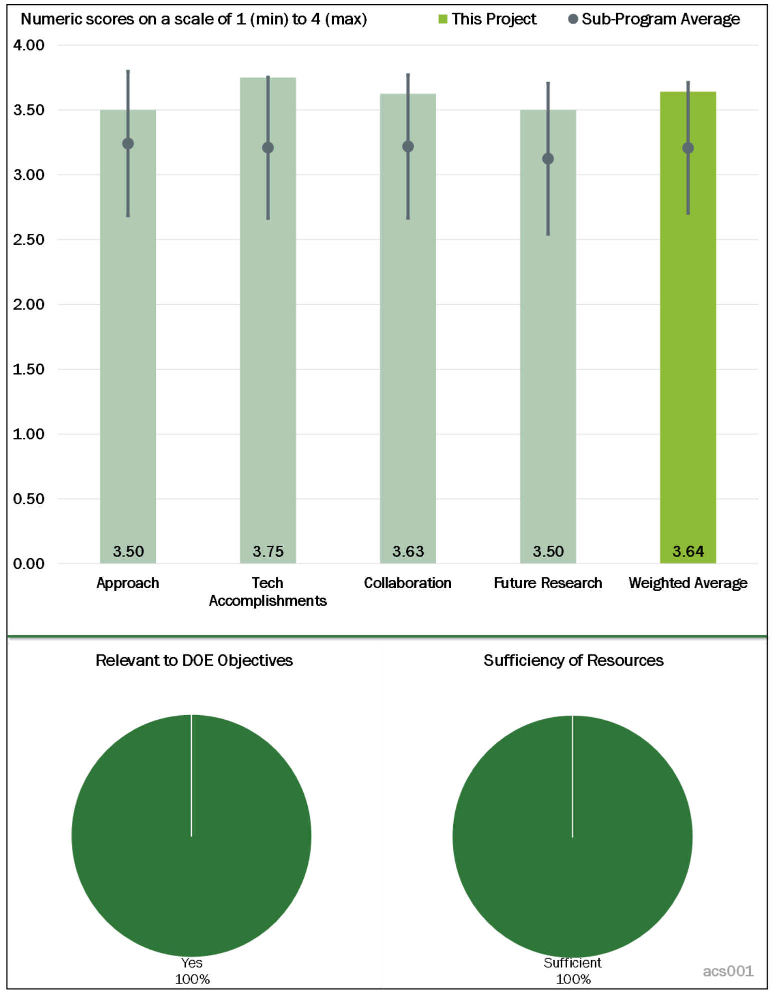

Figure 1-1 - Presentation Number: acs001 Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling Principal Investigator: Mark Musculus (Sandia National Laboratories)

Presenter
Mark Musculus, Sandia National Laboratories

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The approach of using experimental optical studies with modeling for elucidating initial soot production and oxidation is excellent in this reviewer's opinion. Additionally, coupling diffuse back illuminated with natural luminosity imaging seems to be a very effective technique for quantifying net soot production.

Reviewer 2:
The reviewer noted that overall, this is well thought out and planned project. The PI has given great thought toward using experimental techniques to better quantify the impact of late cycle injection on the controlling physics for reducing soot. The project includes a modeling CFD portion that is also very helpful in better understanding and quantifying the controlling physics. The idea toward developing a concept model for soot formation/reduction as a function of post injection parameters is a great idea, but the reviewer indicated concern that the experimental conditions are not broad enough to support such an effort at this point in time. The reviewer recommended that it would be helpful to better quantify time scale effects such as engine speed and injection pressure on post injection and timing on soot oxidation.

Reviewer 3:
The reviewer observed that the approach utilizes a good balance of experiments along with simulation for a fundamental understanding of diesel combustion.

The reviewer recommended further understanding and insight regarding multi-injection schedules would be helpful in order to improve overall engine efficiency.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that very good progress has been made to better elucidate and quantify soot production from post injection. The results are very helpful for better fundamental understanding and to resolve apparent conflicting results from prior studies.

Reviewer 2:
The reviewer indicated that this project has made significant contribution toward understanding of soot oxidation and soot production with pilot, main and post injection strategies.

Reviewer 3:
The presented results have helped the engine community better quantify why post injection leads to soot reduction under certain operating conditions. The reviewer thanked the PI for focusing on supplying such important quantitative data to the community over the past year. As a possible side effect from this great effort, it was not clear to the reviewer if the PI was also closely watching the impact on indicated efficiency from various post injection strategies used in this project.

Reviewer 4:
The reviewer observed that additional geometries should be investigated for spray to spray interactions.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project made good use of the Engine Combustion Network (ECN).

Reviewer 2:
The reviewer observed that collaboration and coordination with other institutions has been excellent in this project.

Reviewer 3:
It has been apparent over the years that the principal investigator (PI) is excellent at collaboration with various partners. In this reviewer's opinion, this is one of many strengths of the PI's past and current work.

Reviewer 4:
There appears to be collaborations with some specific industry partners (such as Cummins, Delphi, and Convergent Science) as well as several universities (University of Wisconsin [UW] and Lund University). The reviewer noted that collaboration with the organizations involved in the AEC MOU is mentioned, but outside of the two presentations per year, it was unclear to this reviewer how much collaboration with those organizations takes place.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that proposed plans of continuing to gain fundamental insights from experiments and models; building conceptual models; and determining how in-cylinder processes affect efficiency across a range of combustion modes and in-cylinder geometries seem very reasonable and useful.

Reviewer 2:
The proposed research plan is very good. The reviewer recommended that, if time permits, the project could expand the experimental work to better understand time scale effects on post injection/soot oxidation/soot formation by varying engine speed and injection pressure in light of any future conceptual model development.

Reviewer 3:
The reviewer suggested that proposed future research regarding in-cylinder temperature and heat transfer across combustion modes to efficiency will be helpful. The reviewer wondered if thermal barrier coating on pistons can be included in this study for optimizing thickness and material conductivity.

Question 5: Relevance — Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer indicated that a fundamental understanding of soot production and how to reduce it should lead to improved aftertreatment systems, which may lead to less fuel required for regeneration. Also, less fuel converted to soot presumably means higher combustion and engine efficiency.

Reviewer 2:
This reviewer stated that the project does support the overall DOE objectives of petroleum displacement because this study has a direct impact on improving overall efficiency of combustion engines.

Reviewer 3:
The reviewer said in short, yes. The post injection strategy for soot oxidation may allow for a more aggressive main combustion strategy approach that could increase indicated thermal efficiency, thus addressing DOE goals. This reviewer noted that although this past year the focus did not appear to be on efficiency, the quantitative data supplied to understand soot oxidation/formation as a function of post injection strategy was worthwhile.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer stated that the resources seem sufficient and that the project seems to be meeting goals seem with current funding levels.

Reviewer 2:
This reviewer indicated that funding seems to be sufficient.

Reviewer 3:
This reviewer suggested that, based on availability of resources, allocating additional resources for modeling work would greatly benefit further advancement of the study.

Presentation Number: acs002
Presentation Title: Light-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

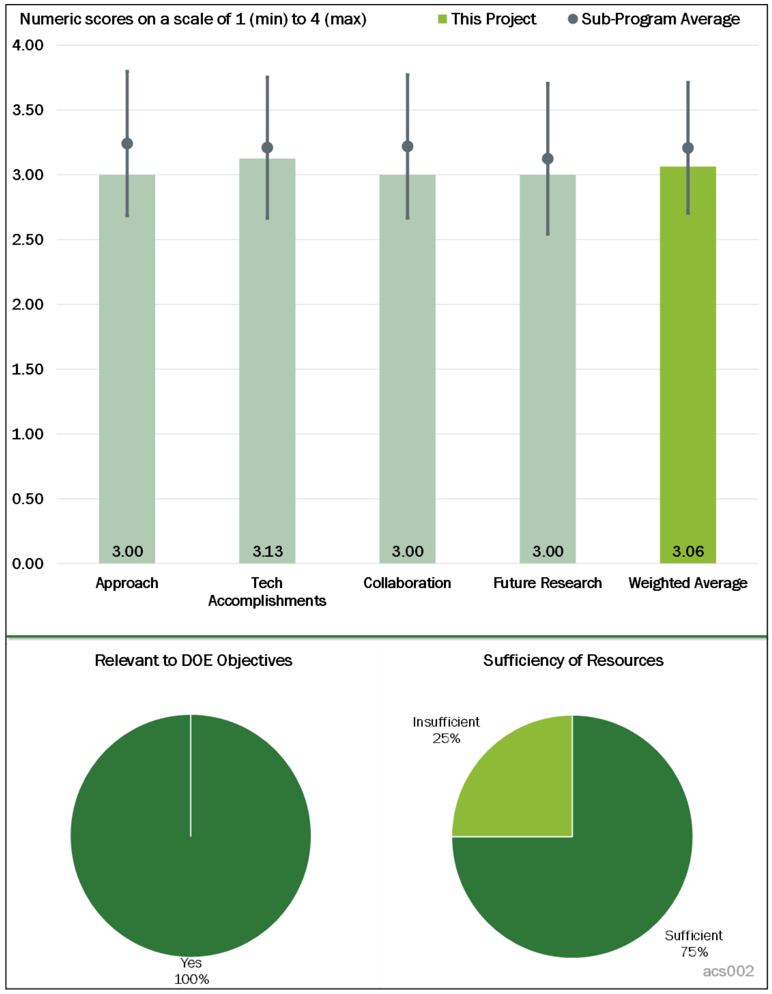

Figure 1-2 - Presentation Number: acs002 Presentation Title: Light-Duty Diesel Combustion Principal Investigator: Stephen Busch (Sandia National Laboratories)

Presenter

Stephen Busch, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The approach is sound, addressing the fundamentals of diesel combustion and the work is made up of primarily optical engine work, looking at injection, ignition, and combustion processes with a focus on exposing fundamental knowledge. This reviewer noted that the work is supported with simulations by UW with their Fast and Reliable Engine Simulation Code (FRESCO) code and Convergent Science.

Reviewer 2:

The current study for piston bowl geometry for overall thermal efficiency and emissions is promising. But, a parametric study CFD for assessing really sensitive piston bowl parameters for thermal efficiency and validation using experimental studies will be vital to the engine community in this reviewer's opinion.

Reviewer 3:

The reviewer said that this is a great example for collaboration between experimental and simulation work. This reviewer did note one concern, raised by another reviewer, wondering if the observed differences between piston geometries was at less than peak efficiency. At peak efficiency, there was not much of a difference, which leads to the question of which bowl parameters are most important and how can they be isolated in the experimental approach. This reviewer wondered if, now that the tools have been developed using the chosen piston profiles, they can be used to look at optimizing and ranking different bowl features with the ultimate goal being to provide guidance to the design process.

Reviewer 4:

The project provides unique data for the combustion process with the dedicated optical engine and that this is very important and useful.

The reviewer did note that it appears the project lacks the definition over its design space to make the study of diesel combustion and predictive CFD tools useful. The study focuses on only on two combustion bowls. For any practical "use," the reviewer recommended that the study would need to consider a space of air-fuel ratio, boost, injection spray, and compression ratio, in addition to bowl geometry.

The reviewer also recommended that the project could benefit from more concrete targets or benchmarks. For example, this person thought the project should focus on efficiency regions near or higher than the baseline, rather than exploring the late timings that operate at poor efficiency.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
This reviewer wondered if the post-processing techniques that are developed to extract additional insights about in-cylinder processes and support experimental findings are specific to FRESCO software or if they can also be used with other CFD software.

Reviewer 2:
This reviewer recommended thinking about how the design space for bowl design can be narrowed.

Reviewer 3:
This reviewer stated that progress seems slow and wondered if the Programmatic approach in Slide 5 can be accelerated. Noise measurements, following Advanced Combustion and Emissions Control (ACEC) guidelines, and tradeoffs with efficiency were proposed last year and this reviewer was encouraged to see that the suggestion to do a First-Law analysis last year were followed.

This reviewer wondered if care was taken to ensure that the conventional bowl and stepped-lip bowl were nearly the same in all other respects, with the only main difference being the stepped-lipped feature. In other words, this person asked if the results can be confounded by geometry differences other than the stepped lip.

This reviewer also wondered if there are any piston-lip geometry issues or design guidelines that can maximize efficiency.

Reviewer 4:
This reviewer commended that the work provides useful images of both experimental and simulation of the diesel combustion, but provides little new insights on the nature of diesel combustion. Focusing on heat release and energy loss spanning very late injection timing are of little practical value as the efficiencies reported are very low. This reviewer recommended that the study focus on the efficiency roadmap (established at the goal of the program) to provide information of any practical pathways beyond what the industry state of the art is.

The report showed similar performance on the two bowls considered at peak efficiency; this is very telling and could have been treated in greater length in this reviewer's opinion.

This reviewer recommended reporting a better description of test conditions as well as exploring future ranges.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer noted that it seems like there is good collaboration with General Motors (GM) and Ford.

Reviewer 2:
While two large original equipment manufacturers (OEMs) are involved, it is unclear to this reviewer how much guidance they provide or the quality of this guidance.

One aspect that is of concern to this reviewer is the lack of reference to previous studies done in this area.

Reviewer 3:
This reviewer recommended collaborations to expand into catalyst heating.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The project proposed multiple efforts regarding injection strategies, catalyst heating, and different experimental studies along with noise-efficiency trade off study.

The reviewer noted that the noise efficiency study date should be changed to summer 2017 instead of 2016, but is not sure how the noise efficiency is relevant to overall scope of this project.

Reviewer 2:
Researchers are encouraged to align their work in the context of previous work in this area, emphasizing new approaches and pathways toward improved combustion efficiency and clean combustion. This work needs to be guided by clear benchmarks targets that support their capability to improve the state of the art. The reviewer got the impression that there is no "picture" of success.

Reviewer 3:
While many pieces of future research are proposed in a somewhat ad hoc manner, this reviewer asked if there is a macro direction to this research. The reviewer asked what the "big research proposal/idea" is that is being investigated. This person wondered if after supplying an initial body of data for simulation comparisons, is it the responsibility of this project to continue to "educate" and calibrate CFD models, or, should this project go on to investigate the next high-efficiency or emissions reduction concept.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer indicated that yes, the project aims to provide fundamental understanding of efficiency-increasing and emissions-reducing concepts in LD diesel engines.

Reviewer 2:
This reviewer stated that the project by nature does, but observed that its present approach does not appear to have the elements to make significant contributions to this objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer commented that based on what has been accomplished in this project so far, the funding for this project has been more than sufficient.

Reviewer 2:
This reviewer indicated that resources are sufficient.

Reviewer 3:
This reviewer observed that current resources are sufficient but future reductions would jeopardize output.

Reviewer 4:

This reviewer suggested that the team try to enlist more active participation from a technical expert in the combustion-fuel-system-air management to help guide the work toward a place where a significant breakthrough can be attained. Without this, this person indicated that it is unlikely that the team will continue to produce data of little relevance.

Presentation Number: acs004
Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research
Principal Investigator: John Dec (Sandia National Laboratories)

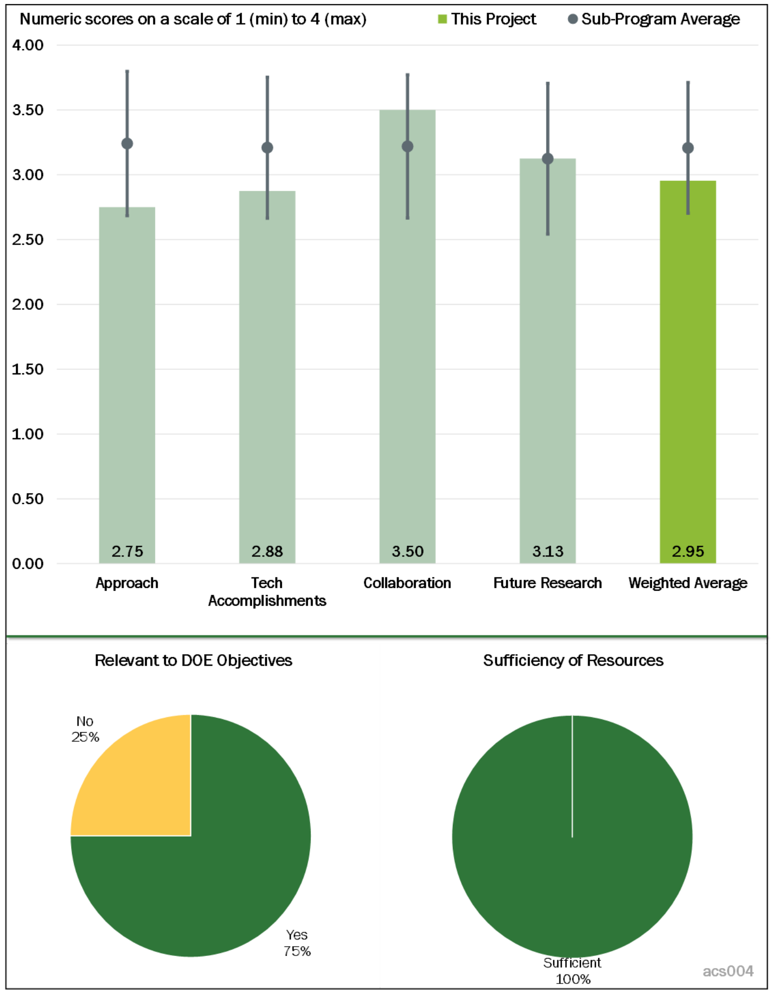

Figure 1-3 - Presentation Number: acs004 Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research Principal Investigator: John Dec (Sandia National Laboratories)

Presenter
John Dec, Sandia National Laboratories

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The work represents a comprehensive experimental investigation of the engine operating parameters affecting the gasoline compression ignition (GCI) engine operation. The work is very high quality and useful; however, the reviewer noted that the data shown to date are already largely available in the literature, albeit not as precisely defined and extensively evaluated. In this person’s opinion, the most significant contribution of this work will occur when the work moves into the optical diagnostics, the arena in which SNL and this PI excel.

Reviewer 2:
This reviewer recommended running compression ignition (CI) combustion mode on candidate hardware to better show baseline versus LTC results.

Reviewer 3:
The reviewer said that a 1.0 liter (L)/cylinder is large for a LD application and gives higher brake thermal efficiency (BTE) than a more typical 0.5 L/cylinder. The reviewer wondered if the BTE data being provided to the Autonomie simulations will be corrected for this effect. This reviewer noted that the project should also keep an eye on combustion noise (CN), as CN should not have abrupt transitions during combustion mode and/or load changes.

Reviewer 4:
This reviewer observed that aftertreatment implications have not been adequately considered because hydrocarbon (HC) and carbon monoxide (CO) were not reported and exhaust temperature was stated to be below typical catalyst light off temperature.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer applauded the use of the uncertainty quantification (UQ) and wondered if this analysis can be used to set requirements for parameters used to control the combustion phasing such as intake charge temperature and pressure.

Reviewer 2:

This reviewer appreciated the very nice and detailed data; however, the level of detail presented in the figures in the slides is far beyond what is needed to make the points covered in this review. The net result was that the presentation was very hard to follow. The reviewer commends the PI for integrating and addressing the uncertainty of the results into his analysis; however, it is not clear from the presentation what aspects of the results have been subjected to the uncertainty analysis. This reviewer was uncertain of the fuel consumption and efficiency performance of the results.

Working with the different stakeholders to make BTE projections was an important addition to the work. This person wondered if estimates of the range of confidence of this projections would be helpful—for example, what would the investigators think the uncertainty is of using a sequence of steady state points to evaluate the performance over a driving cycle.

Reviewer 3:

More progress has been made exploring engine operation and improving indicated efficiency, but the vehicle fuel economy estimate which compares the engine in an HEV application to a production Toyota Prius engine is only 6% better in spite of a cylinder size double the Prius and being skip fired. This reviewer believed that in the time that it takes for this concept to get to market, conventional hybrid engines will improve more than 6%.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer observed that the interaction with the various stakeholders appears to be excellent.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The results presented are consistent with, and represent a very nice refinement of, the current understanding of the approaches to controlling the combustion timing for GCI. This reviewer looks forward to when the research moves into the optical engine phase of the project.

Reviewer 2:

This reviewer indicated that future work appears to be aligned with barriers to implementation such as controls and transients.

Reviewer 3:

This reviewer suggested that future work should include sensitivity of the combustion behavior to boundary conditions. For example, how much can the intake temperature or pressure vary from a typical set point and still maintain combustion within the operating constraints of noise, knock, combustion phasing for efficiency, and emissions. In addition, playing an audio recording of the engine running in the test cell at the AMR will inform the audience of the sound that comes out of the engine at 5 MW/m^2.

Reviewer 4:
This reviewer was concerned that current proposed future research would not meaningfully move barriers to LTC and suggested the team use an increased variety of hardware in experimental efforts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer indicated that the project is very relevant for the DOE objectives. There is potential for a significant fuel consumption reduction with this combustion approach, but there are fundamental challenges that need to be understood. This work address that.

Reviewer 2:
This reviewer suggested that the project needs more hardware variety (fuel injected engine [FIE], pressures and geometry, combustion chamber geometry, etc.)

Reviewer 3:
This reviewer commented that the predicted brake efficiency improvement is not large enough to be relevant in the time frame that this concept could be implemented, so no petroleum displacement will result.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer stated it seems that the PI is making good progress with the resources he has, or he has appropriately adjusted the scope of his efforts to account for the funding and available physical resources.

Presentation Number: acs005
Presentation Title: Spray Combustion Cross-Cut Engine Research
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

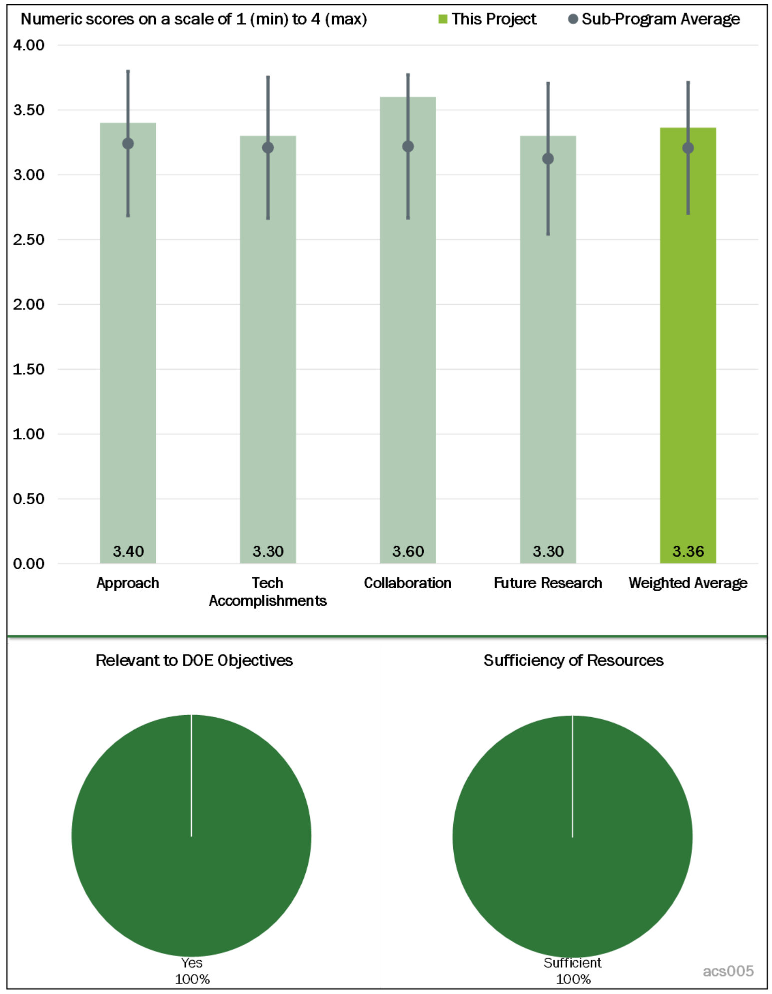

Figure 1-4 - Presentation Number: acs005 Presentation Title: Spray Combustion Cross-Cut Engine Research Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project directly addresses important technical barriers associated with gaps in understanding for fuel sprays. Clearly this project is closely linked to a multitude of other efforts, via the ECN. The PI made a convincing case that work is closely coupled with modeling efforts, which was apparently an area that was criticized in previous years.

Reviewer 2:

The reviewer commented that by measuring and understanding spray characteristics, this work provides information to link fuel spray and air mixing with the combustion and emissions process.

Reviewer 3:

This reviewer wondered how priorities are chosen for the experimentation at engine relevant spray conditions for development of predictive computational tools.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer wondered how simulation contributions for ECN listed in the presentation were used. As stated in the presentation, some simulations are Reynolds-averaged Navier-Stokes equations (RANS) and others are large eddy simulation (LES). This reviewer also wondered how LES can be less expensive to define boundary conditions used for more expensive simulations.

Reviewer 2:
The gas velocity measurement between plumes is a major result for CFD evaluation; however, the differences among the measurement and the computations are quite large. This reviewer suggested conducting a more detailed analysis of the uncertainties of the results and explanation of the differences.

Reviewer 3:
The reviewer said that progress has been satisfactory, but output can be increased. This reviewer found the measurement of soot with the diffused back illumination method very interesting. In particular, the difference between the environment (carbon dioxide [CO_2] and water [H_2O] versus oxygen [O_2] and nitrogen) and the effect of cavitation on soot both very interesting.

This reviewer wondered about work that was proposed last year to probe particulate formation at the tip of gasoline injectors; it was not reported on this year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that this project has close collaborations with software vendors, OEMs, and other research institutions around the world.

Reviewer 2:
The reviewer commented that there is no question that the collaboration is excellent; however, care must be taken to collaborate efficiently and not just for collaboration's sake.

Reviewer 3:
The reviewer said that a clear case has been made for the degree of collaboration with others, particularly with those developing models of spray behavior and effects of sprays on engine combustion. This has apparently been criticized in the past, and was corrected here. This person agrees with another reviewer who pointed out, however, that perhaps too much emphasis was placed on this aspect. The focus of the presentation should be on your technical accomplishments, and while you must address collaborations, you should not be expected to use your own valuable presentation time to promote or highlight modeling accomplishments.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer finds the new high-throughput spray facility particularly interesting and exciting. There have been results from the SNL spray bomb for many years, and now there will finally be better results with improved understanding of uncertainty/repeatability. The reviewer wondered what the fate of the spray bomb is, and asked if the new facility makes the spray bomb obsolete, or will you continue to do work in that chamber.

Reviewer 2:
The reviewer asked if the project PI is planning to leverage the particulate formation for GDI systems from the project ACS001 regarding multiple injections.

Reviewer 3:
The reviewer suggested that the investigation of particulate formation in GDCI engines be given very high priority, especially with regard to soot from large droplets produced when the pintel closes at the end of injection.

The reviewer also recommended a further study of the collapsing behavior of gasoline multi-hole sprays. Other variables that are of great interest to the industry are the back pressure, the conicity of the nozzle, the pitch diameter of the circle where the holes are located, and the number of holes.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer noted that the collaborative research from this project through ECN accelerating CFD model development supports overall DOE objectives of petroleum displacement.

Reviewer 2:

The reviewer stated, yes, the project provides fundamental understanding of the behavior of sprays as well as data for improving CFD models.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This reviewer observed that the budget is high but justified, considering the extent of the work that will be done.

Reviewer 2:

This reviewer suggested that it would be beneficial to split and allocate resources for labor, testing, simulation resources, and miscellaneous items, such as travel, for further understanding of overall resource sufficiency.

Presentation Number: acs006
Presentation Title: Gasoline Combustion Fundamentals
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

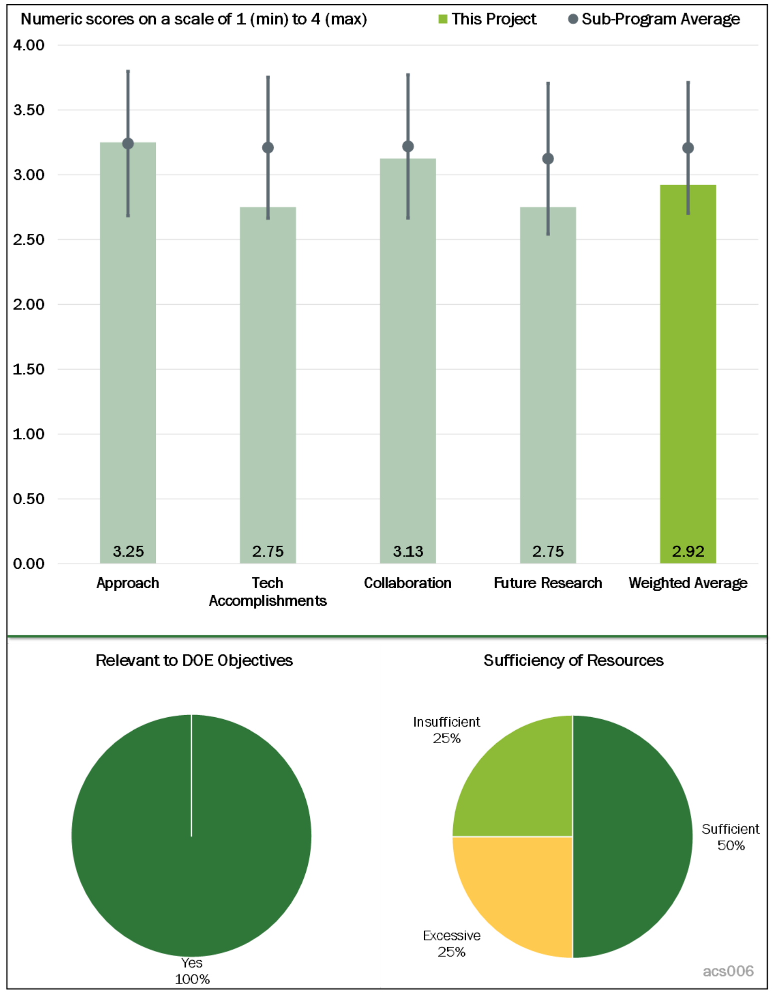

Figure 1-5 - Presentation Number: acs006 Presentation Title: Gasoline Combustion Fundamentals Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter

Isaac Ekoto, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the approach of conducting basic screening tests in an optical calorimeter plus tests in a new engine capable of operating under low-temperature gasoline combustion (LTGC), dilute spark ignition (SI), and boosted SI seems reasonable.

Reviewer 2:

This reviewer stated this was a good approach to determine the physical behavior of new, alternative ignition systems. The detailed bench tests and measurements can help provide insight to address shortcomings.

Reviewer 3:

The reviewer commented on the good work done to close out the negative valve overlap (NVO) study, even though results did not improve efficiency.

Reviewer 4:

The single cylinder engine combustion system is a relevant system to conduct these experiments of lean combustion; however, the ignition process is being studied to a great amount of detail. The reviewer suggested that perhaps the project should adopt a more pragmatic approach to studying ignition systems.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that progress seems to have improved with the test cell revamp.

Reviewer 2:
The reviewer noted that the ignition system behavior measurements provide insight into their fundamental operation and should identify areas of improvement.

Reviewer 3:
The reviewer stated that there was good progress on identifying failure modes on low-temperature (LT) plasma, but the team needs to develop plans to quickly identify the go/no-go decision points on this approach.

Reviewer 4:
While the quality of work is good, the pace of work is not and progress has been very slow over the last 3-4 years. The transition from NVO homogeneous charge compression ignition (HCCI) to ignition system research has taken a long time. This reviewer wonders if there a way to accelerate the pace of work and results in the future.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer observed several industry collaborations with OEMs and suppliers (GM, Ford, Fiat Chrysler Automobiles [FCA], Cummins, and Mahle) and collaborations with three universities.

Reviewer 2:
This reviewer stated that the collaboration is good.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This reviewer stated that the proposed plans seem reasonable.

Reviewer 2:
This reviewer suggested that future work should focus on the fundamental measurements of the ignition system to provide detailed information for ignition system sub-models for combustion simulations.

Reviewer 3:
The reviewer asked what will be different about this turbulent jet ignition project from the one just concluded by Mahle a year ago. The reviewer also asked if the main barrier to lean combustion is extended dilution tolerance or lack of a cost-effective lean aftertreatment system.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer indicated that, if successful, new/improved ignition systems have the potential to enable to modes/methods of engine operation not currently possible with conventional systems and thus improve engine efficiency and fuel economy.

Reviewer 2:
The reviewer commented that the ignition system behavior measurements provide foundational information for engine combustion simulation tools that are important for engine developers to improve engine efficiency.

Reviewer 3:
Yes, it does. However, the reviewer also noted that quantity of work over the last few years has been minimal and has had minimal impact.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that funding should be increased to accelerate progress on ignition system behavior measurements.

Reviewer 2:
The reviewer noted that the project is making faster progress so resources seem adequate.

Reviewer 3:
The reviewer stated that the project is overfunded when compared with the pace of work reported over the last three to 4 years.

Presentation Number: acs007
Presentation Title: Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research
Principal Investigator: Joe Oefelein (Sandia National Laboratories)

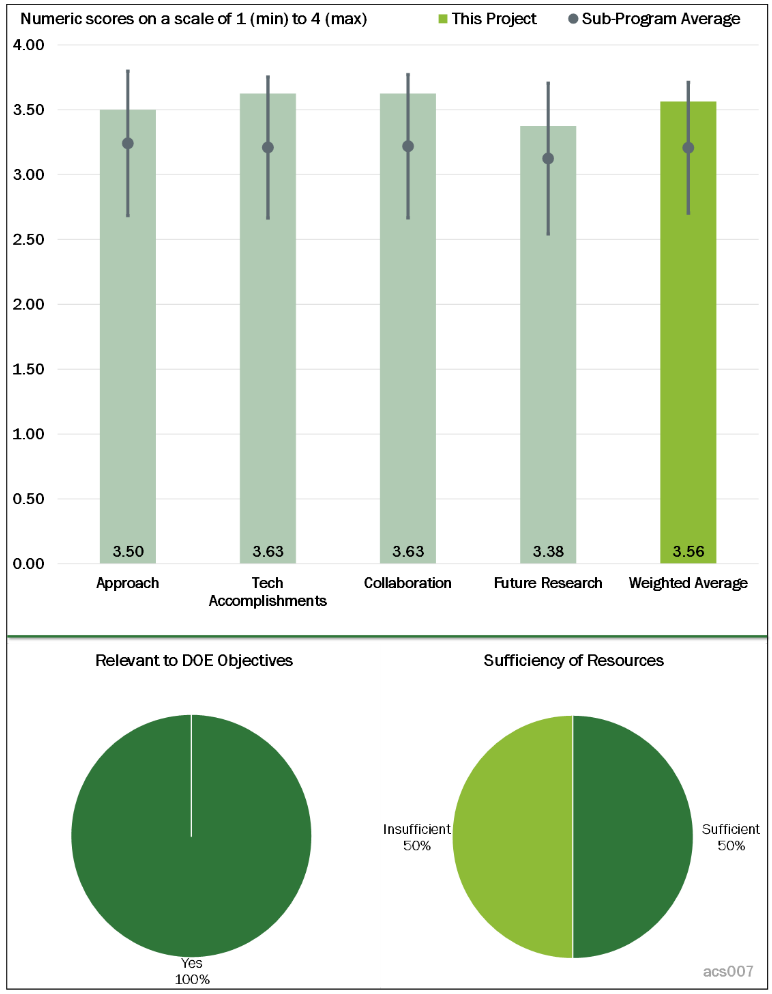

Figure 1-6 - Presentation Number: acs007 Presentation Title: Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research Principal Investigator: Joe Oefelein (Sandia National Laboratories)

Presenter
Joe Oefelein, Sandia National Laboratories

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer indicated that the study, which is focused on the fundamental understanding of spray and combustion based on LES, is very promising.

This person observed that the overall approach highlights the challenges in modeling and simultaneously details the simulation aspects that complement experiments.

Reviewer 2:
The reviewer commented that LES is applied to provide unique insight.

Reviewer 3:
The approach of developing and applying detailed first-principles models for complex in-cylinder processes is excellent; however, it probably will take a long time before it can actually simulate something close to engine spray and combustion. The reviewer observed that it would probably be beneficial in the process of developing to also utilize the tool to conduct detailed numerical experiments to supplement data for model verification and development in the cases that experimental measurements are very difficult or inaccurate.

Reviewer 4:
The reviewer noted that the technical barriers are well identified. Individuals in the field agree and understand that the LES can predict the physics with much higher accuracy than current engineering code; however, the project needs a plan to make this computational tool more viable for engineering. In other words, is there a way to relieve computational requirements without (or with minimal) accuracy compromise.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer congratulated an excellent accomplishment and stated that the content covers the declared milestones well.

Reviewer 2:
The reviewer observed that project details regarding a cascade of nonlinearity coupled interactions highlights liquid injection and combustion and also, all the different efforts and studies that are being worked on for achieving the objective.

Reviewer 3:
The reviewer wondered how more funding would meaningfully affect progress.

Reviewer 4:
This reviewer understands that this research is advanced and very difficult, so the small progress relative to 2016 is possibly due to a lack of resources. Nevertheless, the progress toward the main goal seems to be too slow.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer commended the great list of collaborations and the clear direction for future plans but recommends considering interactions with industry to address the on-going demand.

Reviewer 2:
This reviewer suggested that collaboration with industry partners would be useful for the overall advancement of the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The plan is very clear with measurable and achievable goals. As indicated in the "Remaining Challenges and Barriers" slide, the reviewer agreed it is going to be critical to define common area of interest across academia and industry. This is going to take the current model based engineering to next level.

Reviewer 2:
The reviewer commented that the proposed optimal workflow for model validation and verification is promising, but indicated concern that the computational barriers for the full up engine modeling using LES may prohibit industry from embracing it.

Reviewer 3:
The reviewer stated that the future work on ECN diesel sprays will be constrained because collision phenomena in diesel spray is important and the collision model implementation is not even proposed in the future work.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer observed that the project is working to develop a high-fidelity LES tool to explore conditions where an experiment is not feasible, and/or deepen understandings of physics by decoding unmeasurable details. This will surely help to extend our understanding and develop new designs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer complimented the PI on his organization of the project in that it appears well under control with the given resources and budget.

Reviewer 2:

The reviewer suggested that adding more advanced computational staff would contribute to significant progress in this research. More collaboration and coordination with academia and national laboratories may be helpful as well.

Presentation Number: acs010
Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics
Principal Investigator: Christopher Powell (Argonne National Laboratory)

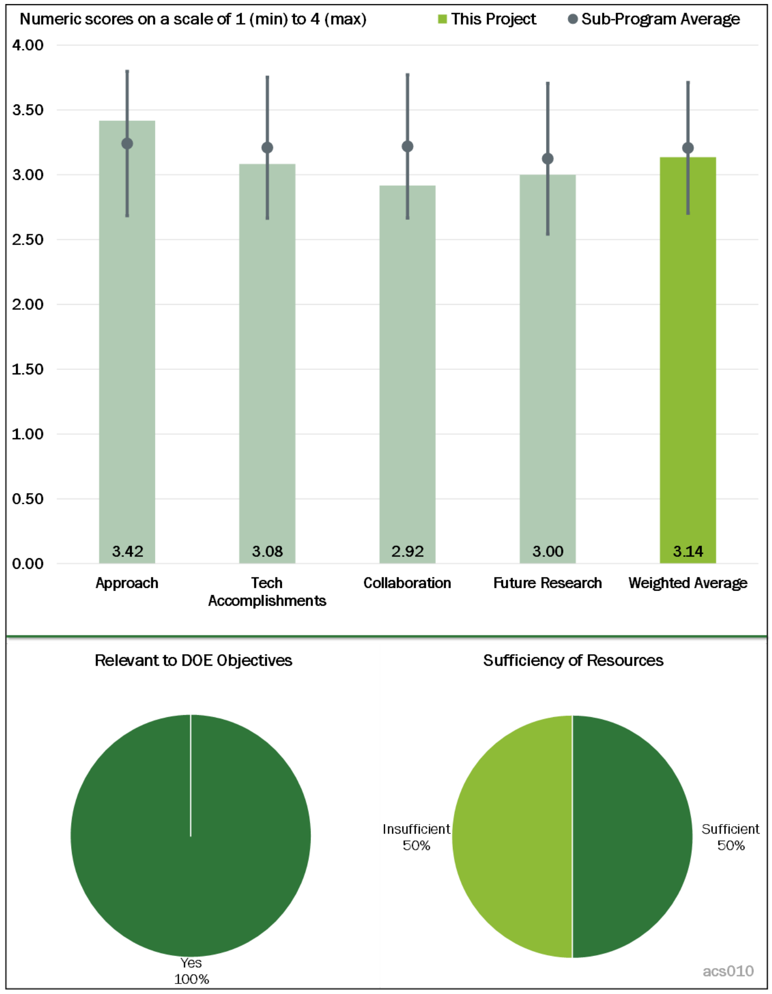

Figure 1-7 - Presentation Number: acs010 Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics Principal Investigator: Christopher Powell (Argonne National Laboratory)

Presenter

Christopher Powell, Argonne National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This project directly addresses technical barriers related to fuel injectors and sprays, and is focused on how the boundary conditions (e.g., detailed internal injector geometry) affect spray behavior/characteristics. Overall, the project seems well-conceived to this reviewer, and is clearly very well integrated with ECN and modeling community. The project also demonstrates that it is complementary to work being done by ORNL on neutron imaging and SNL on optical diagnostics of fuel sprays.

Reviewer 2:

The reviewer complimented the unique capabilities of the project and noted that combining X-ray imaging with neutron imaging gives a very thorough measurement of the injector important for CFD. This person suggested that the project should focus on, and name as a goal, the ranking of injector features most important to the spray and ultimately combustion and emissions.

Reviewer 3:

The project covers a number of areas on interest and the reviewer complimented the authors for doing a very good job describing a number of flow patterns; however, the approach is very one-dimensional and takes place in an apparent vacuum. This person suggested that some of the areas studied need to be put into much greater focus.

For example, on their first project, concern of cavitation and erosion could be accompanied by examination of existing hardware nozzles showing (or not) the severity of the cavitation issue, correlated with usage (e.g. vehicle miles); the drift over the original calibration; and examination across a small sample size, etc. This work may prove to be key to the diagnostics provided. The use of krypton to capture the flow reversal is insightful.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that there was great improvement in the resolution of the X-ray technique.

Reviewer 2:
Clearly the project has made good progress, but the reviewer wondered about the listed accomplishment related to "ducted combustion" work at SNL. This person observed that although it was mentioned once or twice later, the presenter more or less swept right past this in the presentation and it was not clear how this aspect of the project contributes to DOE goals and objectives.

Reviewer 3:
The evaluation of the effects of geometric variability on fuel mass variability is very valuable; however, the linear equation used for the correlation between geometric variability and fuel mass variability might not be appropriate because the correlations are relatively weak, especially for hole inlet and outlet corners. This reviewer stated that the effects of the corners have been demonstrated to be important in previous research, but the effects were not clearly shown in this research.

Reviewer 4:
The reviewer observed that the accomplishments rely on reporting of imaging exercises. The information is insightful, such as the cavitation and geometric variability on the ECN G-spray injector; however, this person noted that the report is rather limited and seems to need the guidance from an experienced combustion and engine engineer. The reviewer suggested that the project put both the cavitation and geometric work in much greater perspective and asks that the presenter see notes on erosion and cavitation. The ECN G-spray geometries could have been (should have been) correlated with both the geometrical tolerances of the parts and to the flow specifications. This may point to what hardware is evaluated.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The collaborations are very well described here but this reviewer would note agreement with another reviewer, however, that the discussion of collaborations was quite extensive and approached too much. This was clearly a response to reviewer comments from previous years, but it is not the PI's job to highlight accomplishments of others (i.e., modelers in this case).

Reviewer 2:
The reviewer suggested that the collaborative team be expanded to include a member or members to help steer the work to a more practical and industrial framework. This person asks the project members to refer to the earlier discussion on cavitation and manufacturing tolerances.

Reviewer 3:
This reviewer recommended a continued pursuit of collaborations with injector suppliers.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the multiple direct injection (DI) impact on fuel spray is good.

Reviewer 2:
The reviewer suggested that a thorough review of the project would help direct its work to a more practical level.

Reviewer 3:
The reviewer noted that proposed future work comes across as incremental. This may reflect the somewhat lower budget, but it seems as though one of the major parts of future work is simply to support other VTO projects.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer stated this project could play a lot more effectively to supporting the DOE goals; as is, however, this work will have limited applicability.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer complimented the impressive progress made with a limited budget, noting that resources for this project are extremely expensive.

Reviewer 2:
The reviewer commented that the upcoming year's budget is significantly lower compared to the previous year, but the proposed upcoming work is also somewhat more limited, so it is probably a good match between the budget and expected milestones.

Reviewer 3:
The reviewer recommended the team seek an experienced engine-combustion-fuel system specialist to help them guide their work.

Presentation Number: acs011
Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition
Principal Investigator: Steve Ciatti (Argonne National Laboratory)

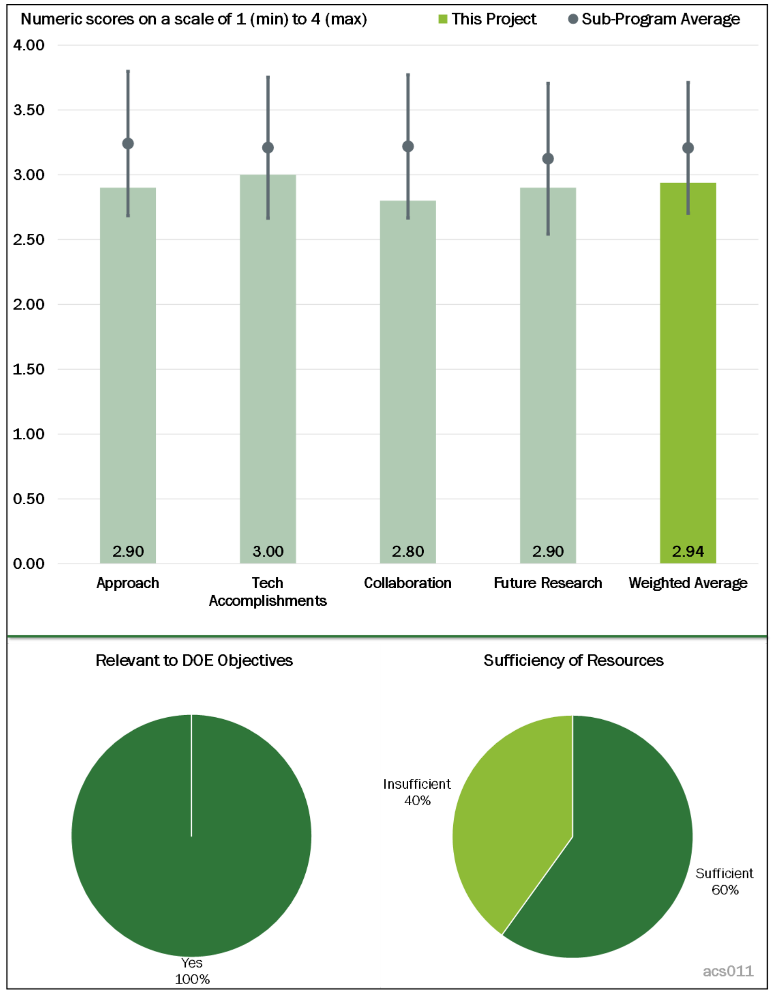

Figure 1-8 - Presentation Number: acs011 Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition Principal Investigator: Steve Ciatti (Argonne National Laboratory)

Presenter

Steve Ciatti, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the approach of conducting parametric engine studies of sweeps of start of ignition (SOI), split ratio, injection pressures, and exhaust gas recirculation (EGR) rates is an excellent way to provide better understanding of GCI fundamentals and how to improve performance.

Reviewer 2:

The reviewer commented that the project is well-designed and well-integrated with other efforts (academia, national laboratories, and industry) that investigate GCI on a multi-cylinder engine setup under conditions representative of actual engine applications.

Reviewer 3:

The reviewer observed that the project's approach seems to look for local optimums in engine performance by sweeping injection timings or studying the effect of EGR and that the project is also studying particulate matter (PM) morphology.

This person wondered if such an approach will solve the challenges of LTC, for example: lack of adequate crank angle position at which 50% of heat is released (CA50) control, challenges in transient control, challenges in switching between combustion modes, high combustion noise, high HC and CO emissions, need for a lean-oxides of nitrogen (NO_x) exhaust aftertreatment system, challenges in cold operation, limited speed and load range, low exhaust temperature, etc.

Reviewer 4:

The reviewer commented that the GM 1.9 L engine may not be most appropriate platform for future use.

Reviewer 5:

The reviewer noted that it appears the project is exploring DI calibration space to optimize a given GCI combustion approach. This person observed that the attribute constrained efficiency is quite poor, though relative to a conventional diesel for instance and recommended the team identify an approach that results in a go/no-go decision on the concept.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The project followed its milestones and the outcomes are in line with current DOE program goals regarding vehicle efficiency and emissions. The reviewer noted that it seems that a lot of the issues or barriers were hardware dependent and would like to see more about how these barriers translate in real engine applications that can use various technical approaches (due to cost restraints).

Reviewer 2:

The reviewer commented that the tasks have been completed in a timely manner but notes that the higher brake specific fuel consumption (BSFC) values at the target values for combustion noise (less than 90 A-weighted decibels [dBA]), filter smoke number (FSN; less than 0.5), HC plus NO_x (less than 4.0 g/kW-hr) and CO (10.0 g/kW-hr) are a concern.

Reviewer 3:

The reviewer wondered if enough of the calibration space has been mapped to allow a multi-parameter model and optimization.

Reviewer 4:

The reviewer was disappointed with the reported BSFC values and noted that one reason given was a turbo charger that might need some optimization. The other reason noted was related to meeting United States Council for Automotive Research (USCAR) guidelines on combustion noise and other engine out emissions targets. This person wondered if this means that this combustion concept is no longer a viable concept for LD commercialization.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed some collaboration with industry (GM and Eaton) and commented that the presenter also mentioned members of the AEC MOU, but noted there was no information given on the extent of the collaboration with those members other than the two meeting presentations per year.

Reviewer 2:

The reviewer suggested collaborating with domestic institutions also, as there are multiple research groups in U.S. academia that have similar interests.

Reviewer 3:

The reviewer wondered if there is any collaboration with a LD OEM that is willing to put such a concept into production someday.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer highlighted that future research continues the PI's excellent GCI work up to this point. The reviewer suggests solving the turbocharger issue under current budget limitations and would also like to see more collaborations for future optical investigations with U.S. universities that have similar or complementary optical facilities. This is important to support and maintain all the GCI work that is performed in the United States under current budget limitations.

Reviewer 2:
Continuing the work to understand how GCI can be optimized is important. The results presented suggest that engine efficiency values have dropped when the targets of noise (less than 90 dBA), FSN (less than 0.5), HC plus NO_x (less than 4.0 g/kWhr), and CO (less than 0.0 g/kWhr) are applied. The reviewer stressed that determining how or whether engine efficiencies can be approved in GCI is critically important, much more important at this point than characterizing the structure of the soot that is formed.

Reviewer 3:
The reviewer suggested that perhaps future work should be focused on proving why this concept may not be promising for LD commercialization.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the project is well aligned with the overall DOE objectives of improving transportation efficiency and reducing the environmental effects.

Reviewer 2:
The reviewer noted that, if successful, GCI should improve engine efficiency, thus improving fuel economy and reducing fuel/petroleum consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
There was no indication to this reviewer that resources are not sufficient to accomplish the milestones.

Reviewer 2:
The reviewer commented that novel experimental work requires a good funding stream, especially when the project needs good hardware to accomplish the outcome or when collaborations are required (e.g., student support at ANL, but understands the budget limitations.

Reviewer 3:
The reviewer suggested expansion of experimental efforts across additional combustion systems (effects of swirl versus tumble on LTC, etc.).

Presentation Number: acs012
Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion
Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

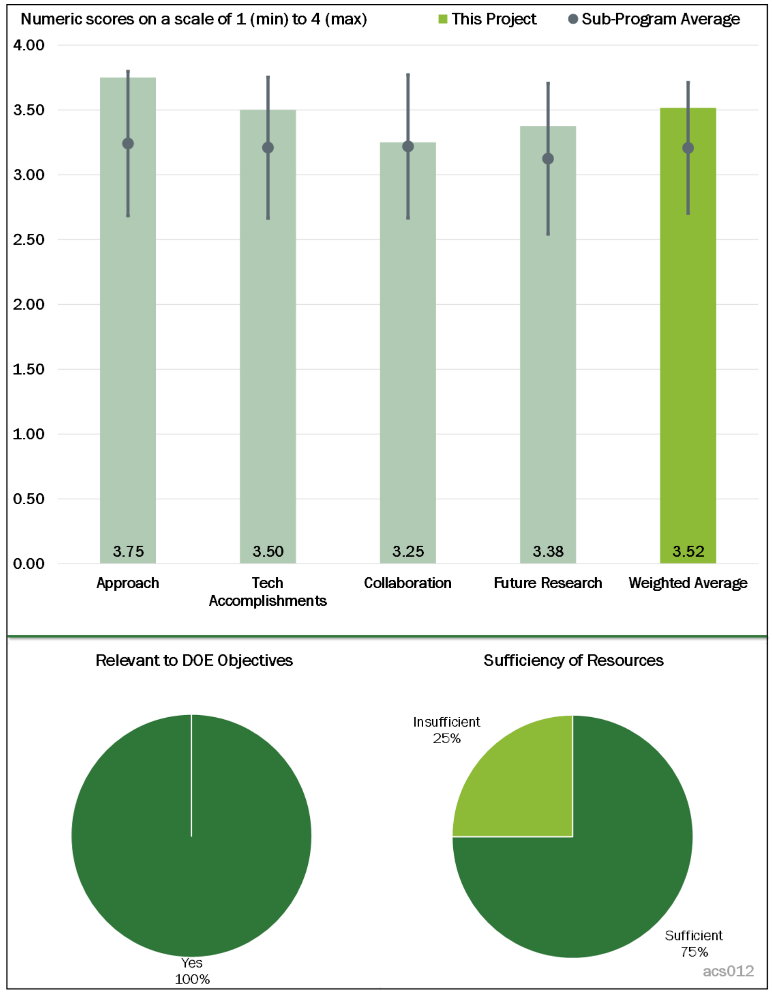

Figure 1-9 - Presentation Number: acs012 Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the fast-chemistry solver is critical to advance the state-of-the-art in engine simulation and indicates the project is well designed, feasible, and very well integrated with others.

Reviewer 2:

The reviewer stated that the UQ and the graphics processing unit (GPU) acceleration work that the project is doing are very useful for building confidence in simulation and reducing overall simulation turn-around time.

Reviewer 3:

The reviewer described the uncertainty analysis strikes as essentially a gauge repeatability and reproducibility (R&R) for simulation and experimental work and wondered if it is possible to rank the variables having the most influence on the model predictions or experimental measurements.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer indicated that the work being done to reduce the computational time for chemical kinetics in collaboration with ACS076 is essential for the engine community to adapt the details chemical kinetics.

Reviewer 2:
The reviewer commented that the new algorithms dramatically improves the computational speed and the work related to uncertainty analysis is very valuable. This person recommended that the PIs provide guidelines to reduce uncertainty.

Reviewer 3:
The reviewer recommended that as the team members employ chemistry to the CFD, they should note that the predictions of engine out emissions (HC and NO_x) are not as important as efficiency.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project is, overall, well connected with industry to commercialize the solver; however, the reviewer noted that CONVERGE is a commercial software and wonders if there is a plan to make the solver more widely available to others.

Reviewer 2:
The collaboration with industry, laboratories, and software vendors that is being pursued for the project is good, but the reviewer indicates that a combination of central processing unit/GPU optimization may be necessary for CFD run time reduction.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer compliments the well-designed plan for the CFD work, the future plan is well designed, but wonders about the uncertainty analysis.

Reviewer 2:
The reviewer indicated that the PI’s fiscal year (FY) 2018 proposed work of UQ in reacting flow CFD sounds interesting.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes, this reviewer agreed that the project supports the overall DOE objectives of petroleum displacement and states that CFD tools will play a more and more important role in future engine development.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated there are sufficient resources for the project to achieve the stated milestones in a timely fashion.

Reviewer 2:
The reviewer noted that combining with ACS076 and a reduced budget will reduce output.

Presentation Number: acs013
Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion
Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Presenter

Bill Pitz, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

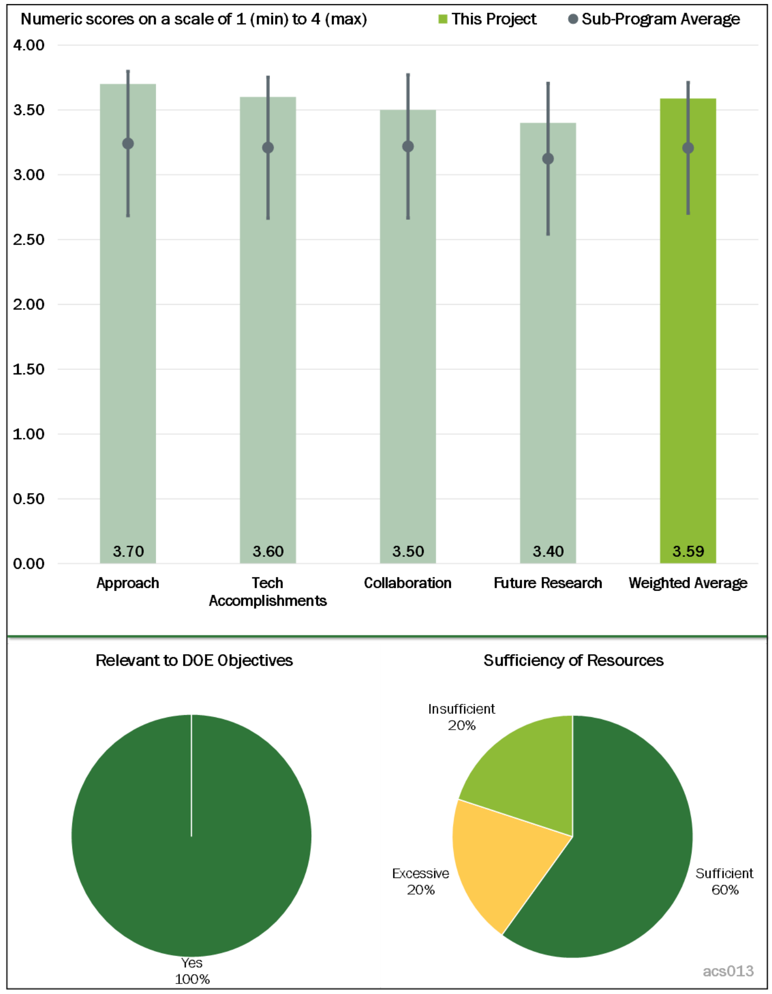

Figure 1-10 - Presentation Number: acs013 Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The work in this project is to develop predictive chemical kinetic models for gasoline, diesel, and other fuels and is key to designing improved engines with higher efficiency and lower emissions. The efforts to validate those models against experimental data from shock tubes, rapid compression machines (RCMs), etc., is very valuable. Further, the reviewer noted that the work to combine the kinetic mechanisms of individual components to form fuel surrogates of complex fuels and evaluate their performance versus those of the complex fuels is very important for development of reduced, tractable models that represent "real" fuels, but are more amenable for use in design of engines.

Reviewer 2:

The reviewer noted that developing predictive chemical kinetic models for gasoline, diesel, and next generation fuels is critical to better design high efficiency and clean combustion engines. The team makes remarkable progress every year to deliver more accurate models and add new molecules. The project is well designed, feasible, and extremely well integrated with others.

Reviewer 3:

The reviewer commented that this is critically important work that lays the foundation for engine combustion simulations and approves of the work on gasoline components as well because it is the dominant fuel in the LD marketplace.

Reviewer 4:

The team is generating chemical kinetic models as surrogate fuels for gasoline and diesel and that they validate these models by comparison to fundamental experimental ignition data taken in a RCM or shock tube. The reviewer stated that such models have become more important in recent years with the growing interest in LTC and the ability to model the combustion process with a detailed chemistry approach.

Reviewer 5:
According to this reviewer, the development of chemical kinetics models in this study is fundamental for accurate engine combustion CFD. And, as the PI noted, this level of detailed chemistry requires a lot of computational resources.

This person suggested partnering with other investigators for innovative ways (the ANL flamelet model is an example) to reduce overall computational effort, which would make it easier for CFD modelers to embrace these models.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer applauded the excellent progress made in developing and validating new, and/or improving existing, kinetic mechanisms for the components present in gasoline, diesel, and biofuels.

Reviewer 2:
Overall, the reviewer noted that the project is making significant progress, including the improved gasoline surrogate models, assembled kinetic model of the Coordinating Council Research (CRC) diesel surrogate palette with preliminary validation, and the collection of more data for mechanism validation.

Reviewer 3:
The reviewer compliments the very good progress on modeling a nine-component model for the CRC AVFL-18 diesel surrogate fuel.

The reviewer recognized that the model for the 10-component surrogate model for gasoline was improved, noting that it has also been applied to engine combustion experiments at SNL and the knock tests at ORNL.

Reviewer 4:
The reviewer commented on the good progress for both diesel components and gasoline components, but would like to see accelerated progress on gasoline components and the accuracy of gasoline components, especially considering dilute, boosted stoichiometric operation. Near-term LD engines will be boosted running stoichiometric with high rates of EGR. The reviewer indicated that the engine efficiency limit for these engines is due to knock at full load, so accurately simulating these operating conditions is critical to improving engines.

Reviewer 5:
The reviewer would like to see the project prioritize the testing of these kinetic models for more engine relevant conditions with changing EGR, equivalence ration and fuel composition.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer approved of the excellent collaboration with industries, universities, and national laboratories globally.

Reviewer 2:
The reviewer noted that collaboration with the relevant RCM, shock tube, and engine tests at the various labs is very good.

Reviewer 3:
The reviewer complimented the very good interactions and contributions to industry through participation in projects sponsored by the CRC, a consortium of automakers and energy companies (CRC Fuels for Advanced Combustion Engines [FACE] working group and CRC projects such as AVFL-18a). This person also noted considerable interactions and coordination with others involved in developing kinetic models and engine simulations at the national laboratories and universities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed plans are very logical and will continue the excellent work in this project.

Reviewer 2:
The reviewer highlights that the proposed future work is very carefully planned, but the team may need to put more efforts on the fuels (such as high-octane ethanol blends) that are urgently needed by the auto industry.

Reviewer 3:
The reviewer would like to see accelerated progress on gasoline surrogate components.

Reviewer 4:
The reviewer recommended that the team give the highest priority to modeling the ignition behavior of the gasoline-ethanol blends in the RCM tests at ANL. This person also indicated that the industry is very interested in gasoline ethanol blends with a high research octane number (RON) and high sensitivity. These fuel types have the potential of working successfully in both flame propagation combustion as well as LT combustion systems. This person stressed that the development of models for these fuels should be given very high priority.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes, development and validation of chemical kinetic models and surrogate fuel models are very important to enable the development of engines with higher efficiencies and lower emissions, which will lead to higher fuel economies and lower fuel consumption in this reviewer’s opinion.

Reviewer 2:
This project supports the overall DOE objectives of petroleum displacement. The reviewer noted that development of predictive chemical kinetic models for gasoline, diesel, and next generation fuels is critical to better design high-efficiency and clean combustion engines, which will reduce petroleum demand.

Reviewer 3:
The reviewer stated that improving the accuracy of chemical kinetics has a direct impact on engine combustion simulation tools that help engine developers improve engine efficiency.

Reviewer 4:
The reviewer commented that, while indirect, this work is very critical in enabling modeling and improving fundamental understanding of ignition and knock processes in a wide variety of combustion systems.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that it appears the team is meeting milestones on a timely basis and so resources seem appropriate.

Reviewer 2:
The reviewer observed that the team is well connected with other researchers to provide experimental data for model validation.

Reviewer 3:
The reviewer suggested that additional funding could help accelerate progress in this critical area.

Presentation Number: acs014
Presentation Title: 2016 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software
Principal Investigator: David Carrington (Los Alamos National Laboratory)

Presenter

David Carrington, Los Alamos National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

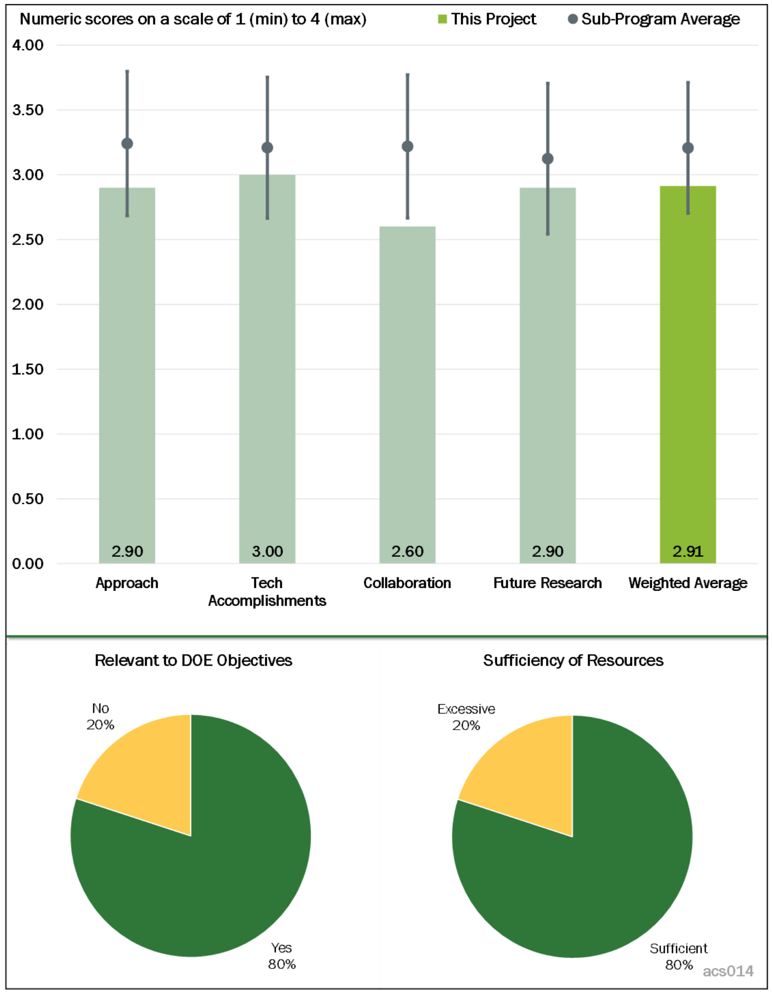

Figure 1-11 - Presentation Number: acs014 Presentation Title: 2016 KIVA-hpFE Development: A Robust and Accurate Engine Modeling Software Principal Investigator: David Carrington (Los Alamos National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer complimented the great work and persistent effort, noting the project has a well-defined goal and that much effort has been put toward it. The PI has been doing a great job in incorporating all the effort aligned with well-defined direction.

Reviewer 2:

According to the reviewer, the technical approach pursued for valve motion using overset meshes and volume of fluid method for injection spray are appealing and advanced compared to what commercial CFD codes had to offer. But, the reviewer noted that the implemented methods need to be validated for full-up engine CFD by the DOE labs and industry. The question remains whether a small team with limited resources for KIVA-hpFE can compete with a commercial software vendor with respect to software development, support, and software maintenance.

Reviewer 3:

The reviewer observed that the approach over the past year has been to incorporate some new capabilities in KIVA that would enhance its usefulness. These include various approaches to modeling sub-processes and improving some computational aspects to make the solution to the governing equations more efficient and less time-consuming. The view is to improve engine efficiency and reduce harmful emissions. KIVA has been around a long time and its virtue is open-source (e.g., unlike for-profit codes like CONVERGE) along with its significant capabilities. Efforts include employing LES to model engine flows, spray modeling grid generation capabilities, and multistep kinetics using Chemkin-pro.

Fuels are multicomponent, especially surrogates, and the PI is starting to work on this problem. The reviewer commented that some discussion of how multicomponent effects would be addressed should be included. This person wondered how confident the PIs are that their property database for mixtures is robust, and what about mixing rules, etc., combustion chemistries of multicomponent liquid mixtures, etc.

KIVA ostensibly relies on certain adjustable inputs (e.g., because it is not an ab-initio solver) and asks if that understanding is correct. The reviewer recommended the team provide a concise list of what needs to be adjusted for predictions and data prior to using KIVA. Also, the reviewer commented it would be nice to have one slide in the review presentations that lists the sub-models needed for KIVA to work.

The presenter mentioned a volume of fluid (VOF) approach for sprays and the reviewer asked if the resulting simulation capability will be at the level of a code like RAPTOR (SNL), which simulates jet injection and its ultimate development into a spray.

The reviewer approved of the pursuit of utilizing dynamic LES for capturing the transition from laminar to turbulent flow and a subsequent move away from the law-of-the-wall.

The reviewer would like a further discussion of the PI's comment that he has "validated with experimental data" the dynamic LES and wondered if this is the backward-facing step and isolated drop configurations mentioned in the proposal. If so, the reviewer also asked how these configurations are related to in-cylinder processes where KIVA is to be applied. The reviewer would also like a better definition for what "validated" meant. The reviewer asked if there a targeted percentage difference between simulation and experiment where "validation" would be considered as having been met, and asked what the contingency is if the agreement is poor. The reviewer requested elaboration of details.

Reviewer 4:
The reviewer reminded the team that DOE funded projects should be developing new technologies that push the boundaries of what is possible and observed that this work is merely making a competitor to commercially available simulation tools without a clear technical superiority.

Reviewer 5:
The reviewer repeated comments that were provided last year, as they felt the comments were still relevant this year.

KIVA-3 and KIVA-4 are seeing less and less use within industry. KIVA has become more of a free resource to universities that want an open-source type format so they can do physical modeling. But even there, other competitors like OpenFOAM are taking over the market share.

The reviewer recommended that the team conduct a serious evaluation of the business model. It would really be healthy to continue to have KIVA as a competitor to other commercial codes. The reviewer wondered what can be done to hasten the development and deployment of KIVA within industry.

The reviewer remarked that the key issue now is whether industry is really interested in KIVA-hpFE, and also questioned why, if the answer is no. The reviewer reiterated that it is a free code, but yet industry prefers to use other commercial codes. The reviewer asked what can be done to make the usefulness and deployment of KIVA-hpFE within industry faster.

The reviewer pondered that perhaps a new business model that increases the chances of KIVA not fading away in the next few years would demand different types of collaborations.

Last year it was mentioned that RFI and ANSYS will be explored to commercialize the code and make it competitive with other codes so that industry can get interested in using it. The reviewer thought it would be healthy to have more competitive CFD codes in the marketplace.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed more validations and described progress as steady and aligned with the goal. The reviewer additionally noted that making the grid generation part easy is a smart move.

Reviewer 2:
The reviewer observed that the team undertook and completed several new and model-enhancing initiatives (Slide 8).

The reviewer complimented the good work done continuing to improve robustness, accuracy, and efficiency of the code.

Reviewer 3:
The reviewer noted that the code framework has been validated for standard benchmark test cases, but full-up engine simulations still need to be validated with spray, chemistry and various sub-models.

Reviewer 4:
The reviewer heard the presenter state that the long-term project of revamping KIVA was 85% complete, but would have liked to have seen a roadmap that showed what was done, what was accomplished over the past year, and what is left to complete the overall project.

Reviewer 5:
In the past year there are been significant advances in improving KIVA's capabilities. The improvements seem to be in the sub-models for things like turbulence, spray injection, transition from finite volume (FV) to finite element modeling (FEM) with significant improvements in computational time, grid generation, etc., and comparisons are shown for basic configurations like 3D flow past a cylinder and the pressure field around an isolated droplet. None of this is easy and the reviewer commended the PI for doing so much. The reviewer suggested that perhaps additional discussions would help to highlight how these improvements will impact the larger purpose of making KIVA a more robust in-cylinder predictor.

The efforts pursued include validation. For example, the PI notes that a dynamic LES approach is "validated with experimental data for pertinent problems." The reviewer wondered what the problems used for validation (cylinder, drop, etc.) are and recommended expanding the concept of validation with discussions. The reviewer asked what is being validated, what happens if there are gaps, how they are closed, and what metrics are used to assess if "validation" has been achieved.

For sprays, the PI noted "true multiphase flow modeling" and the reviewer requested that the PI elaborate, asking if this is like direct numerical simulation (DNS) for sprays. The reviewer also wondered if the spray can include multi-injector nozzles.

The reviewer found the spray modeling particularly exciting and commented that other national laboratories are also developing robust computational capabilities for spray (e.g., RAPTOR). The reviewer asked about KIVA's capabilities compare with RAPTOR's and if there is any duplication of effort here.

The "surface tension test" on a three-dimensional (3D) "static drop" seems interesting; however, it was not clear precisely to the reviewer what the PI was simulating, wondering if it was evaporation, combustion, convection over the drop, etc. Flow symmetry seems to be assumed as a base case, although the reviewer requested confirmation of that assumption, and a pressure field computed around the drop. The reviewer asked what the boundary conditions are and requested more clarity with that information.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that collaboration and coordination has been good with universities, but noted that eventual usage by other DOE labs for engine CFD will be a good validation for the technical capability of the software.

Reviewer 2:
The PI has a range of collaborators, including some from the national laboratories, developers of CHEMKIN-Pro, universities, and one industry. However, the reviewer articulated that the project needs a stronger connection to OEMs who would be the ultimate users, presumably, of a code like KIVA. The reviewer wondered if OEMs have significant interest in KIVA and commented that CONVERGE seems in a better position to aid industry, which is using CONVERGE in design. The reviewer commented that KIVA deserves a place in there too, recommending that the PI and his team get some OEMs on boards to establish relevance and interest.

Reviewer 3:
The reviewer suggested that the team seek more engagement from industry. This would allow for more validation in real engine geometry and operating conditions.

Reviewer 4:
The reviewer noted that collaboration with potential users in industry, where engines are designed and manufactured is poor, suggesting that the KIVA-hpFE code needs more real use in industry.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The PI has identified a number of challenges for future work, including turbulence and spray modeling and conjugate heat transfer. The reviewer appreciated that the PI notes the need for incorporating heat transfer to the engine block which seems to be a move away from correlations for heat transfer coefficient, but does request confirmation of this understanding.

The reviewer recommended that the PI consider not only engine block thermal considerations but materials stress matters associated with significant temperature gradients within the cylinder for future work. In this reviewer’s opinion, that may not have been considered but would separate KIVA from other codes. Engines may not operate indefinitely at peak efficiency if the materials from which they are fabricated fail. The reviewer suggested it is time to incorporate this consideration in robust engine solvers.

The reviewer recommended that, in future work, the PI include on his team of “partners” at least one OEM with some commitment to adopt KIVA for prototype engine design if certain conditions are met (the PI can work with the OEM to define the conditions). Doing so will enhance the relevance of the project to DOE’s interests.

Reviewer 2:
The reviewer suggested that future work should focus on developing improved sub-models that commercial codes can incorporate into their software.

Reviewer 3:
Grid pro software is known for orthogonality near the wall with algebraic smoothing. This reviewer wondered why the project needs a hexahedral mesh approach if the team is also pursuing self-damping at the wall and

also, why not tetrahedral meshes for engine flow with finite elements methods that would allow adaptive meshing and mesh morphing.

Reviewer 4:

The reviewer complimented the great list of future work items, especially the critical work on conjugate heat transfer (CHT). In this reviewer's opinion, the industry would appreciate one single software to do all and recommended that the team consider extending the capability of the code instead of residing only in the in-cylinder combustion area.

Reviewer 5:

This reviewer suggested focusing on the business model for marketing KIVA and asks how the industry can be convinced to use it on a regular basis.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

This reviewer commented yes; once validated for full-up engine modeling, the software will help improve overall thermal efficiency of in-cylinder combustion.

Reviewer 2:

The reviewer noted that the new software should provide more accurate solutions with better computational efficiency. This is to replace or at least encourage the exiting commercial software based on a several decades old platform in order to adopt latest approach.

Reviewer 3:

The project is relevant from a broad perspective and it addresses processes that would improve engine performance. But ultimate evidence of this should come from those using KIVA, which has been in development for a long time. The reviewer appreciated the excellent capabilities that are accessible to the wider community at essentially no cost; however, OEMs apparently do not use it to design engines (at least on a wide-ranging scale), although the PI states that "...most of the following attributes are those heralded by industry as necessities." The reviewer suggested that if the PI is working to provide more relevance of KIVA's capabilities to OEMs, it may be helpful to have some discussions concerning OEMs' thinking on why they may not be embracing KIVA the way they are with other codes (e.g., CONVERGE). This person wondered if it is the open source feature of KIVA and proprietary issues that OEMs do not want to reveal.

Additionally, the reviewer asked for whom is KIVA is targeted in its current form, and stated if it is university researchers, that is fine. KIVA will then assist in the education of the next generation of computational scientist being trained in simulations and that is a good thing.

Reviewer 4:

The reviewer stated that KIVA does not have an impact on industrial users of engine simulation codes and therefore will not contribute to petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that in order to validate the code and bring the software to the user community, the project would require more resources in the short term.

Reviewer 2:
The reviewer suggested that perhaps some funds should be redirected toward promoting greater use by industry and providing support.

Reviewer 3:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Reviewer 4:
The reviewer appreciated the adaptability of subjecting future milestones to the budget; however, this person recommended putting more effort into, and maybe presenting a grand plan, enhancing the model with additional capabilities. In this reviewer's opinion, adding CHT was a great move and suggests also having KIVA-hpFE as a standard platform for all the effort being made at national laboratories with CONVERGE, which is a commercial code. There are numerous comments from PIs saying they are working with Convergent Science because of a willingness to work together. This reviewer requested confirmation on whether KIVA-hpFE is the real "open" code for everyone with the latest numerical scheme.

Reviewer 5:
The reviewer indicated that resources are excessive given the result of the project and the lack of relevance.

Presentation Number: acs015
Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

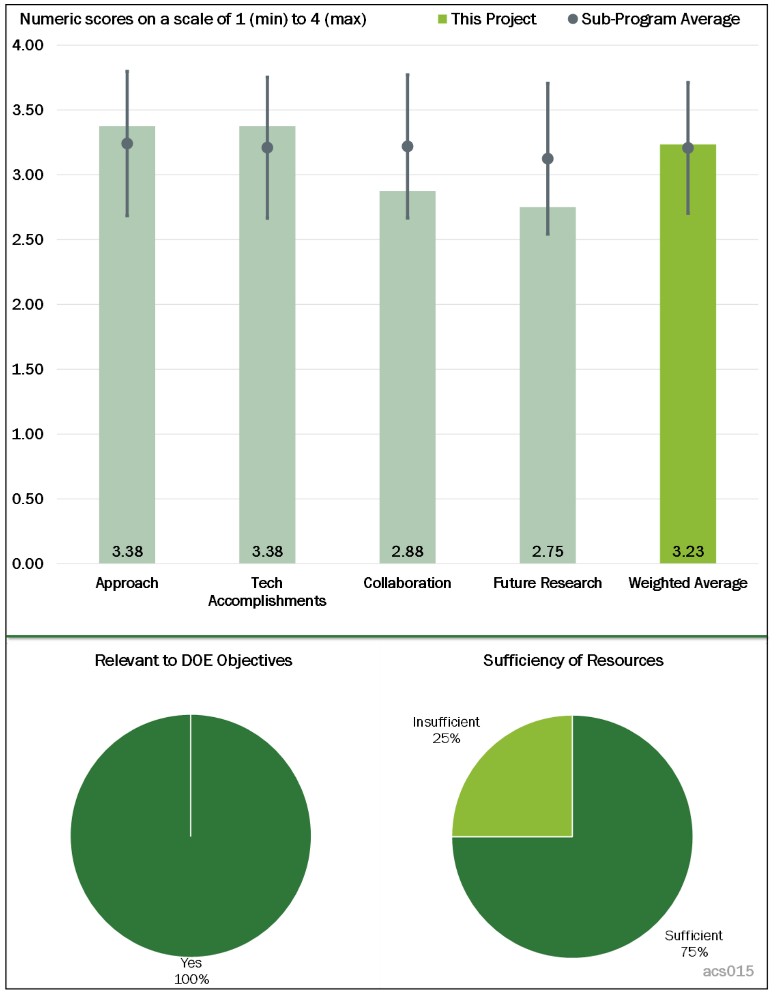

Figure 1-12 - Presentation Number: acs015 Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter
Jim Szybist, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This is an interesting approach, different from dedicated EGR (DEGR), to altering the combustible composition in the cylinder as a means to improve combustion. This reviewer highlighted that the work is anchored by good thermodynamic analysis and includes good catalytic work, good thermodynamic analysis, and good experimental work covering a large range of operating parameters and stated the analysis is well done and the presentation was easy to follow.

Reviewer 2:
On the surface, this looks to be the same as Southwest Research Institute's (SwRI) DEGR concept; however, the creative approach of running lean in-cylinder and using a post injection to reform fuel across the catalyst distinguishes the work from the DEGR concept in this reviewer's opinion. The reviewer appreciated the novel concept, and believes it is this type of creativity that will identify new approaches to improving engine efficiency.

Reviewer 3:
The project appears well organized and follows a previous program on thermochemical recuperation beginning in 2011. The project utilizes partial oxidation reforming to improve steam reforming (exhibited limitations due to enthalpies of reaction and sulfur [S]). The reviewer commented that the team has a strong fundamental grasp of the technical problem, is innovative in its approach, and does a good job in documenting progress.

The reviewer asked if the program could provide more detail on the basic findings, such as what the pressure is and heat release rate (HRR) traces across the conditions studied including the dedicated cylinder and power cylinders.

Reviewer 4:
The reviewer recommended that the team think about emissions opportunities and barriers with this concept.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer complimented the technical accomplishments, highlighting the team's thoughtful analysis and interpretation of the results with a good assessment of what the results mean and what to do next.

Reviewer 2:
Considering the project is less than 1 year old, the reviewer complimented the good progress so far, observing that work continues to build on previous approaches and the team is utilizing a good science basis and explanations for observed phenomenon.

Reviewer 3:
The reviewer appreciated seeing multi-cylinder engine test results with an actual catalyst under test; however, given the importance of temperature on the thermochemical recuperation, this person recommended evaluations of more speed/load points to assess the impact of exhaust.

Reviewer 4:
The work provides an extensive optimization between lean combustion and post-injection fueling for operation of the catalyst; however, the reviewer thought the flows reported seem rather large. For example, 10 grams per minute would be at the 2,000 revolutions per minute (RPM) speed 20mg per stroke. The reviewer stated that optimal regions use higher fuelings and thought it was surprising that these amounts can actually be offset by the other cylinders to attain the gains reported over the baseline.

The reviewer indicated that it is not clear how the modeling results correlate with the engine tests: the thermochemical recuperation and engine efficiency regions appear in rather different areas of the O_2-equivalence ratio plots.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The team has connected with appropriate colleagues for contribution in areas where they lack the expertise; however, the reviewer noted that some of the collaborations are recent, so this person will wait until next year before rating it as excellent.

Reviewer 2:
While there is a list of collaborators, the reviewer saw no particular information given to specific contributions from any of these. Additionally, this person noted an apparent lack of involvement from industrial partners.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the analysis has been thoughtful and there has been a good assessment of what to do next.

Reviewer 2:
The reviewer complimented the team's idea to include a S-poisoning study, but suggested that future work should also explore the entire engine speed/load map to determine where adequate exhaust temperature is available to achieve good thermochemical recuperation.

Reviewer 3:
The reviewer indicated that this was not discussed in any significant detail and stated it would have been interesting to see how the technical partners would contribute to the work, as in the nature of the catalyst formulations.

Reviewer 4:
The reviewer recommended that the team add emissions opportunities and barriers to the proposed future work, namely a cold start approach.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes, this reviewer stated that the nature of the work is of interest to explore how reforming could impact future engine configurations.

Reviewer 2:
The reviewer noted that, if successful, this work could demonstrate an approach that could be readily integrated into combustion systems, stationary or mobile, while preserving the application of existing emission technology—stoichiometric TWC.

Reviewer 3:
The reviewer commented that the approach, which shows a 10% benefit over a boosted, cooled EGR baseline, is a promising improvement and could lead to improved vehicle fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that this was good work within the constraints of their budget.

Reviewer 2:
The reviewer noted that resources seem adequate, but it is hard to evaluate as future work description is not given.

Reviewer 3:
The reviewer recommended more resources to accelerate project progress and develop the concept.

Presentation Number: acs016
Presentation Title: High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines
Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Presenter

Scott Curran, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

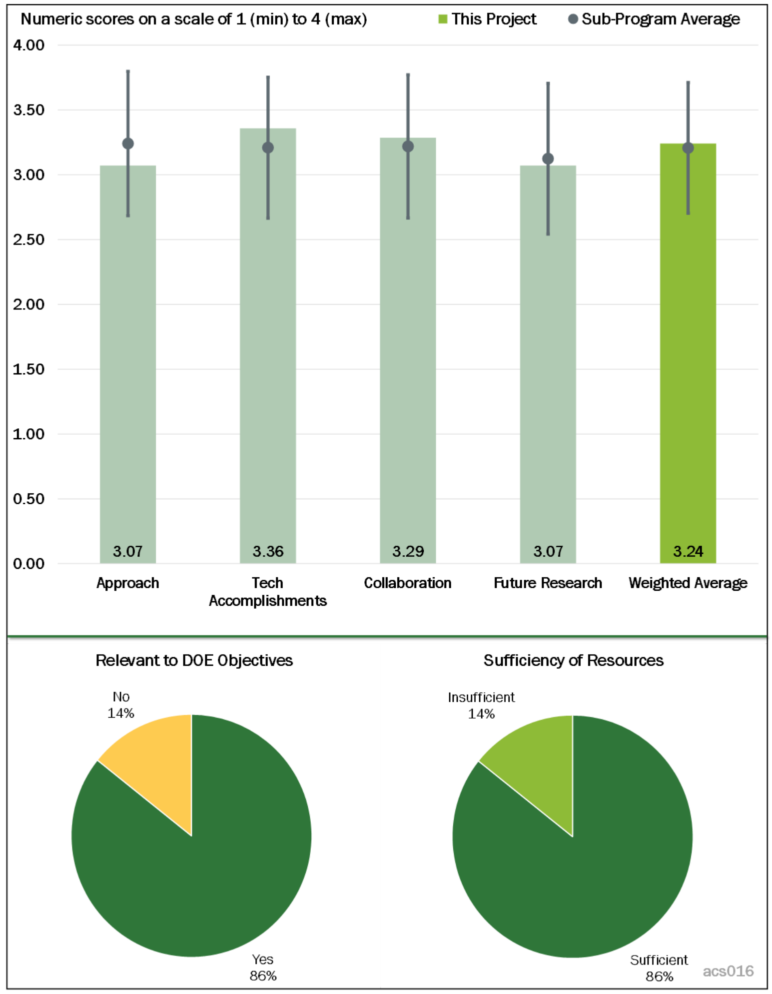

Figure 1-13 - Presentation Number: acs016 Presentation Title: High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

Evaluating high-efficiency, clean combustion (HECC) concepts in a multi-cylinder engine is important for understanding potential in a system that is closer to commercial platforms. The reviewer also approved of the team's experimental and modeling study of transients related to mode switching between reactivity controlled compression ignition (RCCI) and conventional mixing controlled diesel combustion.

Reviewer 2:

The reviewer appreciated that the project is well-designed and well-integrated with other efforts (academia, national laboratories, industry) that investigate advanced combustion regimes for high-efficiency LD engines.

Reviewer 3:

The PI refocused part of this project based on last year's feedback toward transient control. The reviewer found the initial results interesting to say the least and noted they were driving a significant portion of the current effort and approach. The reviewer hopes that this will lead to new answers next year for this key question.

Reviewer 4:

The reviewer appreciated the objective of the project, but noted that it is important that the team present the basic characteristics of the fuel. At a minimum, the reviewer asks what are the RON and motor octane number and suggested that this should be put in perspective with the in-cylinder thermodynamics at the engine operating conditions investigated. These results might be incongruent with the simulations which use primary reference fuels (PRFs) with a sensitivity of zero.

Reviewer 5:
It is unreasonable to expect a LD vehicle customer to be willing to fill two different fuel tanks, thus calling into question the premise of the RCCI approach. For this combustion approach to be viable, the reviewer recommended a single fuel tank and some sort of fuel separator that can provide the two fuels onboard a vehicle.

Reviewer 6:
The reviewer said that the team should revisit the approach in a significant way, stating there are many barriers to the RCCI concept that a national laboratory can work on. The reviewer recommended ordering these barriers and focusing on the top one or two. Obviously, the barrier is not high efficiency, as it has been demonstrated frequently. The reviewer asked if the barrier would be high engine output of HC and CO, or if it would be the need to have two fuel systems and two fuels onboard.

The reviewer identified another high-level question that this project should answer, specifically, the reviewer asked if this is a LD or a LD concept. Answering this question will help greatly narrow the scope of the work and maybe lead to better progress. The approach of exploring high- and low-delta reactivity effects on RCCI combustion sounds promising to this reviewer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer thought the presentation was well organized and scoped for accomplishments and progress.

Reviewer 2:
Progress seemed good, according to this reviewer; the team is meeting milestones.

Reviewer 3:
The reviewer stated that the project followed its milestones and the outcomes are in line with the DOE program regarding LD vehicle efficiency and emissions.

Reviewer 4:
The effort of incorporating hardware-in-the-loop (HIL) with adjustments to transition between RCCI and conventional diesel combustion (CDC) was instructive and encouraging for this reviewer. It seems that there are viable approaches to handle transient engine operation.

Reviewer 5:
The reviewer understood that the stated accomplishment was mapping, but did not see a fuel consumption or engine efficiency map presented. The reviewer stated that mode switching between RCCI and CDC as well as the transient dynamometer cycle simulation addresses a major question from the past regarding transient behavior of the engine.

Reviewer 6:
The reviewer indicated that the transient results and the understanding generated by comparing steady-state RCCI low/high reactivity with CDC was valuable; however, it would have been nice to see any equivalence ratio effects. The reviewer wondered if results will be coming in the future.

Reviewer 7:
While progress has been satisfactory, the reviewer commented that it does not seem to have impacted the long list of challenges with the RCCI concept.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the team has identified and constructively engaged with appropriate collaborators.

Reviewer 2:
This project has included appropriate partners in the past, including this past year. There has been excellent integration of necessary resources, in this reviewer's opinion.

Reviewer 3:
The reviewer noted some collaboration with industry (GM, Mahle, and Honeywell cited) and universities (UW, University of Michigan, and Clemson cited).

Reviewer 4:
The project shows very good collaboration and coordination with the other academic, national laboratories, and industry partners. While the reviewer commended the PI for including several academic partners, this person suggested also interacting with other universities that have common research interests. This is extremely necessary under current budgetary restraints.

Reviewer 5:
The reviewer asked if there is collaboration with a LD OEM that is willing to consider commercializing this concept someday.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Future research continues the PIs excellent work on translating advanced combustion concepts to real engine/vehicle applications. If the budget is further reduced, this reviewer thought that it will affect the project outcome. As a suggestion, the reviewer would like to have seen more details about the fuel property effects on the strategies used in this project, especially if these properties would have a large effect on the interaction between various engine systems (i.e., air and fuel delivery, mixing, combustion, aftertreatment, etc.).

Reviewer 2:
This reviewer recommended extending studies to other engine platforms such as a GDI engine.

Reviewer 3:
The reviewer commented that the research is focusing on how best to incorporate advanced combustion processes into engine operation, as opposed to identifying a particular combustion approach and constraining what can be done to the engine to maintain this combustion approach.

Reviewer 4:
It was unclear to this reviewer how repeating RCCI work on a gasoline based engine platform will result in any different conclusions.

Reviewer 5:
There is a lot of work to do this coming year, but the reviewer would like to see some equivalence ratio effect studies within this project next year.

Reviewer 6:
Multi-cylinder work on the RCCI concept, which has such a long list of barriers, did not make sense to this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes, evaluating advanced combustion concepts in multi-cylinder engines potentially improves the feasibility of identifying and solving issues associated with more production-like engines. The reviewer stated that if HECC is successfully commercialized, it would result in improved fuel economy and lower fuel consumption.

Reviewer 2:
The reviewer noted the project is well-aligned with the DOE objectives of improving the efficiency and emissions for LD engines.

Reviewer 3:
Yes, this is a very relevant hardware demonstration project showing near real world effects of various combustion strategies on LD engine fuel economy and emissions performance. The reviewer commented this was one of the more practical combustion projects.

Reviewer 4:
The reviewer said yes.

Reviewer 5:
As a dual fuel approach, this concept will not impact the objective of petroleum displacement because two fuel tanks in a LD product will not be acceptable to consumers in this reviewer's opinion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Novel experimental work requires a steady stream of funding. This reviewer commended the PI for such a good work considering the budget limitations.

Reviewer 2:
Milestones are being accomplished in a timely manner; this reviewer did not see any indication that funding is insufficient.

Reviewer 3:
It seems that the PI is doing good work with the resources available. It did not appear to this reviewer that the results have been constrained by lack of resources.

Reviewer 4:
Funding was noticeably decreased this past year; it was not clear to this reviewer if funding is an issue with this project and the presenter did not address any such issue.

Presentation Number: acs017
Presentation Title: Accelerating Predictive Simulation of IC Engines with High Performance Computing
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

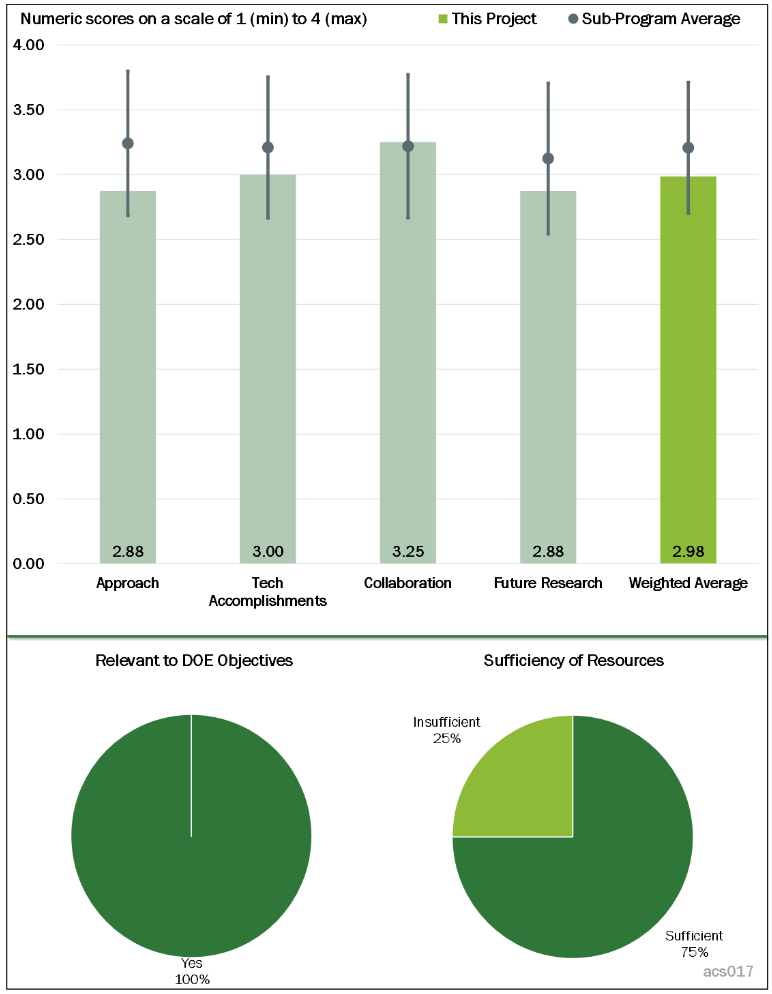

Figure 1-14 - Presentation Number: acs017 Presentation Title: Accelerating Predictive Simulation of IC Engines with High Performance Computing Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter

K. Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that industry does not have the high-performance computing (HPC) resources that the national laboratories have. This project is a good example of using that resource well and paving the way for what is possible and what needs to be done to make virtual engine design and calibration possible.

Reviewer 2:

The reviewer noted that this is an ongoing project initiated in 2012 on accelerating the predictive simulation capabilities through HPC. The project targets three case studies, which appears to be a well-defined pathway to apply the intensive commutation across a variety of problems and to report progress. The reviewer commented that it is unclear how effective this project is or its ultimate impact. The availability of these intense resources for computation is important, but it should be accompanied with an understanding of physics. For example, the project might address how the improved computation closed the gap in knowledge. The reviewer stated that we have seen over time effective modeling with limited resources yielding useful results when a good understanding of physics is present.

Reviewer 3:

The reviewer stated that the project is trying to tackle multiple different challenges simultaneously that need HPC resources without a clear focus for the project.

The reviewer commented that to be feasible and to have a quick impact on the engine development community, it is better to concentrate on one challenge such as “virtual engine design and calibration” and to come up with an innovative framework using either genetic algorithms or Bayesian models.

Reviewer 4:
The reviewer commented that the project needs to identify how the model will be used once it is validated. If the goal is to optimize calibration and design features, it may be time and cost prohibitive considering the huge design space. The reviewer stated that perhaps identifying some interesting operating points from the experimental or OEM data could help narrow the focus.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that this is a good use of DOE funds to address projects that OEMs cannot.

Reviewer 2:
The reviewer acknowledged that good progress has been made investigating a variety of variables (EGR, sprays, speed, SOI rail pressure, etc.) as well as detailed chemistry models on engine design and calibration.

Reviewer 3:
The reviewer observed that the parameters identified for the design of experiments for virtual engine design and calibration are comprehensive. The reviewer noted that instead of running a whole suite of experiments, it would have been better to run a few extreme cases and compare simulation results with experimental results to make sure whether chemistry fidelity and spray parameters are sufficient.

Reviewer 4:
The reviewer stated that the results show a mix of improved fidelity and failure in reproducing real world results. Some discussion is presented as to why the gap occurs, but as the years go by in this program, there appears to be no concrete revelation. The reviewer noted that authors are encouraged to provide a short overview of the virtual engine project; however, in the case of the engine configuration evaluated, the presenter did not seem familiar with it. The reviewer remarked that to pick up on one of the goals sought, it may be useful to have a "kick-off" calibration exercise to see how the new computing capability can improve the current process or what new technical approach may be developed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that good collaboration exists with GM.

Reviewer 2:
The reviewer commented that there are significant collaborators noted. In some cases, the ties are very strong, such as SNL's engine work on premixed combustion. The team may report how other players such as the industrial partner contribute to the project specifically.

Reviewer 3:
The reviewer noted that, in general, the project has good collaboration with industry and national laboratories.

The reviewer commented that for the virtual engine and calibration project, it would have been better to collaborate with ANL regarding best practices of running simulations and other workflow manager tools such as "SWIFT" to manage multiple cases.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the proposed future research is computationally intensive and was not really sure whether it is practical to accomplish all the proposed work in a reasonable time. The reviewer illustrated the issue with the case of multiple simulations with conjugate heat transfer, full cycle, and detailed chemical for virtual engine design and calibration project.

Reviewer 2:
The reviewer noted that concerning the virtual engine work, it is surprising to read that after several years of work, it is only in 2018 that “full cycle simulation” will be considered to capture the mixing and blow-down process. The reviewer questioned if there a reason why this is introduced so late in the program. The reviewer commented that the impact it will have in the previous effort will be interesting to see. A smaller focused design of experiments may be useful before initiating such a large effort on the whole map.

The reviewer requested that the project provide a more comprehensive review of the dual fuel work. The reviewer observed that the project did not indicate the OEM or engine considered. The partial fuel stratification HCCI work on the other hand is more descriptive.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated, yes, this work has the potential to impact DOE objectives.

Reviewer 2:
The reviewer stated that it is important to capture key learnings and knowledge from experiments into models so that at the end of the day we have a tool to help with engine design and calibration.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that it seems adequate.

Reviewer 2:
The reviewer stated that resources are sufficient.

Presentation Number: acs022
Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations Analysis and Coordination)
Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Presenter

Josh Pihl, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

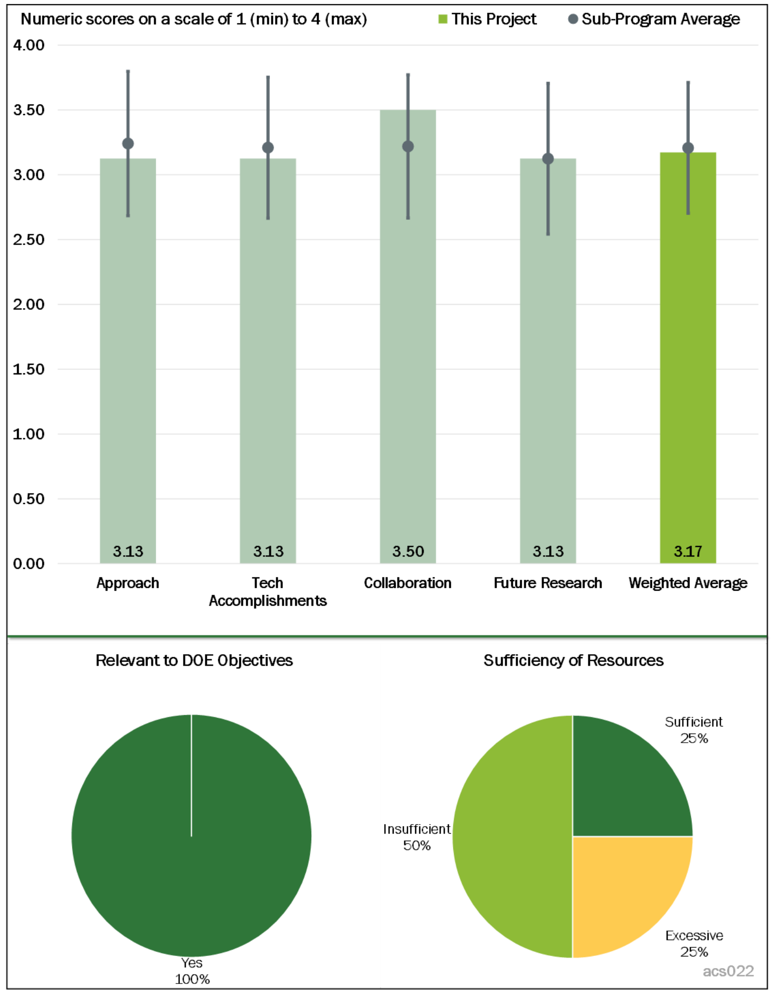

Figure 1-15 - Presentation Number: acs022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations Analysis and Coordination) Principal Investigator: Josh Pihl (Oak Ridge National Laboratory

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated the project was a very good approach to engage USCAR for requirements and to confirm interest with regular meetings and symposiums with a record of industry and academia attendance/participation. The reviewer observed that this project could be outstanding with a simple survey of participants for strengths, weaknesses, and solutions, possibly through a low-cost survey such as Survey Monkey.

Reviewer 2:

The reviewer stated that cross-cut lean exhaust emissions reduction simulations (CLEERS) Workshops and focus group teleconferences continue to provide an effective forum for sharing results and exchanging ideas related to exhaust aftertreatment modeling among participants from OEMs, academia, and national laboratories. Publication of select papers presented at the 2016 workshop in a special edition of *Emission Control Science & Technology* is also effective at promoting the CLEERS missions and activities. The reviewer commented that the recent focus on HC and NO_x storage catalysts and LT oxidation catalysts are timely in view of additional emission control challenges created by low exhaust temperatures from next-generation fuel-efficient engines. One important area where the reviewer hoped to see more activity is catalyst aging and deactivation (including those for TWCs); however, limited resources may well be the problem. The reviewer praised the introduction of a broad mix of speakers, including those from non-OEMs and for the focus group teleconferences, but felt that it would be important to continue to select presentation topics of potential interest to a wide spectrum of the CLEERS members.

Reviewer 3:

The reviewer stated that the approach to address needed research is well grounded in CLEERS surveys conducted with OEMs and the catalyst community. The CLEERS organization has demonstrated its ability to adapt its emphasis to areas of catalyst research that is of high interest to OEMs. A good example of this is the research shift toward passive NO_x adsorber (PNA) characterization and optimization that is needed by aftertreatment groups to provide viable system solutions for LT operating conditions. Continued research in the area of SCR characterization and performance prediction is very desirable from an OEM standpoint given the current and future use of this technology in many lean aftertreatment systems. Just as important, the embracing of LT catalyst formulations and characterizations is critical to helping enable future powertrains enter the LD truck market. However, real world aging conditions and catalyst poisons, along with the effects of temperature on greenhouse gas (GHG) selectivity must be included early in model development efforts.

Reviewer 4:

The reviewer stated that it is not clear how CLEERS is contributing to the lack of cost-effective emission control because it seems to be studying the same technologies as everyone else. The reviewer questioned next steps once CLEERS has data and models. The reviewer remarked that CLEERS should stick to promoting collaborations through workshops and teleconferences.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project demonstrated accomplishments that can be attributed somewhat to the CLEERS effort. The reviewer noted that it would be good to provide a few examples of success stories and/or papers that referenced CLEERS work or can be attributed to the work. The reviewer mentioned that metrics on the number of meetings and attendance is a good indication of performance with specific technological performance highlighted outstanding.

Reviewer 2:

The reviewer noted that the publication of select papers presented at the 2016 workshop in a special edition of *Emission Control Science & Technology* as well as new CLEERS newsletters would further increase the visibility of the CLEERS mission and activities. Also, the recent focus on HC and NO_x storage catalysts and LT catalyst development are in direct support of the LT emission control problem which would become increasingly important with the introduction of more fuel-efficient engines and advanced combustion modes in the future.

Reviewer 3:

The reviewer stated that continuing to provide understanding of the functionality and chemical state of copper (Cu) in SCR formulations is of value to the OEM community. The additional effort now directed at providing tools and methods to characterize PNA functionality and formulation effects on NO_x storage and release is equally important to provide a potential solution for LT NO_x control. However, the reviewer observed that better understanding of multiple NO_x desorption states and formulation methods for manipulating those states is needed. CLEERS contributions to characterization and testing protocols is also of high value to the catalyst community and offers the potential to more easily understand catalyst functionality and sharing of data between research facilities.

Reviewer 4:

The reviewer noted that there is no proof that the CLEERS mission of accelerating development of emission control technologies is being fulfilled. Rather, the development is led by suppliers and OEMs that do not share competitive information. The reviewer commented that CLEERS is supporting collaborations and providing data that mainly helps academics. The reviewer observed that some data is not pre-competitive and most data actually seems post-competitive. The reviewer was very tired of hearing about Cu/chabazite (CHA). The reviewer commented that work on cold nitric oxide (NO) and HC traps is good. The CLEERS survey and workshops are worthwhile. The coordination of DOE national laboratories results is a mixed bag. The reviewer remarked that LT catalysis is meaningful while lean gasoline is going nowhere. The reviewer observed that cooperative research and development agreements (CRADA) with Cummins are perennial.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the collaborative and highly coordinated structure of the CLEERS work as outstanding. The use of yearly symposiums, bi-monthly ACEC engagement, monthly teleconferences, and bi-weekly low-temperature aftertreatment (LTAT) meetings are instrumental to the successful research direction and efforts performed under the CLEERS umbrella. These connections with the OEM, supplier, and research communities allow the efficient exchange of information and feedback for productive research projects. This works well unless resources are too thinly dispersed in the multiple research areas.

Reviewer 2:
The reviewer commented on the excellent pre-competitive work as demonstrated by the record of participants from industry, academia, and national laboratories.

Reviewer 3:
The reviewer noted the good and effective collaboration between engine/vehicle manufacturers, universities, national laboratories, and component/software suppliers.

Reviewer 4:
The reviewer noted that CLEERS is collaborative by design.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the movement toward PNA supporting activities is appropriate as is the continued effort to provide additional SCR characterization. The reviewer pointed out that the area of multifunctional catalyst development and characterization has not yet been incorporated into the CLEERS activities. This is one area OEMs would probably encourage more effort.

Reviewer 2:
The reviewer requested that the project please continue the teleconferences and workshops. The reviewer noted that the forward-looking focus on cold NO and HC traps is good and continued that if some data collection/modeling at national laboratories must be included, make sure it is using relevant samples for exhaust gas such as thermally stable, robust to S, etc.

Reviewer 3:
The reviewer commented that the project has a good plan for future research with a focus on USCAR input such as lean NO_x, LT catalysts, and integrated catalysts/diesel particulate filters (DPF) with priorities identified. This roadmap could possibly be used to raise the bar for other projects not in scope (not pre-competitive or within funding limits).

Reviewer 4:
The reviewer expressed a desire to see more activities addressing catalyst aging/deactivation mechanisms and modeling, if resources permit. The reviewer stressed that this is a critically important area that has a direct

impact on emission compliance during actual vehicle use as well as platinum group metal (PGM) thrifting potential for emission control catalysts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this project well supports the overall DOE objectives by focusing on efficient ways to reduce exhaust emissions while at the same time improving fuel efficiency.

Reviewer 2:
The reviewer commented that the CLEERS activities directly support the advanced aftertreatment research areas of interest to OEMs. The CLEERS work in the area of PNA, SCR, and TWC characterization is important. The reviewer also noted that the LT aftertreatment research is consistent with the direction given by the U.S. DRIVE and ACEC groups to help support the introduction of advanced engine combustion strategies.

Reviewer 3:
The reviewer noted that some of the most cost-effective high-efficiency engine technologies require improvements in aftertreatment technology to become practical in the real-world fleet. The reviewer noted that the CLEERS effort supports high priority aftertreatment solutions to enable fuel efficiency savings.

Reviewer 4:
The reviewer commented that, theoretically, the answer is yes. The reviewer stated that the support is there but the results have yet to be determined.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the funding is sufficient for the scope. The reviewer noted the benefit of identifying roadmaps and collaborative connections. The reviewer commented that additional significant funding was needed for more detailed work in the target areas identified in the CLEERS roadmap.

Reviewer 2:
The reviewer commented that more funding would be appropriate to support the many research area needs in both stoichiometric and lean aftertreatment catalyst technologies.

Reviewer 3:
The reviewer noted that the coordination in funding is good but was not sure about “Analysis” funding, or how Cummins CRADA fits in.

Reviewer 4:
The reviewer observed that this project involves both coordination and support/execution of emission control research. The reviewer noted that it appears that the coordination effort alone takes up a fair amount of resources, leaving behind insufficient resources for the other part.

Presentation Number: acs023
Presentation Title: Cross-cut Lean Exhaust Emissions Reduction Simulation: Aftertreatment Modeling and Analysis
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

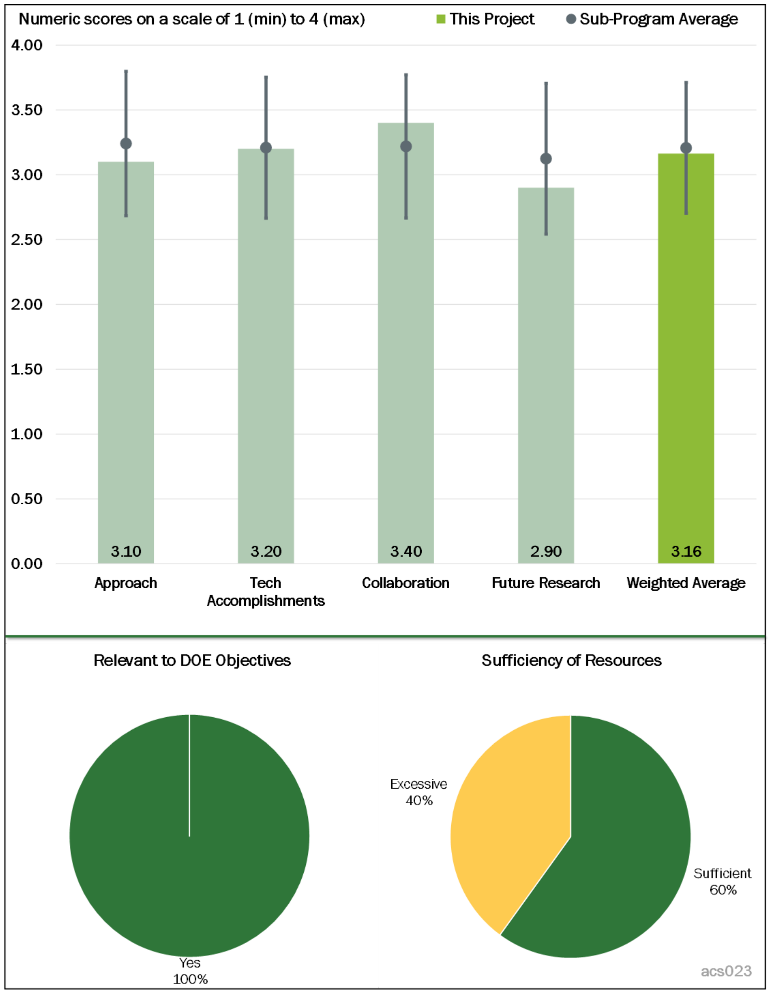

Figure 1-16 - Presentation Number: acs023 Presentation Title: Cross-cut Lean Exhaust Emissions Reduction Simulation: Aftertreatment Modeling and Analysis Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer found the approach to evaluating Cu^{2+} and Cu^{2+}/OH valuable along with the effects of hydrothermal aging on $Cu(OH)^{+}$.

Reviewer 2:

The reviewer commented that the approach described in this project is classic: develop fundamental understanding which then facilitates modeling work from computational chemistry which then leads to application as well as further compositional work. The project hits on major key barriers and gaps in conventional and emerging aftertreatment: SCR, selective catalytic reduction on filter (SCRF), PNA, etc. The reviewer observed that a GPF is missing but part of future direction. This application is very important, emerging, and ripe for optimization, especially when looking at complex catalyst architectures (layering, zoning) on a filter.

Reviewer 3:

The reviewer noted that while the topics are very relevant to modern emission control systems, it is not clear to the reviewer that any insights were gained that were not already known from patent literature.

Reviewer 4:

The reviewer found that the approach of looking at LT performance of SCR, PNA, and LTAT and defining the operational barriers was outstanding. Copper hydroxide (CuOH) limiting of performance at 700°C was particularly illuminating; however, it does not appear that the research has focus. The reviewer commented that it seems from the presentation that the money given to PNNL is not used for specific designed projects but for areas that PNNL researchers find interesting.

Reviewer 5:

The reviewer commented that, first, it bears mention that the organization of the presentation did not show off the work/approach/progress to its best advantage. The reviewer stated that the ORNL portion of the CLEERS talk (Pihl, ACS022) was much more clearly organized and recommended following that format because it benefits the reviewers who need to make detailed comments on the approach, accomplishments, etc. of the project.

Further, the reviewer noted that in the question session it became clear that there are not specific projects funded by the DOE CLEERS money, but rather, somewhat general studies in the four aftertreatment areas: SCR, LTAT, PNA, particulate/filtration. The reviewer commented that this general study approach has some significant weaknesses as it seems to be by happenstance rather than by hypothesis-driven research questions.

The reviewer recommended significantly more specific projects with well-defined tasks and deliverables to which an approach can be formulated and justified in terms of specific barriers. This reviewer requested that they be mentioned and referenced 2.3.1B-G.

The reviewer noted that on Slide 4, the two statements regarding the relationship between the CLEERS work and the CRADA work seem to be in opposition: "Utilize open CLEERS work to support industry CRADA activities, e.g., fundamental SCR studies led to the new CRADAs with FCA and Cummins" and "Maintain clear separation between CLEERS and CRADA activities." The reviewer questioned how there could be separation if the CLEERS work is used to support the CRADA work. The reviewer commented that it seems that the CLEERS money is being used to investigate fundamental questions that arise during the CRADA work, rather than hypothesis-driven research questions.

The reviewer noted that goals need to be "SMART" (specific, measurable, achievable, relevant, and time bound) and questioned how "fundamental understanding" can be measured. The reviewer questioned how the project team will know when this has been achieved. The reviewer recommended defining specific projects that would allow for specific goals that are easily evaluated by reviewers.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the accomplishments are valuable to the industry.

Reviewer 2:

The reviewer noted that advances in SCR, LTAT, and PNA are impressive.

Reviewer 3:

The reviewer noted that the results on LT SCR mechanisms on copper sulfanide (CuZ) are significant. The work is utilizing state-of-the art methods to break down the reaction mechanisms that have been proposed by others using experimental methods. Furthermore, the results are being corroborated here using experiments. The reviewer commented that work on PNAs is helping to explain the relationship between NO and nitrogen dioxide (NO_2) adsorption on modern adsorbers. The palladium oxide mechanism is interesting and will likely lead to optimizing palladium (Pd) utility in these systems. The work on SCRF coating location is quite preliminary, but interesting. As proposed, this work needs to extend GPF.

The reviewer stated that finalization of test protocols is very important and will now provide a harmonized method for evaluating results from different laboratories.

Reviewer 4:

The reviewer was not sure what was accomplished that was new.

Reviewer 5:

The reviewer requested that the project team call out the specific DOE barriers that the work is targeting (2.3.1B-G for cost, durability and fuel penalties of the emissions control devices) especially in each project area. The reviewer noted that because the "projects" funded by this work are not specific with measurable milestones, it is very difficult to determine whether or not the milestones have been met. The reviewer commented that on Slide 5, the first milestone is marked as on track, but the reviewer questioned how the project team will know when the project team has achieved understanding. The reviewer stated that these vague milestones are a side effect of the "approach" to the work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that the project is receiving excellent guidance from industry consortia and focus groups. More collaboration is needed with the catalyzers, especially as the project moves on SCR filter catalyst distribution and interactions with the substrate. They are well equipped to help guide the project, provide contemporary materials, and to apply the results.

Reviewer 2:

The reviewer stated that it seems appropriate.

Reviewer 3:

The reviewer commented that CLEERS has a good mix of collaborators.

Reviewer 4:

The reviewer commented that it would be good to know what portions were used successfully by the companies involved in the project.

Reviewer 5:

The reviewer noted that the strong collaboration with CLEERS lead partner ORNL and the CLEERS industrial and academic partners are a strong feature of this work. Collaboration with the industry partners which is predominant with CRADA projects seems to be what keeps the work done in this project relevant to DOE goals.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer praised the proposed future work in SCR, PNA, and LTAT as outstanding. The reviewer did not notice the future work in PM traps.

Reviewer 2:

The reviewer noted that CuZs have a major problem that is not being addressed here: S tolerance and reactivation. The reviewer cautioned that this ought to be addressed sooner rather than later because the proposed project directions may make the matter worse.

The reviewer commented that SCR filters are emerging now in LD and non-road applications and form the basis of HD low-NO_x remediation. Fundamental understanding is needed on catalyst distribution and substrate interactions, so addressing this is valuable. The reviewer cautioned that formulations and coating architecture is still evolving, so aim for universal understanding rather than that specific to the SCR filter in hand. The reviewer noted that the barriers/challenges description on particulate filtration correctly identifies GPF issues;

however, the project team did not indicate their future direction on this. The reviewer stated that PNA and LTAT directions are okay.

Reviewer 3:
The reviewer noted that the areas of work continue to seem like a characterization of the current state-of-the-art technologies, not necessarily moving technologies forward or discovering anything new. The reviewer questioned what the next steps are once the project team has all the data and models.

Reviewer 4:
The reviewer commented that it would be beneficial if the project team had end-of-life catalyst aging data that can correlate with the hydrothermal aging conditions. The reviewer proposed that the project team consider the following proposals either independently or in partnership with other organizations: Engine testing will age the catalyst radially proportional to the flowrate while hydrothermal ages nearly uniformly; it would be valuable to show SCR performance at beginning of life, mid-life, and end-of-life and show performance as radial function of the catalyst; and, consider adding scope to piece together semi hydrothermal aging as a function of radial position.

The reviewer further recommended the following proposals for the model that exists: Use the models that exist for each hydrothermal aging to consider and estimate a profile of end-of-life aging as a function of radial position; piecemeal the hydrothermal aging curves as a function of radial position to create a pseudo real life aging model; and, use this piecemeal model to predict performance.

Reviewer 5:
The reviewer noted that the future work for this project (Slide 22) seems to be somewhat more specific for SCR in regard to the in operando studies on the copper oxidation state for the models. However, the reviewer described the "new zeolite" supports as much too vague. The reviewer inquired about whether the project team will evaluate them, for what reason, if co-catalysts will be investigated, and how the project team defines "superior" NO activation.

The reviewer commented that the future work for the PNA is all very vague. The reviewer asked to know what will be learned from the synchrotron studies, and what will be evaluated. The reviewer also questioned the following: whether the objective is to simply put the sample in the synchrotron; whether hydrothermal aging effects will be studied as related to efficacy, or on the catalyst morphology; and how the project team will investigate S and HC tolerance, such as on power samples or on cores). The reviewer stated that the future work for the particulate work is well-defined, and commented that the future work for the LTAT is again very vague.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the emphasis on LT emissions performance and filtration are central to future high-efficient engine platforms.

Reviewer 2:
The reviewer noted that the technologies potentially enable more efficient powertrains with lower temperature exhaust.

Reviewer 3:
The reviewer observed that improving catalyst performance for NO_x has a direct link to fuel efficiency.

Reviewer 4:
The reviewer cautioned that with the recent EPA actions against FCA, it is apparent that CLEERS has more work to do to improve aftertreatment performance and durability.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project looks on track.

Reviewer 2:
The reviewer commented that $770,000 for three to four projects seems appropriate. The results demonstrate this.

Reviewer 3:
The reviewer noted that the resources seem excessive for characterization of state-of-the-art technologies.

Reviewer 4:
The reviewer indicated surprise at how low the funding was for the amount of work that was performed. While the work done was impressive, it was not apparent that the funding was being directed to specific topics or projects.

Reviewer 5:
The reviewer stated that the funding should support well-defined, hypothesis-driven research that is more focused.

Presentation Number: acs024
Presentation Title: Ash-Durable Catalyzed Filters for Gasoline Direct Injection (GDI) Engines
Principal Investigator: Hee Je Seong (Argonne National Laboratory)

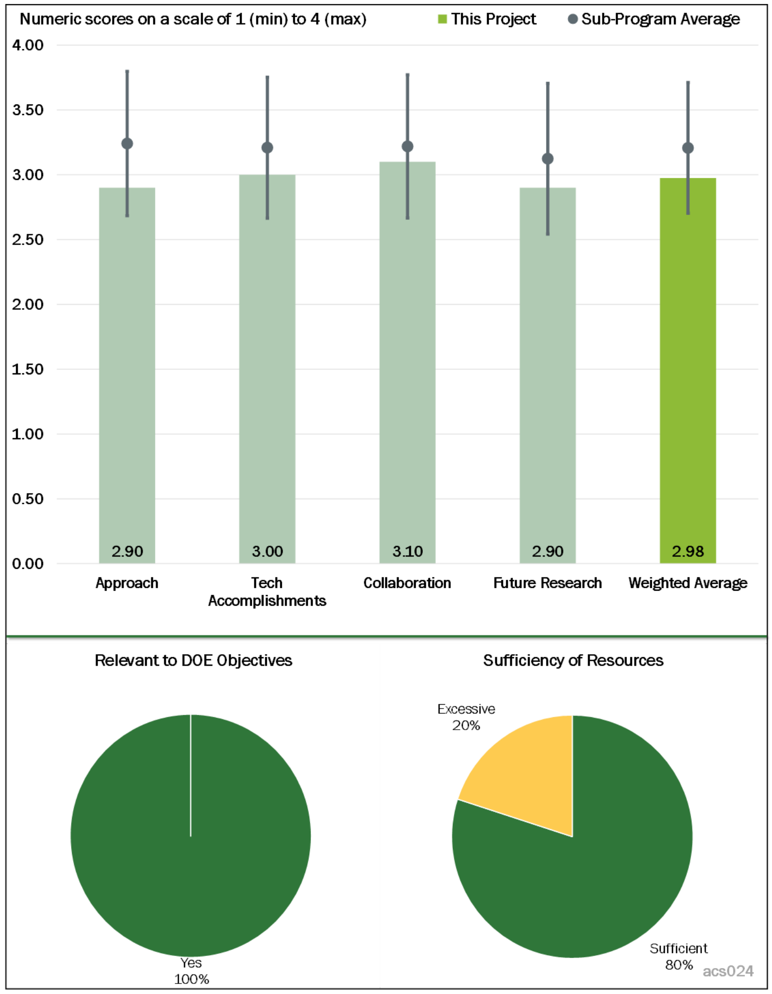

Figure 1-17 - Presentation Number: acs024 Presentation Title: Ash-Durable Catalyzed Filters for Gasoline Direct Injection (GDI) Engines Principal Investigator: Hee Je Seong (Argonne National Laboratory)

Presenter
Hee Je Seong, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the approach is good and the use of the team's resources is excellent. Once ash loading is representative of the real-world ash loading, this project will have the potential to produce outstanding results.

Reviewer 2:
The reviewer stated that the approach is reasonable. The emphasis on ash character, composition effects, and impact is spot-on. The reviewer cautioned the project team to make sure that accelerated bench methods are representative of what happens in the field. There were differences in ash density that might impact the project team's conclusions. The reviewer thought that the project team had a handle on this.

Reviewer 3:
The reviewer commented that the approach on this project has improved from previous years. The project now seems focused on phosphorus (P) poisoning of the washcoat in the GPF and how that affects cerium (Ce) state. Chemical performance was shown. The reviewer noted that the project did not comment on improvement of soot oxidation with oxygen storage capacity (OSC) and did not show (or measure) total OSC, which will tell you how much Ce is useful. The reviewer stated that a TWC in front will absorb most of the P. The TWC washcoat in the GPF will see less P.

Reviewer 4:
The reviewer commented that the approach seemed fine but the presentation of results was somewhat difficult to link to the approach.

Reviewer 5:

The reviewer noted a large improvement to the approach as compared to previous years, with an especially big improvement in focus and in including ORNL for the characterization work of the catalysts.

The reviewer commented that the reactor setup that is shown in the slides does not separate the mass transfer and kinetic limitations. The reviewer stated that when working on core samples, both effects are present, unless you can experimentally prove (investigate flow rate effects) otherwise, which there is no evidence of. The reviewer remarked that if the project team is interested in kinetic control, then the team needs to work on the powder scale or with single channels.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer found the results quite interesting. The ash impact on the temperature at which 50% conversion occurs (T50) is immediate with ash loading. This reviewer continued that conversion of emissions versus lambda and temperature points to a catalyst reactivity issue rather than diffusion through the ash, for example. The shift away from lambda 1 for both the reducing and oxidizing reactions points to an OSC issue and the team is appropriately delving into this. The puzzle is which ash component is causing the deterioration. The loss of activity suggests a component that affects more than the surface catalyst. The team seems to be getting a handle on this.

Reviewer 2:

The reviewer observed that a key result was that light off temps ranged between 270°-310°C with ash loads of 0 to 20 gallons/liter (gal/L). The reviewer noted that many charts were provided and suggested highlighting the main takeaways.

Reviewer 3:

The reviewer noted that the approach of using the different expertise of the teams, including other national laboratories, allows for success in this project. The reviewer observed that the identification of compounds and penetration of compounds in the trap led to interesting discoveries.

Reviewer 4:

The reviewer stated that the technical accomplishments for the year were good. The ash loading from the current experimental setup was shown not to be as densely packed as field aged samples—this is important in terms of the particle contact, for sintering and for pressure drop effects. The reviewer suggested that in order to match field conditions in the lab, the project needs to run higher flowrates through the core samples, which could mean adding a pump and pulling flow through the core rather than pushing flow, which seems to be how it is done now. The reviewer observed that the Ford work referenced on Slide 28 goes to higher temperature (1,000°C, where S is oxidized) as compared to this work. The reviewer advised that the new reactor should be benchmarked against the ORNL bench reactor or other known reactor systems.

Reviewer 5:

The reviewer noted that ash loading addresses one aspect of GPF (P poisoning of washcoat), but does not represent any other important aspects like backpressure and filtration efficiency. The reviewer stated that the expectations for GPF chemical performance in this project are unclear. The reviewer observed that X-ray absorption near edge structure analysis did not give much real quantitative information and proposed that sample weights and X-ray fluorescence would have given more information. The reviewer commented that just because the project team has a synchrotron does not make it the best tool to use. The reviewer suggested that funds could be more effectively used.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the use of national laboratories, universities, and industry as outstanding.

Reviewer 2:
The reviewer identified the collaboration with ORNL as a strong factor improving the scores of this project. The reviewer recommended that the project team consider some additional collaboration in the characterization of the kinetics.

Reviewer 3:
The reviewer noted that this was a question from last year and the presenters identified the linkage at the end of the presentation.

Reviewer 4:
The reviewer observed that good collaboration with universities and industrial partners is evident here in the analyses and direction. The reviewer recommended that the team needs to reach out more to catalyzers, if only on a consulting basis, to make sure the results are pertinent to application. The reviewer advised that having a partnership with Afton is critical if changes in oil formulation is indicated.

Reviewer 5:
The reviewer stated that Corning and Hyundai do not appear to have very frequent involvement and are only consulted as needed. The project team did not mention meeting frequency. The reviewer noted that it appears that Corning gave filters and Hyundai gave a motor.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that this project is about midway through its term and has identified interesting future research that it plans to address in the future work.

Reviewer 2:
The reviewer noted that the future work proposed seems appropriate.

Reviewer 3:
The reviewer observed that continuing the work on elucidating accelerated aging versus field aging, and determining deactivation mechanisms seems the right path. The reviewer noted that given the impacts on OSC, the team might consider getting a peek at how OSC formulation changes might impact results.

Reviewer 4:
The reviewer stated that is was not clear what the ash distribution was in the field aged filter and questioned what this project was aiming to mimic. The reviewer continued that the project should include a measurement of OSC if the aim is to determine the effect of P on Ce. Further, the reviewer questioned why a liquid source of P, such as phosphoric acid, was not applied to the catalyst because gaseous P would be much more difficult.

Reviewer 5:
The reviewer noted that it is unclear that the future work planned will actually achieve the project goals, especially in regard to the reaction kinetics. The reviewer recommended that the project team consider additional collaboration.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed that improving catalyst performances has a direct link to fuel efficiency.

Reviewer 2:
The reviewer noted that better aftertreatment allows for more efficient engine operation.

Reviewer 3:
The reviewer noted that GDIs are playing a key role in reducing LD fuel consumption, but observed a PN problem. The reviewer noted that this topic is very timely, as GPFs are being utilized in the European Union this year and China in subsequent years, with OEMs considering the United States as a way of harmonizing technology. About 70% of the GPFs in the first introductions are uncoated, but the trend is towards increasing coated GPF penetration. The reviewer concluded that ash impacts on GPF TWC performance is still not well known.

Reviewer 4:
The reviewer stated that this project might support the overall DOE objectives of petroleum displacement because the application of filters to GDI will create backpressure that will negate a portion of the fuel economy benefit of these powertrains.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that the project team has an impressive amount of resources between the laboratories and industry.

Reviewer 2:
The reviewer noted that this seems appropriate.

Reviewer 3:
The reviewer noted that the project team seems to have a plan in place if funding is cut short and continued that sponsors need to know what will lapse if this is this case.

Reviewer 4:
The reviewer stated that the budget seems excessive and that there were at least more technical accomplishments this time.

Presentation Number: acs027
Presentation Title: Next-Generation Selective Catalytic Reduction-Dosing System Investigation
Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Presenter

Abhijeet Karkamkar, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

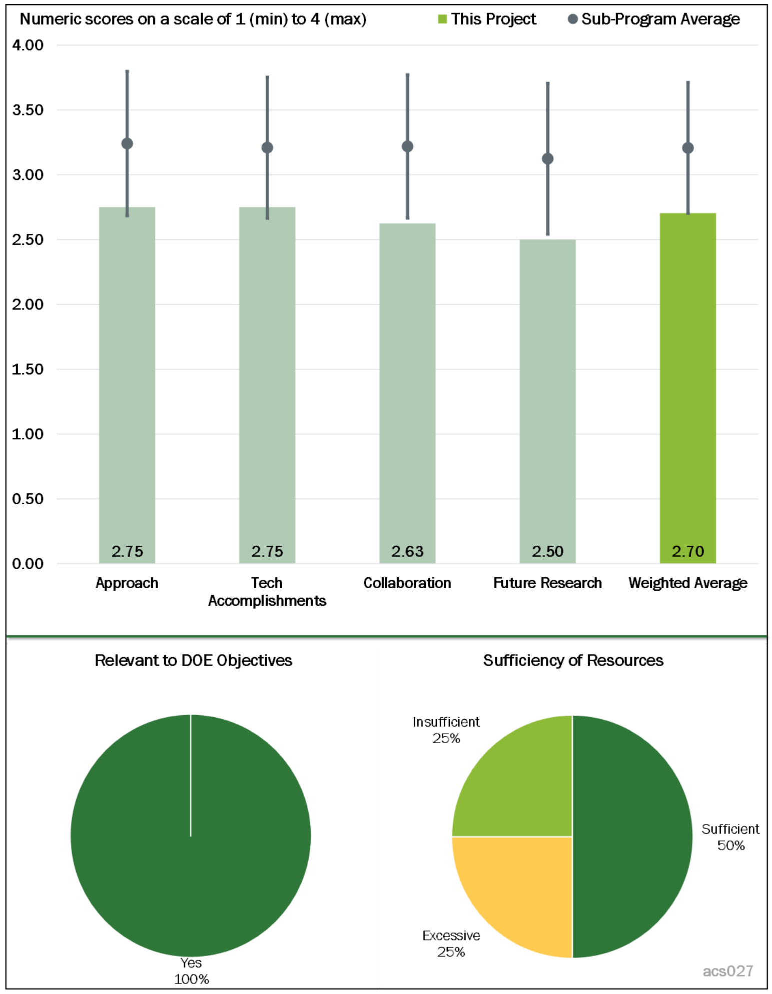

Figure 1-18 - Presentation Number: acs027 Presentation Title: Next Generation Selective Catalytic Reduction-Dosing System Investigation Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that a study on ways to generate ammonia (NH_3) other than urea is coming up again because of the need for LT NO_x conversion. The reviewer commented that the simplest thing would be to increase the exhaust temperature and continue to use the eutectic mixture of urea in H_2O.

Reviewer 2:

The reviewer stated that the project was a good approach considering the interest in alternative SCR dosing systems from USCAR. The reviewer noted that the evaluation of a full list of possible materials to support solid SCR delivery systems was good. The reviewer continued that the approach could be improved by considering up front the overall requirements for vapor delivery systems such as metering vapor, material volume, material expansion, and two-way process as well as whether the overall cost is improved with a LT vapor system plus a high-temperature traditional injection system. The reviewer explained that some background on possible improvements/costs/risks relative to potential improvements to traditional urea injection would improve the score. The reviewer concluded that substantial effort in injector design targeting, droplet size, and mixing of traditional designs may eliminate the need for a two-step system.

Reviewer 3:

The reviewer noted that LT dosing can have a significant effect on NO_x emissions especially for engines which are often operating at exhaust temperatures below 200°C which is a lower limit for urea dosing. As a result, the reviewer was not convinced of the value of density functional theory (DFT) for this work. The reviewer continued stating that it is appropriate to evaluate the effect of inadvertent exposure of the material to exhaust gases as keeping the exhaust steam out of the storage material is important; however, it was unclear to the reviewer how the project team was accomplishing this. The reviewer questioned the relevance of molten salts and asked if the salts molten at engine exhaust temperatures. The reviewer's biggest concern was the project team putting so much emphasis on chloride compounds which seems unwise because of the risk of hydrochloric acid (HCl). The reviewer was uncertain if this project is headed in a useful direction.

Reviewer 4:

The reviewer observed that emissions standards are progressively becoming more demanding, while at the same time exhaust temperatures are decreasing due to higher efficiency engines entering the marketplace to achieve fuel economy requirements. The reviewer noted that these trends are not compatible with the use of urea as a NO_x reductant. The reviewer continued that this activity supports the search for alternative materials that can supply the NH_3 required for NO_x reduction in lean aftertreatment systems without the LT limitations associated with urea. The reviewer stated that developing materials that exhibit higher NH_3 density storage and have appropriate release temperatures will be needed to reach the level of NO_x control and customer satisfaction needed by OEMs. However, the reviewer cautioned that the cost of these materials and their ability to be reconstituted easily should provide additional constraints for choosing materials. Simply characterizing known materials is not necessarily the best use of national laboratory resources. The basic bench testing required is also something that could be performed by an independent laboratory.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that the technical accomplishments seem reasonable; however, there is very little background given as to the need for some of the accomplishments. The reviewer questioned, for example, the mitigation approaches for HCl. The reviewer continued stating that investing so much time trying to mitigate the volume change for the chlorides is not necessarily helpful if the chlorides are judged to be too risky. The reviewer concluded that the downselect to the MgCl seemed abrupt.

Reviewer 2:

The reviewer observed that with respect to project goals, better definition of target release temperatures and maximum recovery of NH_3 are needed. However, the tunable nature of the material combinations under study is a desirable property. The reviewer continued stating that this project would benefit from an understanding of the kinetics involved for the different formulations, so that a model can predict the optimal combination and composition of binary salt materials. The reviewer concluded that the level of testing in this project does not seem to be the best use of laboratory resources.

Reviewer 3:

The reviewer noted that this project has been in place for quite a while, since October 2014, and is ending in September 2017. It appears unlikely that a materials candidate will be found to replace or use with aqueous urea.

Reviewer 4:

The reviewer praised the project as a solid accomplishment to downselect material that can perform properly without significant increase in volume and is two-way lithium chloride-magnesium dichloride double salts, and to assess impacts of other constituents. The reviewer noted that because requirements for vapor delivery have not been identified, the project team could improve the score with this assessment for downselected materials (i.e., how to use unstable release temperature of NH_3 in control system). This reviewer further suggested that the method to achieve system assumption/requirement that the material does not come in contact with exhaust gases should be at least conceptualized.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project demonstrated good collaboration with USCAR industry input.

Reviewer 2:
The reviewer noted that USCAR and PNNL are pretty insular collaboration groups. The reviewer questioned if the project team could bring a supplier into this activity.

Reviewer 3:
The reviewer noted that partnering with USCAR OEM members for their input on the material requirements is very appropriate. However, the reviewer commented that the use of PNNL resources to perform the base level testing and formulation is not as appropriate. The use of an outside vendor should have been considered for the testing and preparing the new salt combinations used in the testing. The reviewer stated that PNNL should support novel material development and kinetic insight into the NH_3 storage and release functionality.

Reviewer 4:
The reviewer observed that PNNL meets with USCAR partners every three months, and this seems infrequent. Further, it was not clear to the reviewer what each OEM is actually contributing other than advice.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that this project is due to end this year and the deliverables are consistent with this timeline.

Reviewer 2:
The reviewer commented that the future work plan is good and the project team should consider a cursory look at hardware and control system design requirements and overall cost first. The reviewer cautioned that too much focus on materials science without considering the overall system design and guidance cost may result in outstanding material requirements to meet vapor reactant needs with an overall system cost which is prohibitive.

Reviewer 3:
The reviewer noted that proposed future research was very vague and the project did not include suggestions for other materials.

Reviewer 4:
The reviewer observed that there is not much time left in this project, the items proposed are minimal, and the likelihood of discovering a useful material is very low. Even if the project team did, the work would need to include heating the material in a timely, efficient manner and dosing NH_3 vapor into an exhaust stream. The reviewer cautioned that any generation of NH_3at pressure would need a safety evaluation.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed that getting NH_3 to the SCR catalyst at temperatures below 200°C will greatly improve the NO_x reduction. The reviewer stated that this project has great potential.

Reviewer 2:

The reviewer noted that the project meets DOE goals as it supports USCAR's need to develop LT SCR to enable LT combustion and NO_x reduction at low temperatures in traditional combustion cycles.

Reviewer 3:

The reviewer commented that the urea reductant alternatives under investigation in this work show promise in providing suitable, higher NH_3 density storage materials that can be used by OEMs. The ability of these materials to selectively release NH_3 species at low temperatures is an important need for lean aftertreatment systems that must function at lower exhaust temperatures. However, the reviewer cautioned that establishing a target metric for this function is required. In addition, maximizing the service interval between reductant replacements is a very desirable consideration from a customer satisfaction perspective and for packing/servicing in vehicles.

Reviewer 4:

The reviewer observed that if a material could be discovered that might deliver NH_3 earlier during a cold start or at lower temperatures than aqueous urea, this would seem to promote more efficient powertrains. The reviewer noted that if something feasible were discovered, it would become necessary to study the temperature required for NH_3 release and how to get that temperature quickly, which will cost energy. An energy balance would be needed to ascertain if the powertrain were overall more efficient or not.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that funding for the current scope is good. The reviewer added that additional funding to assess system design and cost could improve the potential of the project for production success.

Reviewer 2:

The reviewer commented that there is no indication that aspects of the inquiry have been skipped because of a lack of resources.

Reviewer 3:

The reviewer stated that better use of national laboratory resources and skills should be considered. The reviewer noted that aspects of this project could be performed by a third-party laboratory, while leveraging the modeling and formulation capabilities of PNNL more effectively.

Reviewer 4:

The reviewer commented that more funding would be needed to understand the true usefulness of the proposed materials. The reviewer noted that additional areas in need of consideration are NH_3 vapor dosing, fast heat up of the materials to release the NH_3, and a safety review of any NH_3 pressure on the vehicle.

Presentation Number: acs032
Presentation Title: Cummins-ORNL Emissions CRADA: NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines
Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

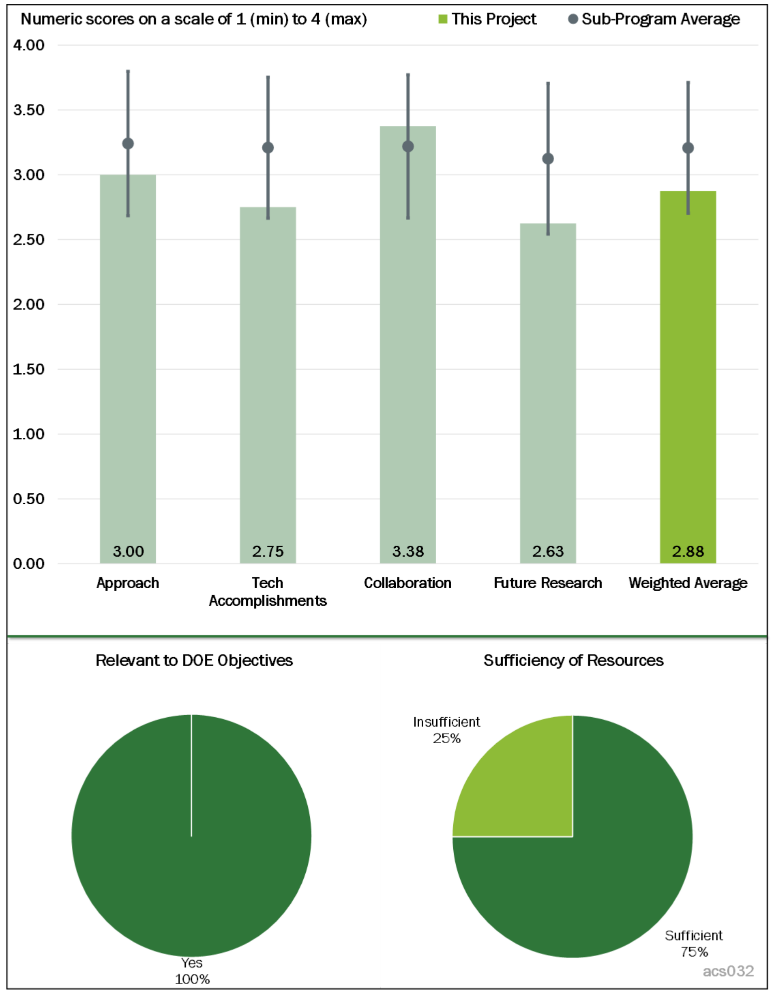

Figure 1-19 - Presentation Number: acs032 Presentation Title: Cummins-ORNL Emissions CRADA: NOx Control and Measurement Technology for Heavy-Duty Diesel Engines Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Presenter

Bill Partridge, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the focus of this work is to refine a model for the SCR catalyst. The reviewer observed that the project is especially focused on the transient portions of the testing and also attempts to tune the reaction mechanism to the spatially local (along the channel) concentrations and storage of the catalyst. Especially important is describing the inflections which are an indicator of the transients which occur in all of the driving cycles. The selection of a field aged Cu/CHA is especially encouraging because it is pretty much the state-of-the-art commercial catalyst.

The reviewer questioned if the Cummins model has been published. In addition, the reviewer asked if the space velocity of the laboratory experiments was known. The reviewer noted that if there is any mismatch between the experimental space velocity and the model space velocity the differences will show most dramatically in the high gradient regions. The reviewer questioned if there was a chance that the spatially resolved capillary inlet mass spectrometer (SpaciMS) probe is causing a change in the space velocity. The reviewer questioned what an inflection point means kinetically if the measurements are still integral reactors.

Reviewer 2:

The reviewer commented that it was not really clear what impact the project will have regarding new insights into SCR catalyst behavior during field aging because details the of model could not be shared.

Reviewer 3:

The reviewer commented that this CRADA project is focused on developing a method to “sense” the state of a catalyst in order to better understand the functionality condition of the catalyst and to derive better models to optimize control of the catalyst and catalyst system. The reviewer noted that at the center of this technique is the ability to observe and record "conversion inflections" to assess the state of the catalyst. The reviewer stated that this is a novel approach to in-situ measurements of how well a catalyst is performing reactions that support its function, but sufficient details of how the data was were obtained was not presented. The reviewer noted that some information is CRADA protected but more information was needed to sufficiently determine the merits of the approach.

Reviewer 4:

The reviewer commented that the project was a good approach to facilitate improvements to SCR durability performance and diagnostics with system modeling. The reviewer noted that the project could be improved with specific targets which are being investigated such as SCR catalyst degradation detection and subsequent dosing strategies; or SCR catalyst degradation mechanisms and detection with state estimator to minimize degradation. The reviewer stated that a list of common issues with SCR catalysts and how state detection could improve with focus on priority concerns could improve the approach and score.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the time resolution (or apparent resolution) of the concentrations as impressive. The reviewer commented that it allows the resolution of concentrations so subtle that inflection points can be analyzed. The reviewer was uncertain if the information on the storage condition of the catalyst is easily extracted from this data. The reviewer stated that consistent comparison with a model makes this a very helpful collaboration; however, the reviewer did not notice a reference to the detailed kinetic model; consequently, developing confidence in relation of the measurements to the model are a bit problematic. The reviewer did not know what the form of the inhibition term is.

Reviewer 2:

The reviewer stated that it was somewhat difficult to properly assess the technical approach of the project due to the presenter's concerns related to CRADA protected information. However, some of the data from different catalyst samples required a constant space velocity to accurately compare results, this was not obvious from the presentation. Additionally, it did not appear that portions of the transients were captured well, nor was there good agreement between model prediction and experimentally measured inflection data. The reason for this was not well communicated. Also, much of the transient work appears to be using standard SCR conditions. To be more useful in many applications, fast SCR results would be of value.

Reviewer 3:

The reviewer stated that CRADA has limitations that does not allow for full disclosure of details so it was hard to judge the technical progress made.

Reviewer 4:

The reviewer noted limited visible accomplishment. The CRADA claim of proprietary models is valid and does limit what data can be made available, however, some high-level results should be presented and related to specific SCR catalyst durability, performance, or diagnostic concerns. The reviewer stated that sharing high-level results related to objectives could improve the score (i.e., how the chlorine phenomenon can be modeled and related to an on-board diagnostics (OBD) metric, or dosing strategy).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the combination of Cummins, Politecnico di Milano, and ORNL is a powerful team. It incorporates industry, Europe, and national laboratories. The reviewer commented that it would be hard to improve on this.

Reviewer 2:
The reviewer commented that partnering with Cummins in this area of SCR characterization is very appropriate and expected, given their level of knowledge and model development to predict catalyst behavior. However, the reviewer noted that the connection to CLEERS for new research is not evident. The reviewer observed that their help could be better leveraged to help explain some of the anomalies between the inflection model predictions and the actual data.

Reviewer 3:
The reviewer noted that the project appears to include a significant collaboration between ORNL and Cummins given that Cummins is contributing work-in-kind and not cash. The reviewer noted that university is also included, as well as coordination with CLEERS.

Reviewer 4:
The reviewer observed that CRADA with Cummins indicates a corporate interest and there seems to be some cooperation concerning models. The reviewer suggested a designated partner with focus to extract non-proprietary content for general use (an individual in CLEERS or other project) to possibly improve the collaboration score.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer would like to have seen a variation of space velocity to be included in the future plans. The reviewer would also like to have seen sharing of the SCR model for other institutions to test.

Reviewer 2:
The reviewer observed that a more demonstrated understanding of the differences between CI predictions and experimental data must be addressed going forward. Also, the reviewer noted that applying an accurate model to OBD monitoring strategies should be one of the important deliverables of this work.

Reviewer 3:
The reviewer noted that due to nature of CRADA, the future work is not written very clearly; consequently, the reviewer found it difficult to judge if the proposed tasks will logically address overcoming barriers.

Reviewer 4:
The reviewer commented that the characterization of CI approach is ongoing topic. The reviewer noted that the "mining" of results should have a hypothesis, physical model approach, or other construct which is being proved, disproved or improved with clear ideas on what this is.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the topic is relevant to DOE goals as modeling of SCR performance and degradation can improve performance of fuel efficient technologies over useful life.

Reviewer 2:
The reviewer commented that increasing the effectiveness of SCR catalysts will make the implementation of small consumer diesels and lean gasoline engines more likely.

Reviewer 3:
The reviewer observed that more insight into SCR catalyst behavior over mileage might improve the NO_x conversion with more fuel savings, but this really is not clear from the presentation.

Reviewer 4:
The reviewer noted that understanding the state of an SCR under transient conditions is an important aspect of system development work to achieve super ultra-low emissions vehicle (SULEV) emissions standards. However, the reviewer observed that some of the work shown here has been performed by other groups. The reviewer commented that with only 1 year left on the project, there may not be enough time remaining to adequately address all the intended goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the current level of funding should be ample to acquire the necessary data and model refinement.

Reviewer 2:
The reviewer commented that resources seem sufficient for 1:1 CRADA given that Cummins is contributing work-in-kind, assuming this is in an adequate amount.

Reviewer 3:
The reviewer stated that the funding level is difficult to assess without clearer goals on what is being modeled and the value proposition of a successful result.

Reviewer 4:
The reviewer noted that funding for this project has been eroding over the years, even though it has continued to be successful. The reviewer commented that this project is lacking sufficient manpower and that issue needs to be addressed. Consequently, it is very likely that more than the final year will be required to bring this project to its full usefulness.

Presentation Number: acs033
Presentation Title: Emissions Control for Lean Gasoline Engines
Principal Investigator: Jim Parks (Oak Ridge National Laboratory)

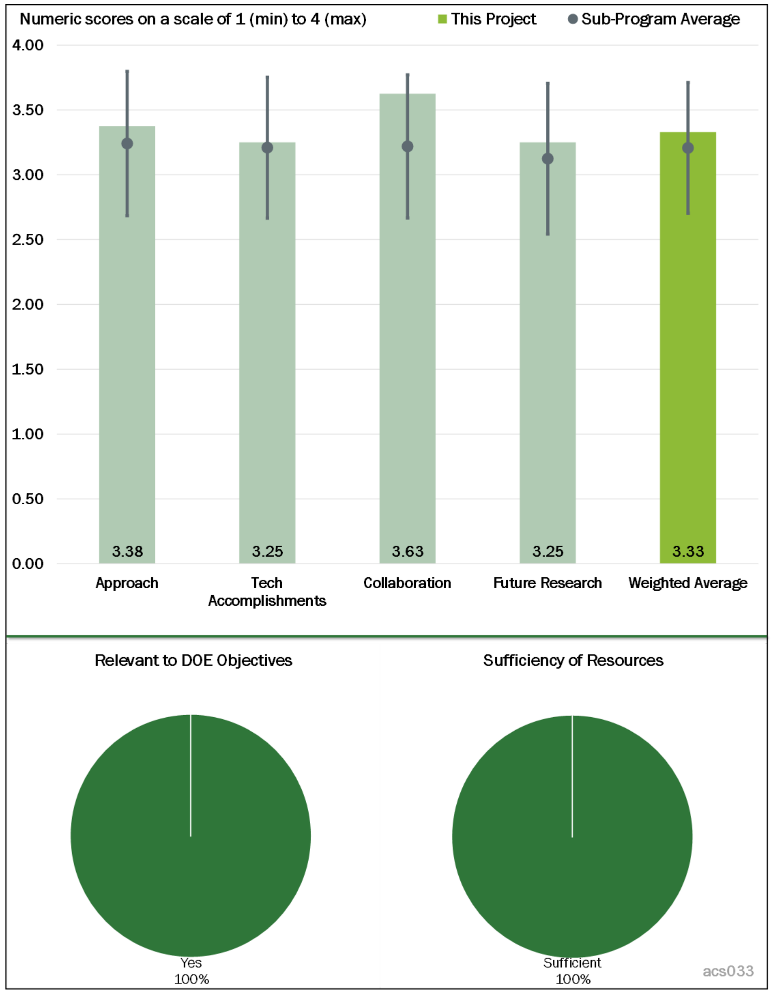

Figure 1-20 - Presentation Number: acs033 Presentation Title: Emissions Control for Lean Gasoline Engines Principal Investigator: Jim Parks (Oak Ridge National Laboratory)

Presenter

Jim Parks, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that this project employed a systematic, well-integrated approach to the problem, which involves engine control as well as catalyst formulations for TWC and SCR.

Reviewer 2:

The reviewer noted that this project addresses the need for an alternative approach to lean gasoline NO_x reduction other than urea. With decreasing exhaust temperatures driven by more efficient lean engines, where urea is not appropriate, passive NO_x control systems represent an attractive option to meet SULEV30 emissions standards without sacrificing significant fuel economy. The reviewer observed that much of the catalyst characterization presented in this project relies on technologies that will be able to function at lower exhaust temperatures as demonstrated by aftertreatment system testing on a fully functional and controllable engine. As such, combining elements of both TWC and lean NO_x trap (LNT) catalysts upstream of a SCR is an innovative approach to meet the need for simultaneous three-way emission control. However, because these systems will need to operate at lower temperatures, both GHG and criteria emissions will require stringent control. Therefore, NO_2 emissions must be inventoried at multiple operating points to access the emissions over a Federal Test Procedure (FTP) cycle. Also, because this is a gasoline application, aging of the SCR under conditions other than high temperature must also be investigated to determine the feasibility of a SCR system for 150,000-mile durability. Finally, the reviewer noted that when considering the cost of the various systems studied here, the catalyst represents a relatively smaller portion of the total system cost relative to a purely TWC system. Lean aftertreatment system costs are driven more by hardware expense such as sensors and additional components as well as controls and OBD needs.

Reviewer 3:

The reviewer commented that one significant barrier to lean gasoline engines is cost and this was partially addressed in this project. The reviewer noted that another significant part of the cost is OBD and the sensors required; however, this was not addressed in this project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that it is obvious much effort has been applied to this project to characterize a variety of passive lean gasoline aftertreatment systems on an actual engine. Incorporating engine controls into optimizing aftertreatment performance is a highly desirable capability to properly assess aftertreatment effectiveness and efficiency. The reviewer stated that addressing the required transient operation of these systems through the project test plan is well thought out and appropriate. The reviewer said that because these systems must work under both rich and lean conditions, the upstream catalyst must be thoroughly characterized to ensure it is providing the required level of NH_3 under rich conditions and NO_x storage and HC/CO oxidation under lean conditions. This functionality is clearly demonstrated in this project, as well as different aging effects and sulfur poisoning degradation. Additionally, this work has shown that attention must be paid to strategies that minimize fuel use to regenerate the upstream catalyst, while still providing a level of emissions control.

Reviewer 2:

The reviewer commented that the data on faster NH_3 generation was especially interesting when comparing catalysts with and without NO_x storage materials.

Reviewer 3:

The reviewer noted that the well-integrated, system-level approach used has identified some promising conditions for NH_3 production, one of the requirements for the passive SCR strategy investigated in this project. The reviewer commented that although sufficient amounts of NH_3 production over the TWC are desired, it would have been more interesting to show how the additional NH_3 production translates into tailpipe NO_x emission reduction under realistic operating conditions.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that this project is an excellent example of how to greatly leverage the knowledge learned in one area and apply it to many more. The data provided in this work is very useful within the CLEERS organization as well as to the supplier base (Umicore), OEMs (GM), and the university partner. The reviewer noted that the collaboration and coordination associated with this project is well thought out and maximizes the value associated with the results.

Reviewer 2:

The reviewer stated that the project appears well coordinated between partners including university, OEM, and supplier.

Reviewer 3:

The reviewer commented that the PIs have had very close interaction with OEM (GM) and catalyst supplier (Umicore). However, it is not clear how University of South Carolina fits in to the program.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that focusing future activities on understanding the effects of various aging scenarios on system performance and selectivity is critical for determining the feasibility of this approach for passive, lean aftertreatment systems. Including the optimization of fuel utilization during regeneration events, both NO_x and sulfur oxides (SO_x), is also important for assessing the overall system functionality. Finally, using challenging speed/load points in the analysis will benefit the usefulness of the data.

Reviewer 2:
The reviewer stated that the PIs seem to well recognize the remaining challenges; namely, NO_x emission performance during transient drive cycle operation, HC/CO clean-up, and SCR deactivation, especially under high-temperature stoichiometric or rich conditions. Also, there is a literature report that NH_3 production during the NO reduction in the presence of sulfur dioxide tends to be suppressed (as observed here), but at the expense of increasing nitrous oxide (N_2O) production. Thus, it would be important to keep an eye on N_2O emissions in future work.

Reviewer 3:
The reviewer identified a need to assess OBD impact and cost because more components add cost and complexity that was not addressed in the project. The reviewer added that the project team needs to consider what to do when the current engine is at end of life.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project addresses multiple needs for future, lean aftertreatment systems: LT performance, selectivity toward N_2/CO_2, minimal fuel use, and Tier III/low emission vehicle (LEV) III capability.

Reviewer 2:
The reviewer stated that lean burn is one potential way to increase fuel efficiency.

Reviewer 3:
The reviewer commented that lean-burn gasoline engines that this project focuses on can provide significantly higher fuel efficiencies compared to conventional stoichiometric gasoline engines, but there is no cost-effective, reliable, production-ready emission control system available yet.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that this project should continue to be funded at this level or higher as a significant amount of useful data can be derived from this work.

Reviewer 2:
The reviewer noted that it appears that the resources for this project would be sufficient provided that a similar level of funding continues for the third year.

Presentation Number: acs052
Presentation Title: Neutron Imaging of Advanced Transportation Technologies
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

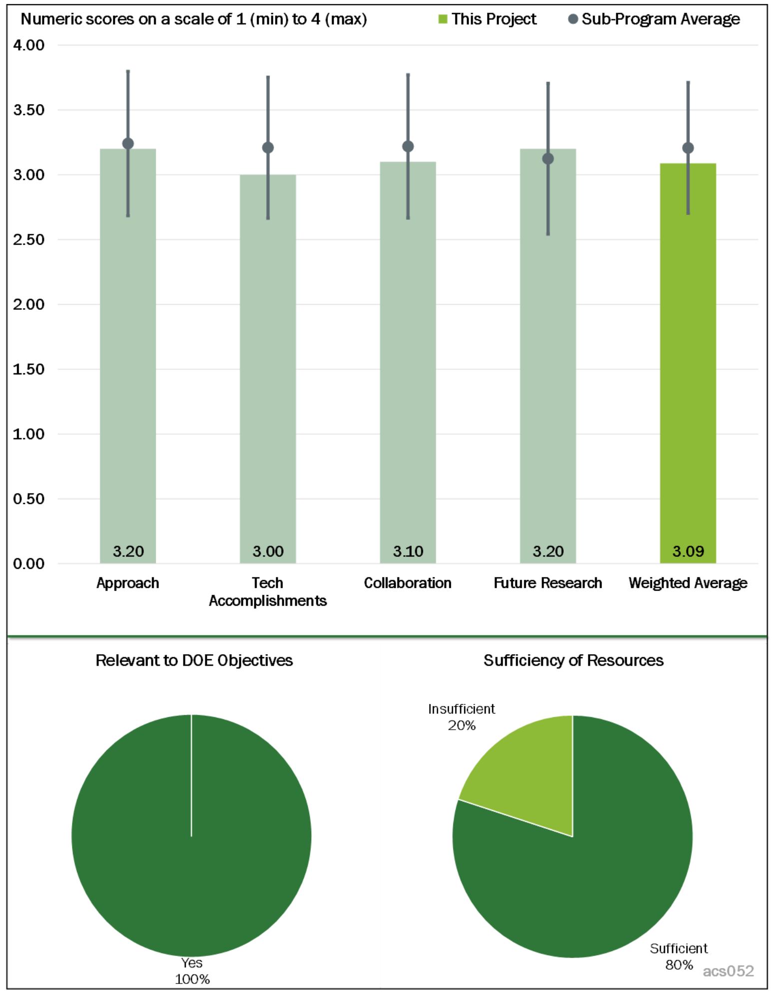

Figure 1-21 - Presentation Number: acs052 Presentation Title: Neutron Imaging of Advanced Transportation Technologies Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that this project uses a novel approach to non-destructively investigate injectors and particulate filters. This is the sort of creative application of technology that DOE should be supporting.

Reviewer 2:

The reviewer commented that this research uses unique measurement capabilities to generate new learning relative to internal phenomenon in injectors and particulate filters that should be useful to industry. The reviewer noted that industry does not have the capabilities to make these measurements.

Reviewer 3:

The reviewer noted that this project is a good example of using tools and capabilities such as neutron imaging that are only available at the national laboratories to diagnose engine-related problems.

Reviewer 4:

The reviewer noted that stated barriers addressed by the project are fine, but it is not clear if/how the project is actually addressing these barriers. For example, the first stated barrier relates to cost-effective emission control, and the project is claiming to address this by leading to “improved regeneration efficiency in particulate filters.” The reviewer commented that while the project does have some rudimentary measurements of soot on particulate filters, the connection between this and improved regeneration efficiency remains unclear. It is also not clear how this project will lead to better understanding of fuel injector durability.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the project has progressed and there are some neutron beam images of injectors in various scenarios. It does not seem, however, as though there are a lot of data that have been acquired or analyzed. The reviewer stated that it seems that competition for "beam time" is an issue, as emphasized by the presenter.

Reviewer 2:
The reviewer noted that the researchers have made good progress in acquiring detailed images of fluid dynamics within GDI injectors, along with internal loading and regeneration phenomenon in particulate filters. The reviewer commented that the researchers have also advanced their analytical capabilities as evidenced in determining the liquid mass leaving the nozzle.

Reviewer 3:
The reviewer stated that the insight gained from the particulate filter tests is great and is not attainable in any other way. However, the resolution of the injector tests is still not good enough to draw significant conclusions. In addition, the injector pulse width of 0.25 millisecond (ms) may be low enough to be in the non-linear, non-repeatable range of the injector operation, introducing shot to shot variation in the injector spray.

Reviewer 4:
The reviewer noted that more progress has been made in providing some insights for gasoline fuel injector behavior for flashing versus non-flashing operating conditions. However, compared to last year, the incremental progress has been somewhat limited. The resolution of this technique is limited. The reviewer questioned if the point of diminishing returns on the capability of this tool has been reached.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that collaboration with ANL gives a very nice synergy to this effort. The reviewer praised the project for using the strengths of the two programs combined to increase the quality and extent of the data.

Reviewer 2:
The reviewer commented that collaboration was not a highlight of this presentation. It was not clear to the reviewer if there are strong collaborations here, nor was it clear if the modeling community can make good use of the neutron imaging data. The reviewer noted that fuel injection/spray modelers should be interested, and so should modelers of particulate filters and regeneration but the presenter did not indicate strong collaborations in these areas.

Reviewer 3:
The reviewer noted that collaboration should be sought with more fuel injector suppliers like Bosch or Delphi as they know the issues needing to be solved in detail and stand to benefit the most, indirectly impacting the OEMs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the proposed future work seems to address deficiencies that the reviewer has mentioned in earlier comments. The project will strengthen collaboration with modelers, and work will progress toward the study of interesting scientific problems such as multiple injections and gasoline soot versus diesel soot.

Reviewer 2:
The reviewer noted that the project has a good plan for carrying this work forward and expanding the reach of the work.

Reviewer 3:
The reviewer commented on the need to include efforts to increase the flux for the fuel injector tests in order to improve resolution.

Reviewer 4:
The reviewer stated that discussions should be initiated with fuel injector and particulate filter suppliers to know their critical issues with these parts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project is an excellent of example of a using a unique national laboratory capability to make measurements and generate new knowledge about fundamental phenomenon that industry would like to know and yet does not have the resources to pursue.

Reviewer 2:
The reviewer noted that improved understanding of particulate filter behavior can help engine designers improve engine efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the project team is dealing with the reduced financial resources well and that more support would be nice, of course.

Reviewer 2:
The reviewer commented that this is a low-budget project, particularly compared to the efforts using X-ray imaging at ANL and optical diagnostics of fuel sprays at SNL. The reviewer stated that the information that could be gained in this project is complementary to those efforts, and appears to need more resources to accomplish more.

Presentation Number: acs054
Presentation Title: Rapid Compression Machine Studies to Enable Gasoline-Relevant Low-Temperature Combustion
Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

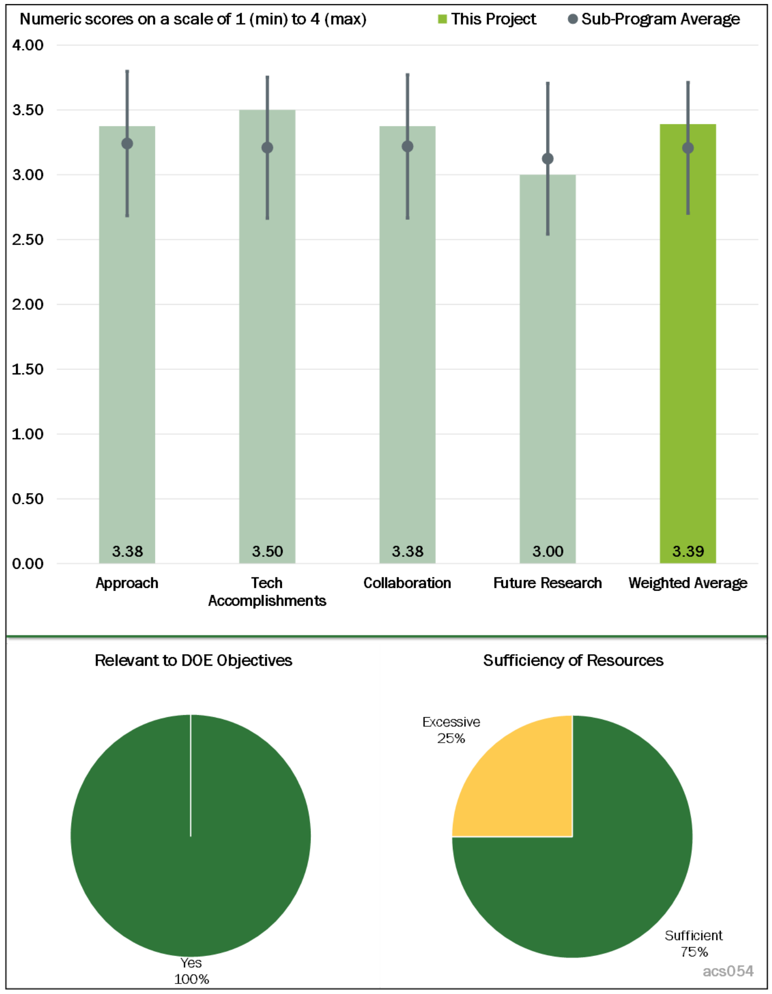

Figure 1-22 - Presentation Number: acs054 Presentation Title: Rapid Compression Machine Studies to Enable Gasoline-Relevant Low-Temperature Combustion Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

Presenter

Scott Goldsborough, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project is well-designed and well-integrated with other efforts (academia, national laboratories, and industry) that investigate LT combustion using gasoline fuels.

Reviewer 2:

The reviewer commented that fundamental data are critical to develop/validate/refine chemical kinetic and relevant models for transportation-relevant fuels at conditions representative of advanced combustion regimes. An RCM is an excellent tool to do this work. The work is aligned well with other projects, such as ACS013. The PI also put a tremendous amount of efforts to organize the RCM workshop, which is critical to expanding understanding of RCM and providing high-fidelity RCM data. The reviewer found that, overall, the project is well designed, feasible, and integrated with other efforts.

Reviewer 3:

The reviewer noted that data of ignition delays expand from 3-100 ms. The reviewer remarked many important engine combustion chemistries take place in real life at approximately the 0-2 ms range, and cycles can be completed in 20 ms. Whereas pressure and temperature regimes are matched, the time scales appear to be significantly slower. The author explained the need for regions where fidelity can be attained, whereas data may be extrapolated. Still, it would be of interest to understand better this gap. The reviewer noted that variability in the machine at times below 2 ms should be fixed.

Reviewer 4:

The reviewer asked if upgrades were made to track piston location and improve operation of the RCM, does this make previous data suspect. The reviewer also questioned how fuels are chosen.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the project for excellent outcomes. The reviewer noted that the project is important for the great effort done to correctly determine the differences in results between experiments and models. The work is extremely important for the development of chemical kinetic models at conditions representative of modern combustion strategies. The reviewer commended the PI for his involvement in organizing the RCM workshop.

Reviewer 2:
The reviewer commented that good progress was made to measure ignition delay (ID) of gasoline/ethanol blends and map combustion regimes. The reviewer complimented the project team for excellent work in organizing the RCM workshop.

Reviewer 3:
The reviewer noted that the project provides important data of auto-ignition behavior of full boiling range fuels with surrogates (aphthenes) and ethanol mixtures. The reviewer requested that the figures on Slide 10 (ID labels a and b should be explained).

Reviewer 4:
The reviewer commented that it is important to support data that feeds kinetic models at Lawrence Livermore National Laboratory (LLNL). The reviewer questioned if the project team was working on problems most relevant to LLNL.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project shows very good collaboration and coordination with the other national laboratories and industry partners. The reviewer suggested that the project team also interact more with universities that have common research interests outside the RCM workshop. The reviewer thought this is extremely necessary under current budgetary restraints.

Reviewer 2:
The reviewer commented that the project was well connected with CRC and provided data for LLNL for model validation. The reviewer stressed again the excellent work done in organizing the RCM workshop.

Reviewer 3:
The reviewer stated that the work on the consolidation of data across multiple RCM machines is welcome. The reviewer commented that the presentation could have explained practical insights (if any exist) where the gaps were closed.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project work is outlined. The reviewer commented that there could have been more description on Slide 25 of the work such as what “individual components” are being planned for testing, what “various techniques” are being planned, what “surrogate blends,” and what “engine conditions.”

Reviewer 2:
The reviewer commented that the accurate ignition delay measurements at conditions representative of advanced combustion strategies are very important for both fundamental and applied engine work. The reviewer observed that future research will continue the PI's excellent work on helping the industry to implement advanced combustion concepts to real engine/vehicle applications via improved engine simulations. The reviewer noted that if the budget is further reduced, it will affect project outcome.

Reviewer 3:
The reviewer noted that the future plan is well designed to provide more data for model validation. The reviewer questioned in addition to ID measurement and intermediate speciation, what else RCM can do to advance our knowledge of the combustion in ICEs and ultimately advance engine technology.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated, yes, the work will positively impact DOE objectives.

Reviewer 2:
The reviewer commented that the project is well-aligned with DOE objectives of improving efficiency and emissions in the transportation sector.

Reviewer 3:
The reviewer stated, yes, this project supports the overall DOE objectives of petroleum displacement. Providing high-fidelity experimental data for validating and refining chemical kinetic models is critical to better design high-efficiency and clean combustion engines, which will reduce petroleum demand.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that novel, experimental work requires a steady stream of funding and commended the PI for such good work considering the budget limitations.

Reviewer 2:
The reviewer stated that it seems adequate.

Reviewer 3:
The reviewer stated that resources are sufficient.

Presentation Number: acs056
Presentation Title: Fuel-Neutral Studies of Particulate Matter Transport Emissions
Principal Investigator: Mark Stewart (Pacific Northwest National Laboratory)

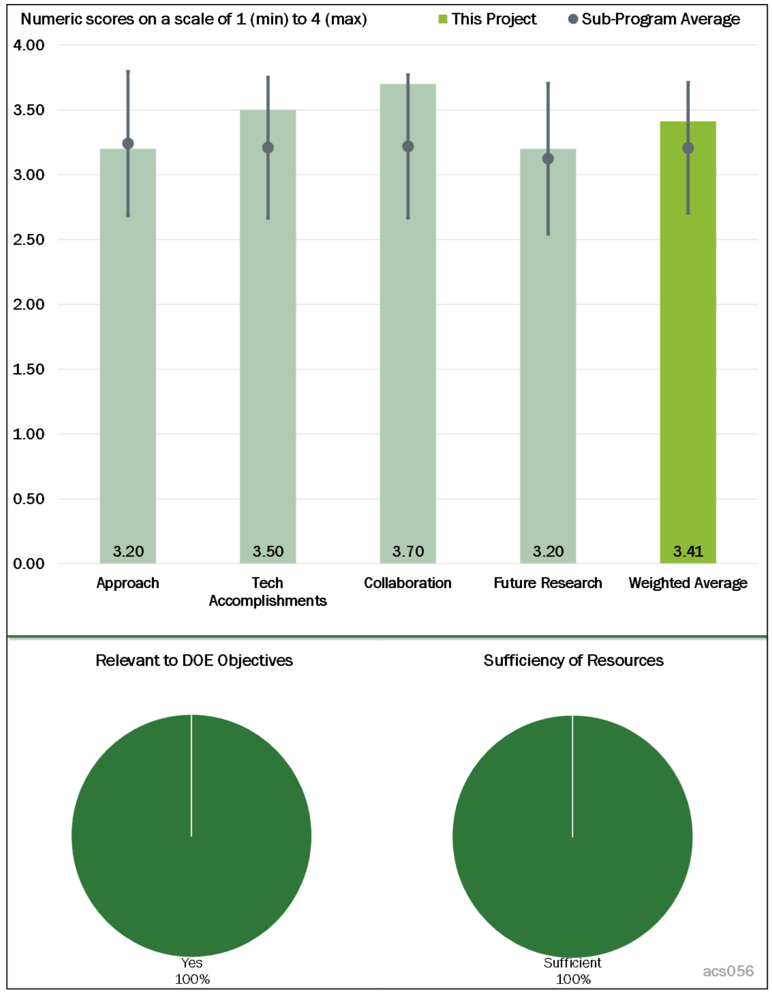

Figure 1-23 - Presentation Number: acs056 Presentation Title: Fuel-Neutral Studies of Particulate Matter Transport Emissions Principal Investigator: Mark Stewart (Pacific Northwest National Laboratory)

Presenter
Mark Stewart, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented on the strong approach to the work, good collaboration with Wisconsin and Massachusetts Institute of Technology (MIT), great progress in converting the spherical unit collector model to the constricted tube model, and in investigating the geometrical pore networks.

Reviewer 2:
The reviewer commented that the researcher used a large number of approaches to determine flow path tortuosity and void volume. This is a good fundamental research project

Reviewer 3:
The reviewer stated that the approach of characterizing the particles and filter porosity and then correlating this to filter performance is generally excellent. The extension into modeling is worth a try to help hasten material development. This may minimize the need to make filters to test compositions. The reviewer was impressed with the wide range of analytical tools that are being used. The reviewer cautioned that the team needs to be cognizant that fresh filters are applicable only for the first thousands of miles, and then ash begins impacting efficiency and back pressure.

Reviewer 4:
The reviewer stated that the approach looks good from the fundamental experiments (spark ignition direct injection [SIDI]) particulate characterization, filter characterization and exhaust measurements) to the improved filter models.

Reviewer 5:

The reviewer noted that it is not clear how this project is going to address all the barriers listed. The project addresses filter technology but no path is shown to save cost. Emissions data on a SIDI engine were mentioned yet no connection was made to improved filtration ability or if a filter is still needed. Existing filters were characterized and modeled. The reviewer asked what follows once the project team has a model.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the technical work on filter characterization is nice and detailed.

Reviewer 2:

The reviewer noted that the technical accomplishments were presented well.

Reviewer 3:

The reviewer observed that the model is coming along very well

Reviewer 4:

The reviewer noted that the team is certainly pushing the analytical technology to new horizons with this world class work. The capillary flow porometry versus mercury intrusion porosimetry work is interesting and yielding results. The reviewer is anxious to see how ash affects these. The reviewer commented that the pore model development is also bearing fruit, with correlations between pore diameter and throat diameter for the different compositions and then correlating this to back pressure. This is very critical and probably more important than initial filtration efficiency in application. The lattice-Boltzmann simulations are also now being applied by corroborating them with observations and pulling in permeability. With all these tools and results, the reviewer expressed interest in a summary of how all this fits together in a story (i.e., back pressure is impacted by [pore or throat] diameter, but this shifts with catalyst loading, ash, etc.). The reviewer would like to know what the best compromise is of the trade-offs.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the team of UW-Madison) and MIT is extremely impressive.

Reviewer 2:

The reviewer noted the excellent interaction between PNNL, GM, UW-Madison, and MIT has allowed for great progress in the past year.

Reviewer 3:

The reviewer commented that the collaboration between PNNL, GM, UW-Madison, and MIT is evident.

Reviewer 4:

The reviewer noted that the results and direction show that good collaboration is accomplished. As the project team is now getting into catalyzed filters, some consultation with catalyzers may be beneficial.

Reviewer 5:

The reviewer noted good collaboration with GM, UW-Madison, and MIT.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer looks forward to seeing the model in its final form

Reviewer 2:
The reviewer noted that the project had a good plan for moving forward and continuing to improve modeling. The reviewer was looking forward to the eventual inclusion of the reaction kinetics for regeneration being incorporated into the model.

Reviewer 3:
The reviewer recommended that the study include both uncatalyzed and catalyzed filters.

Reviewer 4:
The reviewer commented that extending the testing to LT and HT seems reasonable. Model improvement is needed with extensions into different catalyst, ash, and soot loadings. The reviewer noted that one consideration will be to look at gaseous impacts; for example, how pore structure affects back diffusion of NO_2 in a catalyzed soot filter or SCR filter. SCR filters are emerging and significantly degrade passive regeneration. This can be partially remediated with catalyst architecture, such as putting the catalyst on the exit wall.

Reviewer 5:
The reviewer questioned next steps once the project team has data on existing filters and an improved model. The reviewer asked if any of this work helps us design lower backpressure, higher efficiency filters, or will it help us with new technology to avoid conventional filters on gasoline vehicles.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented, yes, improving catalyst efficiency promotes better fuel efficiency.

Reviewer 2:
The reviewer noted that it is conceivable that all engines will have filters and filters can have a big impact on engine efficiency. This team is developing fundamental knowledge to help.

Reviewer 3:
The reviewer commented that it is unfortunate that future, more fuel-efficient engines may require filters that put backpressure on the engine, negating part of the fuel efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that resources seem tight, but the team has delivered excellent value.

Reviewer 2:
The reviewer commented that the resources seem appropriate.

Presentation Number: acs075
Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing Resources
Principal Investigator: Sibendu Som (Argonne National Laboratory)

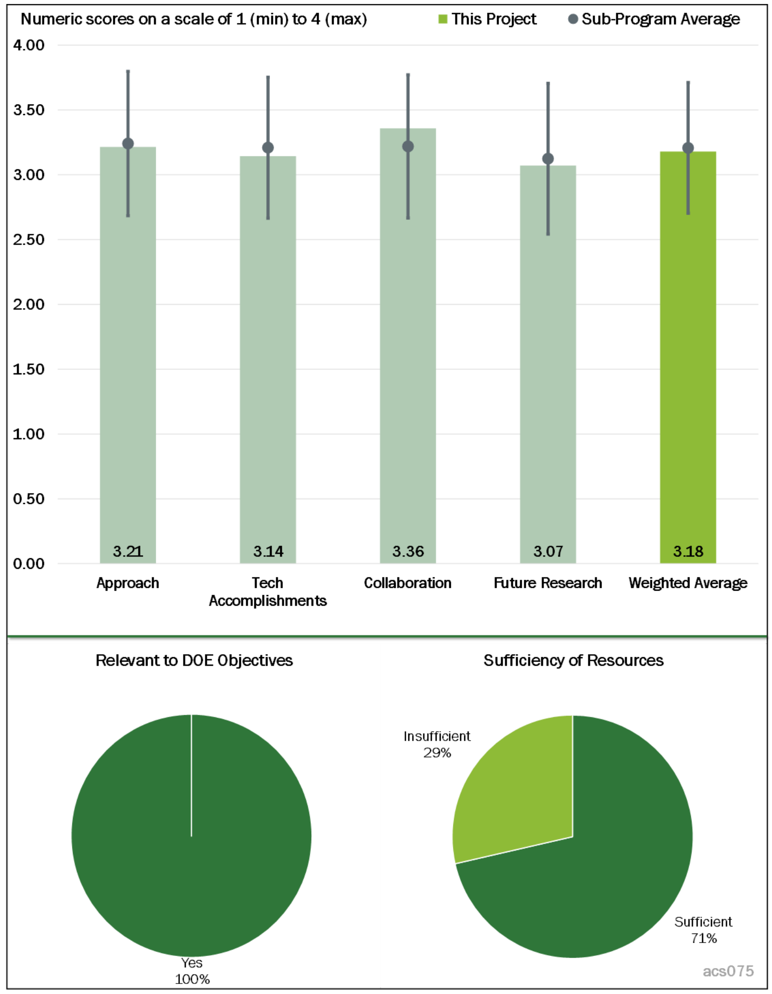

Figure 1-24 - Presentation Number: acs075 Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing Resources Principal Investigator: Sibendu Som (Argonne National Laboratory)

Presenter

Sibendu Som, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project addresses a wide range of elements to improving in-cylinder processes in combustion engines. Included are incorporation of detailed kinetic mechanisms and HPC tools related to spray processes. The PI wants to move away from tuning exercises that will match experimental data, which is good. The framework is the code CONVERGE, which is extensively used by OEMs. A “one-way” coupling approach is employed that will allow near nozzle simulations to be coupled with nozzle flow simulations.

The PI covers a lot of bases and is to be commended for attempting to bring a lot of elements together that will result in a robust and improved code for engine performance prediction (perhaps too much, or perhaps the project should be more focused). The reviewer stated that this is a very good project.

Reviewer 2:

The reviewer stated that the project is well-designed and well-integrated with other efforts (academia, national laboratories, and industry) that investigate fuel spray and combustion modeling.

Reviewer 3:

The reviewer commented that the overall approach for engineering best practices for the industry are helpful for optimization of the engine analysis work flow.

Reviewer 4:

The reviewer stated that, overall, plan and efforts are well organized towards the identified barriers. It is nice to see that analysis is leading the effort around to address physics and deepen understandings.

Reviewer 5:

The reviewer commented that the approach involves developing spray and combustion models and validating and improving the models against ECN and other available engine data.

Reviewer 6:

The reviewer commented that the approach of incorporating more detailed chemistry into the combustion model and the use of LES one-way coupling for nozzle and spray seems very reasonable. The reviewer also noted that it was good that the model predictions are compared to experimental data.

Reviewer 7:

The reviewer noted that the quality of the work, tools, and documentation process is very high. The reviewer stated that the driving factors for such an in-depth focus on phenomena such as hole-specific differences are unclear. The question arises because there is no foundation given of typical deviations in modern hardware, how dependent this is on injector design configuration, and very importantly what effect these deviations have on combustion performance. The reviewer continued stating that there are a number of other unexpected approaches on key parts of the work, such as the work presented under "extensive" validation of a thickened flame model (TFM). It is unclear why the project team chose the optical engine data with methyl decanoate fuel for validation. The reviewer asked why the choice of this fuel, why the choice of a two-hole injector and the very unusual HRR rate. There are many more applicable test data available of interest to the combustion community.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the project followed its milestones as much as the budget allowed it. The reviewer commended the PI for the excellent work done in modeling the fuel spray under conventional and advanced combustion conditions.

Reviewer 2:

The reviewer stated that technical accomplishments are made using one code from a CFD vendor. The reviewer noted that it will be beneficial for DOE goals to assess codes such as KIVA-hpFE technical capability and provide feedback for overall development.

Reviewer 3:

The reviewer noted that very good progress has been made; milestone 1 is complete and milestone 3 is 60% complete.

Reviewer 4:

The reviewer commented that good progress had been made in modeling individual flow and spray differences in a multi-hole gasoline injector. The reviewer observed that spray simulations can better predict SNL entrainment and collapse data with the exception of higher temperature evaporation data. TFM combustion model was exercised for LTC. The reviewer also commented on LES modeling with a four-component diesel surrogate mechanism.

Reviewer 5:

The reviewer noted that the 2017 milestones included validating one-way coupling against diesel and gasoline nozzle flow in collaboration with a CRADA with Cummins and CSI, as well as simulating performance of a four component diesel surrogate kinetic mechanism. The reviewer commented that this component is apparently not yet completed. The reviewer recommended that the PI should provide some discussion of precisely what the PI means by "validation." Precisely what is being compared to simulation and when is the difference sufficiently small that the PI will conclude that the code has been "validated." The reviewer noted that a surrogate is being simulated and that this is a miscible mixture. The reviewer recommended that some discussion of the properties used in the simulation be included in future presentations as well as how the mixture properties were estimated. The reviewer asked what, specifically, are the properties of interest, especially relevant to a spray (e.g., surface tension, viscosity, etc.). The reviewer observed that this is a multicomponent problem and would not seem to be trivial. The reviewer noted that an ECN injector is employed in the nozzle flow simulation. The reviewer questioned what the ECN brings to this problem and who supplied the injector. The reviewer noted that the plume cone angle was simulated and the results look impressive when compared to photographic visualization. The reviewer asked if the PI has more quantitative comparison beyond the qualitative comparisons shown. The reviewer noted that a high-fidelity turbulence model based on LES is being used to predict liquid penetration. The reviewer questioned how this approach compares to the RAPTOR simulations being done at SNL and if there is collaboration between ANL and the SNL group that is doing a first-principles approach to the spray injection problem. The reviewer noted that the simulations also cover situations where flash boiling is occurring for an iso-octane/ethanol blend. The reviewer recommended that this problem be further discussed in future presentations including the criteria for flash boiling and the physics involved. The reviewer concluded stating that the accomplishments include comparisons of ignition delay between the experiment and the simulation. The PI notes that the comparisons shown prove that the simulations have been validated against the experiment. However, at lower ambient temperatures (less than 1,000 Kelvin [K]) and O_2 concentrations this does not seem to be the case, or perhaps the PIs notion of validation is very liberal.

Reviewer 6:

The reviewer noted nice progress overall. But, it is not very clear if the achievements are being made in a timely manner. It would be nice to have a high-level road map of the development. The reviewer suggested that the project team create a table showing a table of milestones in a long run, perhaps for 3 years or so. In that way, the community can easily figure out the way forward and direct the effort. Also, it is not very clear what exactly ANL's role in the project is. The reviewer posited model development, or running the calculations, or organizing the overall progress. The reviewer requested that the project team please elaborate in more detail.

Reviewer 7:

The reviewer observed that the project is working on important sub-model development, studying the impact of grid size, development of tabulated flamelet and homogenous reactor models for turbulence-chemistry interaction, and in-nozzle flows and spray models. The reviewer noted that the work reported is rather extensive and there is a lot of information provided. How it will impact real world simulation or faithful prediction is a big question for this reviewer. One-way coupling allows the differentiation over individual nozzle holes and the report highlights back flow of chamber gases into a gasoline injector counter-bore. The reviewer stated that it is unclear how significant this is in real life, or how necessary it is, or how it would be incorporated and used in standard tools. LES was used to capture the collapse of GDI sprays, and this is another example of a very particular situation that may not be very universal.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the project had a good group of collaborators. The Virtual Engine Research Institute and Fuels Initiative (VERIFI) workshop is a very good initiative.

Reviewer 2:
The reviewer commented that the PI is an example of collaboration with academia, national laboratories, and industry.

Reviewer 3:
The reviewer observed collaboration with some engine manufacturers (Cummins and GM), the members of CRC AVFL-18a project, the participants in the VERIFI workshops, software developers, universities, and other national laboratories were mentioned.

Reviewer 4:
The reviewer noted that regular collaboration exists with other laboratories, universities, Convergent Science, and industry.

Reviewer 5:
The reviewer noted that this project is collaborating with other institutions and universities for research and experimental data.

Reviewer 6:
The reviewer observed that the team is well organized with necessary expertise around. It has been pointed out several times that having a single software vendor as a partner might be limiting opportunities of impact. The PI illustrated the project team's effort to extend an invitation for collaboration in that regards, which is nice but needs to be pushed again.

Reviewer 7:
The reviewer noted that BES is noted among the leveraging collaborations. The reviewer questioned what they are providing to the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project plans to continue to extend models to multicomponent mixtures, to extend the one-way coupling approach and coupling with TFM, and to validate the four-component surrogate model against experimental data seem reasonable.

Reviewer 2:
The reviewer commented that the proposed work on uncertainty analysis will be beneficial for industry partners with engine development and calibration.

Reviewer 3:
The reviewer commented that future research will continue the PI's excellent work on translating advanced combustion concepts to real engine/vehicle applications via state-of-the-art engine models. The reviewer cautioned that if the budget is further reduced it will likely affect project outcome.

Reviewer 4:
The reviewer noted that all of the future work proposed is relevant. However, plans should be made to continue to model all the issues around multi-hole gasoline spray collapse in conjunction with the experimental work at SNL.

Reviewer 5:
The reviewer commented that future work seems reasonable. The reviewer encouraged the PI to devote more discussions to the notion of validation and articulate regions where agreement is good and where it is not and what the strategy going forward would be to close the gaps. The reviewer observed that the list of future tasks mentions validating a four component diesel surrogate against the TFM for a constant volume combustion and optical engine. This approach would seem to only be valid if either of these configurations can be simulated with a first-principles (*ab-initio*) approach (no tunable constants). The reviewer noted that it is not clear if this is the case at this stage and requested that the project team please elaborate.

Reviewer 6:
The reviewer noted that the project could use more guidance from expert OEM representatives or subject experts to align the LAB capabilities towards challenges and barriers that are more closely tied to the roadmap to more efficient and clean combustion. The reviewer recommended that the team align the work with data that show sensitivity to the issues studied. This may require a relook at the work scope.

Reviewer 7:
The reviewer observed that it seems that the plan needs a better road map. It is getting a little difficult to figure out the focus. The reviewer asked how the PI is going to prioritize the tasks.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the project is well-aligned with the DOE objectives of improving the efficiency and emissions in the transportation sector.

Reviewer 2:
The reviewer observed that this project does support overall DOE objectives of petroleum displacement through collaboration with industrial partners and transfer of engineering best practices.

Reviewer 3:
The reviewer commented that working on a more predictive analytical tool definitely assists in the quick development of fuel efficient engines.

Reviewer 4:
The reviewer commented that improved spray and combustion models lead to more accurate, robust models needed for faster development of higher efficiency, lower emissions engines.

Reviewer 5:
The reviewer stated that fundamental understanding of the injection process is key for optimized engine design.

Reviewer 6:
The reviewer answered, yes, from a broad perspective and noted that this work is very much needed. The PI is doing a lot and should be commended. The reviewer expressed concern that too much is included in the project that defocuses the impact.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the PI’s work requires a steady stream of funding. The reviewer commended the PI for such a good work considering the budget limitations.

Reviewer 2:
The reviewer commented that the resources allocated for the project are sufficient because this project leverages other projects.

Reviewer 3:
The reviewer observed that milestones are being met on a timely basis, so there is no indication that resources are not appropriate.

Reviewer 4:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE’s investment relative to the commercialization potential.

Reviewer 5:
The reviewer stated that the project team needs better direction from OEM subject experts to define the areas of research that can make significant impacts to higher efficiency and clean engines.

Reviewer 6:
The reviewer commented that, frankly, the information presented is not sufficient to make a judgement, because the roles and the scope of work between collaborating partners is not well understood. For example, if ANL is developing the model, the reviewer asked why it was not included on the collaboration slide.

Presentation Number: acs076
Presentation Title: Improved Solvers for Advanced Engine Combustion Simulation
Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

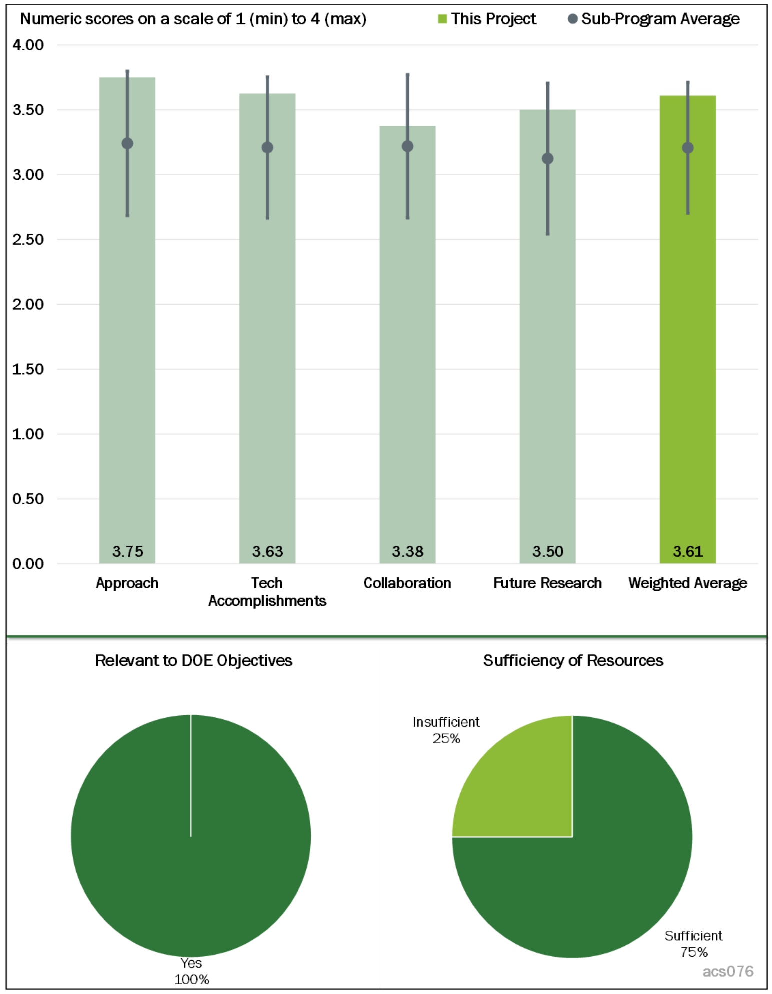

Figure 1-25 - Presentation Number: acs076 Presentation Title: Improved Solvers for Advanced Engine Combustion Simulation Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Presenter
Matthew McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer noted that the approach to reduce the computational cost associated with chemistry solvers is very promising. This research will have enormous impact as more simulations are being done with detailed chemical kinetics involving thousands of reactions.

Reviewer 2:
The reviewer commented that the technical barriers are clearly identified and addressed. It is clear that exploration of new combustion regimes is often attempted with computational methods and its accuracy is dependent on the computational cost due to the depth of physics included. In the era of optimizing fuel properties as well as engine hardware, it becomes ever more important to speed up the solver. The project team's work is sharply focused on the topic in that regard.

Reviewer 3:
The reviewer commented that the web based tool to diagnose simulation errors is good.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that overall project progress towards extending the Zero-order Reaction Kinetics chemistry solver to more applications impacting VTO research has been promising.

Reviewer 2:
The reviewer commented that it appears that more effort has been put towards validation of the tool over applications and making the tool available to public.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that collaboration and coordination mentioned in the presentation with industry, academia, and national laboratories has been exemplary.

Reviewer 2:
The reviewer observed a lot of evidence indicating good collaboration; the results are being used by a number of projects.

Reviewer 3:
The reviewer noted that it would be ideal to contact multiple software vendors for the solver implementation and utilization for the maximum impact.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that joint sensitivity for rapid reaction rate screening is promising. The reviewer questioned if this sensitivity could be developed into a library with the capability of being coupled with any general purpose CFD code. The reviewer observed that the detailed spray dynamics with reduced computational cost proposed in FY 2018 and beyond will have great impact on engine modeling accuracy.

Reviewer 2:
The reviewer noted that publishing a web based tool to diagnose simulation errors looks promising.

Reviewer 3:
The reviewer commented that while high-level targets are well poised, details of the plan are not well illustrated. The reviewer questioned if the author was planning to check and improve all the numerical scheme of software or is the improvement to be done for a single platform.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project supports overall DOE objectives by increasing the speed and accuracy of various VTO modeling efforts.

Reviewer 2:
The reviewer observed that the goal of this project is speeding up the numerical solver for faster turnaround to explore better engine design with less fuel consumption. The savings of computational time itself (power consumption/design evaluation) also saves energy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that additional information would be useful.

Reviewer 2:

The reviewer commented that proposed future research work is ambitious with the resources requested. The reviewer suggested that progress can be made by leveraging research with other initiatives mentioned in the study.

Reviewer 3:

The reviewer commented that combining with ACS012 and sharing the budget will inhibit project deliverables.

Presentation Number: acs084
Presentation Title: Advanced Ignition Systems for Gasoline Direct Injection (GDI) Engines
Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

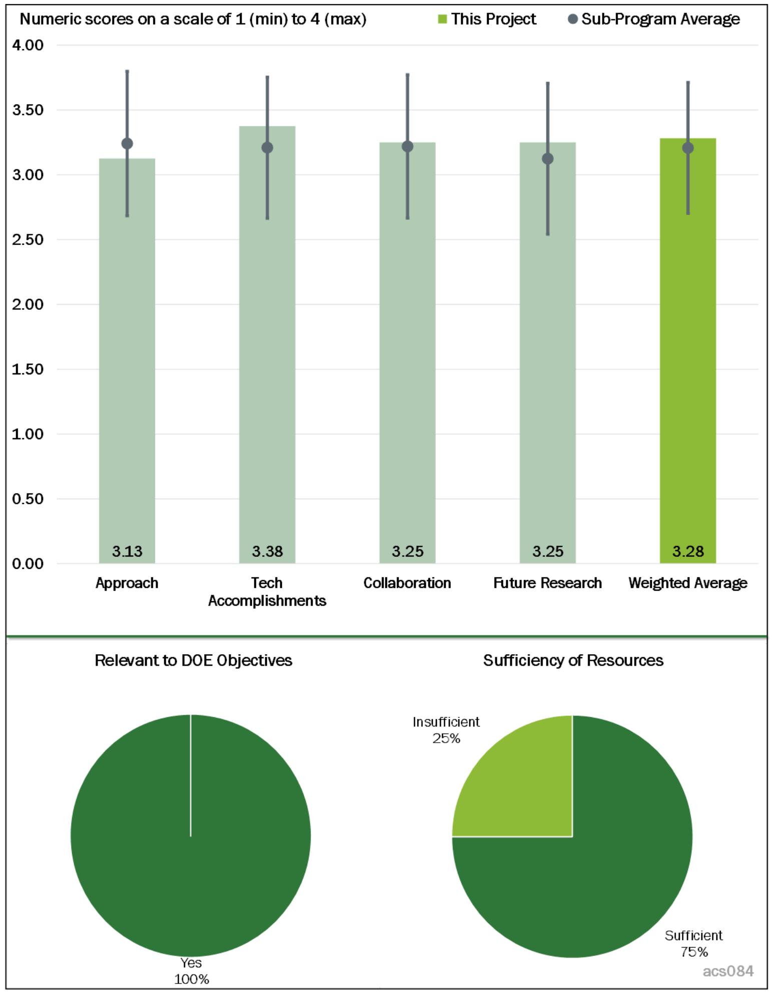

Figure 1-26 - Presentation Number: acs084 Presentation Title: Advanced Ignition Systems for Gasoline Direct Injection (GDI) Engines Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Presenter

Riccardo Scarcelli, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the work being done in this project regarding the ignition systems is unique and needs to be accelerated as the automotive industry moves towards GDI, downsizing displacement, and boosting with a turbocharger.

Reviewer 2:

The reviewer stated that the approach of comparing model predictions to experimental data were good.

Reviewer 3:

The reviewer stated that this was an effective coupling of experimental and modeling efforts.

Reviewer 4:

The reviewer mentioned that this approach uses CFD modeling of the arc and plasma to understand the physics. The experimental learnings are being captured in the code.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project's technical progress appears to be good. The milestones up through March 2017 have been completed (the next milestone dated June, 2017 is listed as "on-track").

Reviewer 2:
The reviewer commented that progress has been made in modeling conventional arcs as well as non-equilibrium plasmas. The effect of laser ignition location has also been evaluated.

Reviewer 3:
The reviewer wondered if non-equilibrium plasma modeling that requires expensive chemistry could use some of the advanced solvers from project ACS012 or ACS076 to reduce the overall computational cost.

Reviewer 4:
The reviewer stated that there should be additional efforts on laser ignition, funding permitting.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer commented that the existing collaboration with Ford and relevant ignition companies was good.

Reviewer 2:
This review noted that it looks like more collaboration has been initiated with the automakers (Ford and USCAR mentioned) in response to issues raised last year by evaluators and reviewers.

Reviewer 3:
The collaboration with Sandia National Laboratories appears effective to this reviewer.

Reviewer 4:
This reviewer pointed out that for computational efficiency, the PI may need to collaborate with the LLNL algorithm investigators.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that further understanding of the ignition process is key to LD efficiency, especially as dilution increases (lean and/or EGR).

Reviewer 2:
The reviewer commented that proposed future work in FY 2018 to build/validate a comprehensive ignition model accounting for different plasma technologies/characteristics is reasonable provided that plasma technologies continue to offer promise as improved ignition systems.

Reviewer 3:
The reviewer questioned whether the proposed work in FY 2018 for cyclic variability requires LES. If yes, that can add significant computational cost to the already expensive chemistry for plasma modeling.

Reviewer 4:
The reviewer questioned if the proposed work will have an impact in removing barriers to high-dilution engines.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer noted that the ignition system is novel and advanced for GDI engines and has the potential to improve engine efficiency which supports DOE objectives.

Reviewer 2:

The reviewer commented that the project supports the overall DOE objectives of petroleum displacement by performing research related to various ignition technologies.

Reviewer 3:

The reviewer stated that ignition is still key in multi-mode LTC or dilute combustion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that modeling efforts should be accelerated.

Reviewer 2:

The reviewer stated that milestones are being met in a timely manner, which suggests that the resources are sufficient.

Presentation Number: acs085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

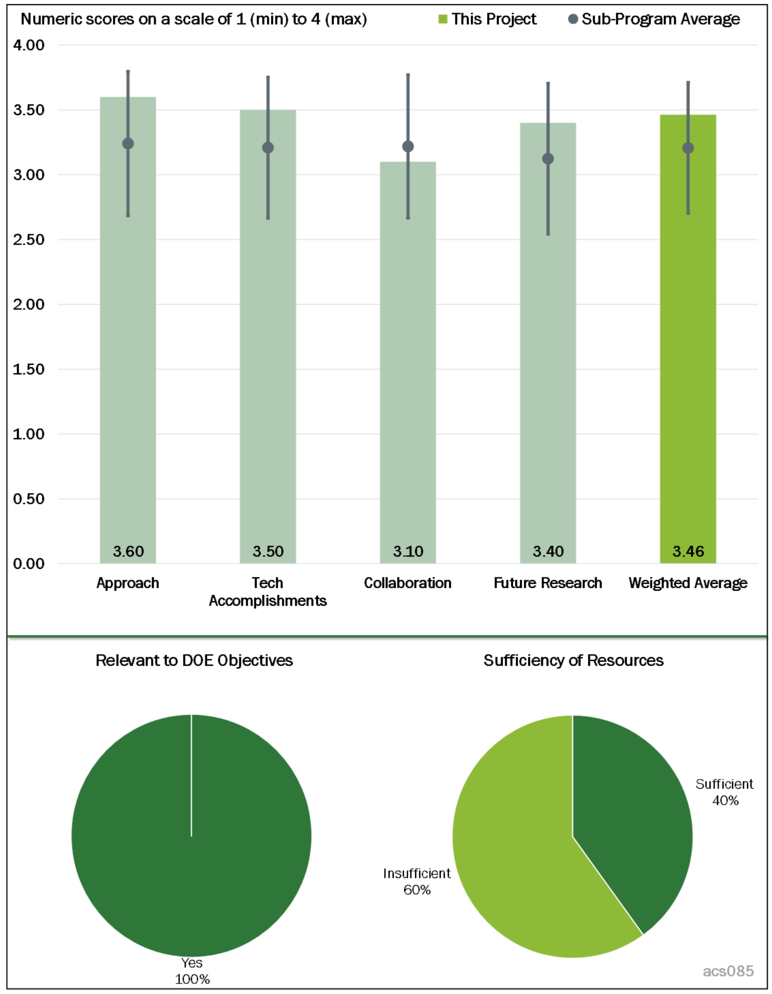

Figure 1-27 - Presentation Number: acs085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter

Todd Toops, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that this project has an excellent approach in collaborating with universities and scientists funded through BES. The reviewer stated that this is a great way to leverage funding to learn fundamental information regarding applied systems.

Reviewer 2:

The reviewer noted that the four-pronged approach of optimizing conventional catalysts, exploring fundamentals, taking novel approaches (PGM-free), and incorporating traps is yielding interesting results using the LT test protocol. The reviewer expressed that looping back to real-world exhaust is missing, wherein checks with actual exhaust might be prudent before focusing on any given formulation.

Reviewer 3:

The reviewer noted that the project approach is comprehensive, involving many key steps, such as support modification, trapping material development, and PGM-free mixed metal oxides. The reviewer went on to state that aging impact needed to be addressed. For example, the results shown in Slide 16 indicate that meeting 150^0C target is also challenging for all other species shown in the plot after 800^0C 10 hours aging in addition to propane because T90 points moving to right direction, or higher temperature is quite evident.

Reviewer 4:

The reviewer expressed that the multi-laboratory and university approach is a great way to leverage resources, equipment, and expertise. The reviewer stated that it seems to have high organizational overhead—in terms of team meetings and especially at the AMR, where the reviewers could only get the briefest of overviews into the six projects covered by this talk. The reviewer expressed that all of the projects in this section are focused and on highly important topics. The reviewer went on to state that none of these fuels or combustion concepts is deployable without meeting emissions so the emissions control is therefore a key area.

Reviewer 5:

The reviewer stated that the approach is appropriate.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that advances are being accomplished on all fronts, with the silicon dioxide-zirconium dioxide shell and core design still showing the best results. However, the reviewer stated that after all this effort the T90 goal is still approximately 50^{0}C away with diminishing returns. The reviewer went on to say that there seems to be some potential here if the different approaches are integrated.

Reviewer 2:

The reviewer noted that several of these projects were on-going and re-branded as co-optima, so there is very good progress under the relatively young co-optima banner. The reviewer observed that the interaction between the fuels, emissions, and emissions control catalysts is key to evaluating the future of the fuels.

Reviewer 3:

The reviewer was unsure whether 800°C aging for 10 hours is the right aging criteria, and referenced Slide 16, but noted that this was different from Slides 7 and 8. The reviewer suggested making the aging criteria and protocol clearer.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer acknowledged that this is a complex but well-managed project with a diverse set of players. The reviewer commented that the collaborations will be tested when integrated approaches are implemented.

Reviewer 2:

The reviewer acknowledged the good inter-lab collaboration, but would like to see more work with university and industry stakeholders.

Reviewer 3:

The reviewer noted that the university partner used 700^{0}C aging for 100 hours. The reviewer suggested seeing how the project can share the results or show how these worked together to summarize the results.

Reviewer 4:

The reviewer noted that the lack of industry support makes the program less valuable in terms of DOE program objective.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked how no single approach is getting the project to its goals. The reviewer would like to see further integration of the varied approaches here. An illustrative example is using the strong electrostatic adsorption PGM application on the ZrO_2-SiO_2 shell and core catalyst, layered with the co-precipitated CuO_X, CoO_y, and CeO_2 catalyst and trapping materials. The reviewer recommended that the project pick its best shots and begin to move in this direction. Tweaking of formulations along the way will likely be needed. The reviewer suggested that the project consider looping back with real exhaust and S tolerance before going too far down this path. Also, as any lean NO_x approach will need NO_x aftertreatment, the reviewer recommended that the project consider nitrogen dioxide (NO_2) more seriously. Finally, the reviewer recommended that the project look at exotherm impact with faster ramp or test cycle simulation.

Reviewer 2:

The reviewer suggested adding engine aged catalysts to the study. The reviewer noted that this would be valuable as engine aging deactivates the catalyst radially.

Reviewer 3:

The reviewer noted that the project's future directions are stated in Slide 25. The reviewer expressed a desire for this project to work more actively with industry.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that the LTC methods are showing the best promise for highly efficient engines, but the project has a LT HC plus CO issue. The reviewer expressed that this project will be very critical to their success.

Reviewer 2:

The reviewer acknowledged that improving catalyst performance yields better fuel economy.

Reviewer 3:

The reviewer remarked yes, if the project can demonstrate the benefits with an engine dynamometer, teaming with a vehicle OEM.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project should be able to achieve the program goal with the resource it has. Having internal funding to explore potential commercialization is helpful.

Reviewer 2:

The reviewer commented that if the team moves into integration of the best methods, for example into complex layered or zoned catalysts, combined with some engine testing, more resources might be needed. The reviewer stated that $400,000 seems to not be enough.

Reviewer 3:

The reviewer stated that this seems appropriate.

Reviewer 4:

The reviewer warned that more resources are clearly necessary to meet program goals.

Presentation Number: acs092
Presentation Title: High-Efficiency Variable Compression Ratio Engine with Variable Valve Actuation and New Supercharging Technology
Principal Investigator: Charles Mendler (Envera LLC)

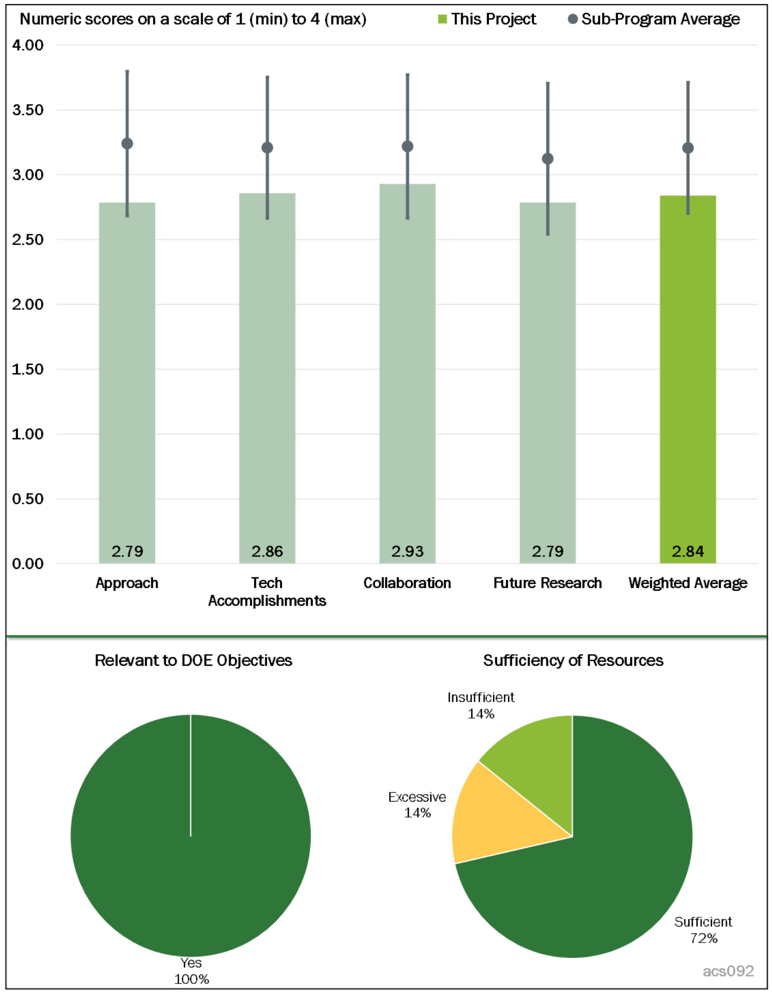

Figure 1-28 - Presentation Number: acs092 Presentation Title: High-Efficiency Variable Compression Ratio Engine with Variable Valve Actuation and New Supercharging Technology Principal Investigator: Charles Mendler (Envera LLC)

Presenter
Charles Mendler, Envera LLC

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer noted that this is an interesting approach and the researchers have made good progress over the last year. The reviewer acknowledged that the project is just starting its data collection now, so the next year's testing will be critical to the overall assessment of its success.

Reviewer 2:
The reviewer commented that a big concern with variable compression ratio (VCR) engines is long term durability. The reviewer acknowledged that a superficial analysis of this project seems to indicate an attention to high-quality parts. The reviewer warned that it is more difficult to identify a systemic problem which is a major danger here.

With VCR, the reviewer questioned whether the cylinder residual change was appreciably from a non-VCR engine. The reviewer pointed out that this could have an impact on the EGR conclusion.

Reviewer 3:
The reviewer stated that the project within itself is achieving near fuel efficiency goals, but went on to comment that the goals are not exceptionally challenging and could possibly be met with less complex technology.

Reviewer 4:
The reviewer remarked that VCR is a promising technology to improve engine efficiency. However, the reviewer noted that the approach seems heavy, which will impact the actuator power required to change the CR, and the response time to change the CR. The reviewer stated that the impact of response time on engine efficiency over a drive cycle has not been considered and will reduce the improvement from this approach.

Reviewer 5:

The reviewer was concerned that too much emphasis is being spent on convincing others of the benefits of VCR, variable valve actuation (VVA), and boosting to achieve high efficiency. The reviewer would like to see more emphasis on the technical barriers of the VCR mechanism's life expectancy.

The reviewer remarked that a demonstration with 87 octane fuel would be more relevant; that the project is not really finding the real world, knock limiting operation. The reviewer observed that demonstrating high efficiency at part load, with high compression ratio and 93 octane fuel could be done by existing high-performance engines that require premium fuel.

Reviewer 6:

The reviewer observed that the project seeks to use VCR to improve engine efficiency over the operating map by adjusting CR with the Envera designed engine. The reviewer stated that the fundamentals of the approach are sound as combustion efficiency at different loads depends strongly on CR. The design has been implemented to build hardware, and collaborators are evaluating the engine, however, the reviewer commented that there are several aspects of the project approach that could be improved. The reviewer remarked that the engine is operating with port fuel injection when GDI would be more appropriate for improving efficiency relative to existing state-of-the-art. Boosting is also not addressed significantly which also needs to be included for fair comparison to (and advancement from) state of-the-art. Finally, the reviewer stated that the system is complex, and durability needs to be part of the research.

Reviewer 7:

The reviewer was not convinced why this program requires two expensive technologies, VVA and VCR, as a package to achieve the program goal. The reviewer stated that the key is what is next after the end of this program. The reviewer questioned who would potentially use these two technologies for production because of cost and reliability issues for many years to come.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the engine is built and on a test stand which is a great accomplishment. The reviewer asked what the interim fuel economy and emissions are. The reviewer remarked that this is crucial.

Reviewer 2:

The reviewer acknowledged that the project has made good progress in the past year. The reviewer stated that the project's mechanism integrates nicely into the engine block and tests with statically varied CR give desired results. The reviewer remarked that the real test will be whether these advantages hold up under full dynamic operation of the engine and mechanism. The reviewer looks forward to seeing the project's final results.

Reviewer 3:

The reviewer stated that the project has been successful in buildup of the engine with VVA and VCR and has generated some preliminary data. The reviewer noted that this, in itself, is not a trivial achievement. The reviewer remarked that the project must remember, however, that this team and their VCR approach have gone through a number of iterations over many years.

Reviewer 4:

The reviewer noted that building and testing a prototype engine is no small or easy task, so good progress has been shown towards this and getting measurable data from the engine prototype.

Reviewer 5:
The reviewer remarked that the project does show some impressive progress at the cost of the complicated technologies as a whole, however, it only shows the selected modes. The reviewer noted that it still relies largely on simulation with GT-Power models. The reviewer commented that it would be better if baseline results can be shown for comparisons in its tests results.

Reviewer 6:
The reviewer was expecting to see much more in terms of engine test results given that the project ends this year. The reviewer stated that showing a couple of points running naturally aspirated is not enough to demonstrate that a boosted Miller engine meets the goals or is going to be successful. The reviewer noted that burn rate is slow for a modern boosted engine.

Reviewer 7:
The reviewer remarked that while designs have been implemented in hardware and engine efficiency made, the project has not addressed transient operation to the degree one would expect for a project at this point in the project cycle (last year of a four-year project). The reviewer commented that more results are needed. The reviewer stated that other important data that would be useful for the project to provide would be emissions. The reviewer wondered if there are there emission advantages to the variable compression approach. The reviewer noted that the project is primarily funded by DOE, but no publications are cited in the work. The reviewer commented that Envera owns patents of the technology, but public funding is supporting the research, therefore, the research should be provided to the public in journal or conference papers; even if details related to proprietary design are not included in the publication, the research results on efficiency would be valuable to the public.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that coordinating all of the parts development and delivery with multiple partners is a major challenge. The reviewer remarked that this has been done well.

Reviewer 2:
The reviewer stated that it seems that this project has good participation with appropriate stakeholders.

Reviewer 3:
The reviewer commented that the project has engaged an exceptional test site in Mahle and has received good support from Eaton. The reviewer noted that a missing feature of the project is a side-by-side comparison to one of the other VCR engines or an engine map from one of the other engines. The reviewer said that this project lacks benchmarking other engines (at least this year).

Reviewer 4:
The reviewer stated that this project has a good, well qualified team of Envera, Eaton, and Mahle.

Reviewer 5:
The reviewer remarked that the project seems to have all partners involved in the program.

Reviewer 6:
The reviewer stated that Eaton and Mahle are collaborators/partners on the project and that there are some other smaller industry roles. The reviewer remarked that this project would benefit from an OEM partner who would be the ultimate customer for this technology.

Reviewer 7:
The reviewer stated that listed collaborators are really suppliers.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that at this point in the project the future plans are obvious. The reviewer observes that no major speed bump seems to have occurred which is a testimony to the planning from the prior work on the project.

The reviewer prefers a continuous evaluation of the fuel economy of the engine. The presentation does not really tell the reviewer if the project has reached its goals.

Reviewer 2:
The reviewer stated that the project is nearing completion. The reviewer commented that development of an engine map and exercising that map in an engine and vehicle simulation are appropriate final steps.

Reviewer 3:
The reviewer remarked that proposed demonstration of operation over a wide speed/load range will be a good achievement as the project comes to a close at the end of the FY.

Reviewer 4:
The reviewer stated the project needs to complete their testing.

Reviewer 5:
The reviewer acknowledged that limited time is available in the remainder of the project. The reviewer commented that transient results would be of interest, but it is unclear what can be accomplished in the remaining time.

Reviewer 6:
The reviewer stated that the project includes a lot of details on the R&D and future plan. The reviewer commented that it is helpful to have 12 test points as the future plan, but that it would be important to compare the results with the baseline engine that does not have such sophisticated technologies.

Reviewer 7:
The reviewer acknowledged that 12-part load mapping points are barely adequate to predict vehicle fuel consumption. The reviewer commented that additional points would provide more robust results.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Assuming the engine reaches the projected fuel economy and has tolerable emissions then, yes the reviewer commented that the project will have reached its goals.

Reviewer 2:
The reviewer stated that the concept and potential of variable compression ratio is known. If this concept is successful, viable, and able to be manufactured it would have beneficial impact on operational efficiency.

Reviewer 3:
The reviewer noted that variable compression ratio is a pathway to improve engine efficiency.

Reviewer 4:
The reviewer remarked that high efficiency demonstration of the engine concepts meets the DOE objectives.

Reviewer 5:
The reviewer noted that variable compression technology can increase fuel efficiency and reduce petroleum use if the barriers can be overcome.

Reviewer 6:
The reviewer said yes, but it is too expensive to achieve the program goal.

Reviewer 7:
The reviewer remarked that the project is attempting to show VCR as a path to improved fuel consumption. The reviewer noted that to some extent this particular approach has been largely overtaken by the performance and efficiency of other prototype and even production engines. The reviewer commented that the project still has emissions compliance to prove.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer wondered whether the project has enough resources remaining with 89% of the budget gone, while the program is still largely in the modeling stage.

Reviewer 2:
The reviewer remarked that it appears that the researchers will be able to complete the work in their statements of tasks within the allotted budget.

Reviewer 3:
The reviewer commented that this project was funded at a significant level for over 4 years, allowing it to achieve the stated goals and objectives.

Reviewer 4:
The reviewer sees no indication that the project is starved for money.

Reviewer 5:
The reviewer noted that resources have been sustained for a number of years. The reviewer stated that building engine prototypes is pretty costly.

Reviewer 6:
The reviewer noted that DOE has provided approximately 80% of the total project cost. In comparison to other industry-led DOE projects, the reviewer stated this government funding proportion is quite high (a 50/50 mix is more common). The reviewer remarked that more investment from industry for the project would be preferred and would justify relevance to industry.

Presentation Number: acs093
Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles
Principal Investigator: David Sczomak (General Motors)

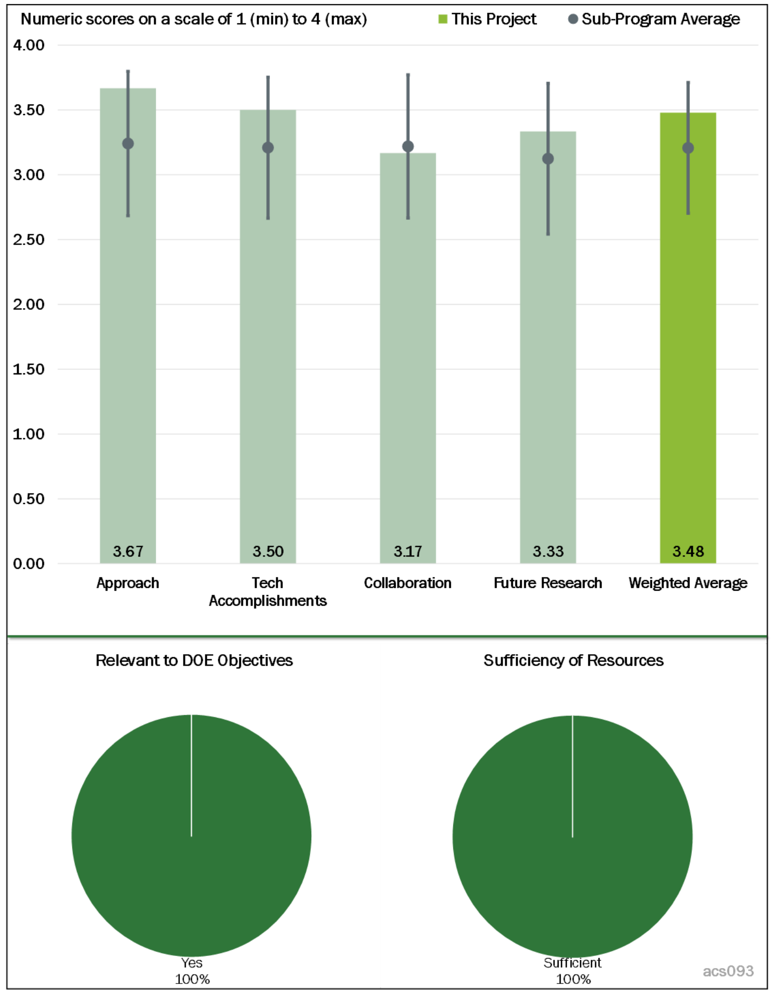

Figure 1-29 - Presentation Number: acs093 Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles Principal Investigator: David Sczomak (General Motors)

Presenter

David Sczomak, General Motors

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that this is a rather complex project with many facets—variable valve timing (VVT), lean, supercharging, EGR, FIE, and advanced thermal management. The reviewer noted that the approach is utilizing the best of all "incremental technology" approaches that are all in the market today but not yet integrated. The reviewer likes the parallel tasking approach—testing, simulation, aftertreatment, engine build, etc. occurring in parallel. The reviewer stated that this will be very interesting to see it develop.

Reviewer 2:

The reviewer stated that the multi-faceted approach looks comprehensive and should lead to a successful outcome. The reviewer noted that the spray imaging appears to be giving significant insight into the project.

Reviewer 3:

The reviewer noted that the approach is appropriate for the stated goals of the project. The lean miller cycle is projected to be capable of exceeding the downsized boosted stretch goal of 35% at 20% load at 2,000 RPM and the 2 bar 2000 RPM goal of 26% with 36 and 31%, respectively. The reviewer recommended that the project also examine stretching the range of lean miller cycle operation.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer stated that the project has already demonstrated exceeding two of the three stretch DOE targets on the single cylinder engine.

Reviewer 2:

The reviewer remarked that multiple accomplishments were reported here, which are making significant progress to meeting goals. The reviewer commented that important work on fuel injection is multi-pronged and is showing focus. The main hardware options are scoped out on all fronts—FIE, head design, supercharging—and the CFD seems on target to this reviewer. The reviewer commented that chances are good BSFC targets will be hit. The reviewer said that aftertreatment system has several options, but for brake mean effective pressure less than 3 bar there will be challenges. An electrically heated catalyst is a possible option, but LNT may make more sense, as this is the preferred system for light-duty diesel (LDD).

Reviewer 3:

The reviewer remarked that fuel spray evaluations were well done and the description of the spray plume breakup as bushy was amusing. The reviewer would have liked to see more engine data.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the necessary parties are present, and seem to be working together.

Reviewer 2:

The reviewer noted that there are many suppliers involved in the project, although it is not clear the exact level of input they each had.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the multi cylinder build and dynamometer demonstration is laid out nicely to follow the extended single cylinder phase.

Reviewer 2:

The reviewer noted that the research plan for this project looked good. The reviewer recommends that it go forward.

Reviewer 3:

The reviewer expressed that the project tasks are nicely laid out. The reviewer went on to state that the project is utilizing classic engine development approaches. The reviewer has a little concern on the aftertreatment work, as this might be more difficult than envisioned at low load, however, one can borrow much from LDD: LNT/ TWC+SCRF+ SCR.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

This reviewer stated that the project is combining various production technologies into a new package with optimization. The reviewer noted that the project stands a good chance of meeting the goals, and being that it is "incremental," it might be implemented sooner than more risky approaches.

Reviewer 2:

This reviewer commented that the project directly addresses the DOE thermal efficiency goals, which will achieve petroleum displacement.

Reviewer 3:

The reviewer said that low load efficiency is necessary to lower petroleum consumption because that is where the engine operates a majority of the time.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that extension of intermediate timing indicates some resource issues, but the plan looks like targets will be met on time.

Presentation Number: acs094
Presentation Title: Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion
Principal Investigator: Keith Confer (Delphi Powertrain)

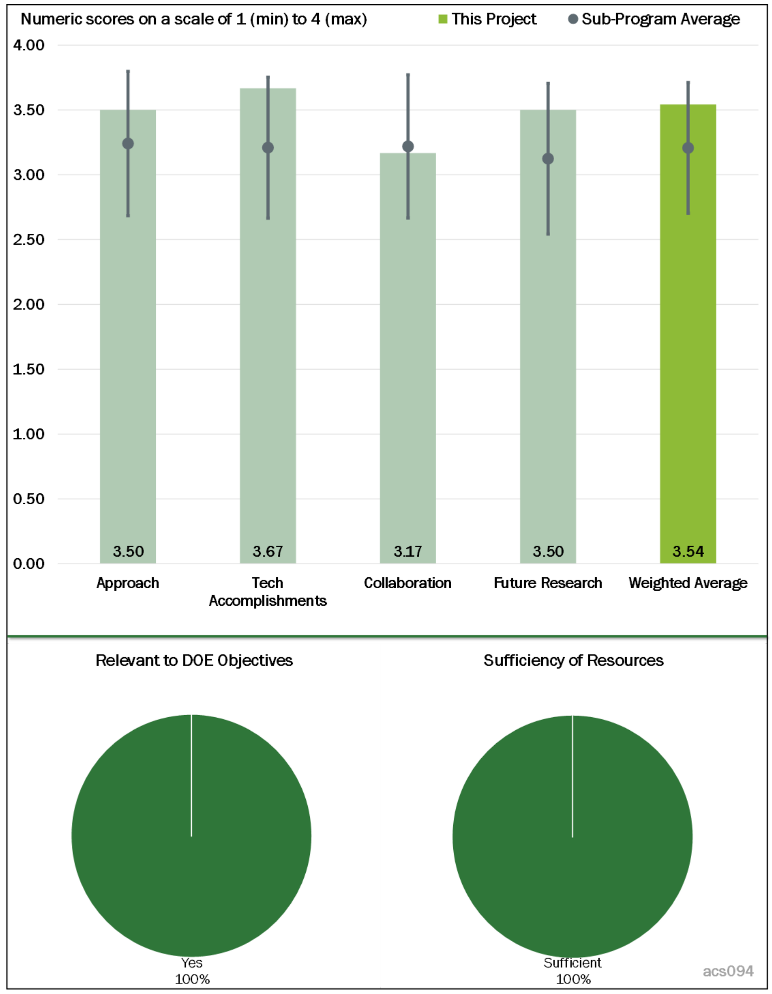

Figure 1-30 - Presentation Number: acs094 Presentation Title: Ultra-Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion Principal Investigator: Keith Confer (Delphi Powertrain)

Presenter

Keith Confer, Delphi Powertrain

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that this is a strong project approach focused on utilizing unique LTC called GDCI combustion to achieve the targeted fuel economy and also focusing on the aftertreatment system appropriate for meeting Tier III emission standards for this new concept. The reviewer remarked that this Advanced Technology Powertrain (ATP) II project builds on the Delphi DOE ATP I project that utilized single cylinder, multi-cylinder engine, and complete vehicle that met the fuel efficiency target. The reviewer observed that the final outcome is for the Gen three 3 GDCI engine to meet the 35% vehicle fuel economy improvement target in early FY 2019 while meeting the Tier III emissions.

Reviewer 2:

The reviewer stated that developing a highly efficient combustion engine is strongly encouraged given the reality that combustion engines will power commercial LD powertrains for many years to come. The reviewer noted that the engineering work to improve the base engine efficiency by 32% is noteworthy for this combustion approach. The reviewer expressed that this benchmark level of improved efficiency, however, negatively affects the exhaust energy needed by current day aftertreatment technologies. The reviewer noted that exhaust temperatures associated with the combustion strategy used in this engine and aftertreatment development project are insufficient for providing the level of emissions control needed with the proposed aftertreatment. Several aftertreatment areas of concern for this reviewer include first, the use of urea for such LT NO_x control. The reviewer stated that because the level of engine out NO_x is low, other options for directly providing NH_3 for NO_x reduction are more suitable or the use of NO_x traps for LT operation. Second, the production of GHG is excess of un-penalized levels is a possibility given the use of PGM in components and the LT environment. Third, desulfation of components will be necessary to maintain the level of efficiency needed to meet Tier III/LEV III standards, but clearly identified methods for providing additional heat in the exhaust stream have not been presented. Fourth, passive GPF may not work in this temperature environment, unless additional heat energy is available.

Reviewer 3:

The reviewer remarked that borrowing from previous efforts, the Delphi team identified the barriers for the present effort to be gasoline direct fuel injection system and aftertreatment system that can operate at very low (175°-350°C) temperatures. The reviewer stated that subsequently, the project focused its efforts in developing technologies to overcome these two barriers.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that there are many technical accomplishments on the engine portion of this project. The reviewer expressed that the project has clearly demonstrated very good performance and stability of the engine, however, the aftertreatment approach is insufficient to provide the level of emission control that would allow this powertrain to enter the market as a Tier III/LEV III system. The reviewer concluded that immediate effort is needed to ascertain the modal cycle emissions, so that an appropriate aftertreatment can be developed.

Reviewer 2:

The reviewer stated that the project has demonstrated significant progress and appears to be on track. The reviewer remarked that the project has managed to design, build, and perform initial testing on a Gen3 GDCI engine on a dynamometer platform. The reviewer also noted that the project compares the engine's efficiency and emissions performance with previous versions.

Reviewer 3:

The reviewer observed good progress on the vehicle level including controls refinement (combustion phasing and stability on Gen 2 engine hardware). The reviewer mentioned that the design and build is completed on the Gen3 GDCI. The reviewer pointed out that the Gen 2 GDCI vehicle is being used to develop the controls with focus on transient operation. The reviewer went on to state that the "Wetless" fuel system concept has been developed for low smoke because injector and spray characteristics are one of the most important design factors for successful GDCI combustion control. Finally, the reviewer stated that an exhaust aftertreatment system has been designed and is undergoing testing but the challenge is efficient operation at low engine-out temperatures.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that Delphi has partnered with ORNL whose role is to perform measurements and analyze data, and with University of Wisconsin, Madison, whose role is performance characterization of the fuel injection system. The reviewer stated that the listing of publications that have resulted from this work by these two partners would be appreciated in future reviews.

Reviewer 2:

The reviewer stated that while initial vehicle OEM is no longer part of the project, Delphi secured a vehicle OEM alliance to help advise the program. The reviewer noted that Delphi has all of the needed engine development expertise and a good track record of DOE co-sponsored engine development projects while Umicore and ORNL are experts at emission control characterization and catalyst development. The reviewer stated that the project is collaborating with other DOE national laboratories with relevant combustion expertise (ANL, ORNL, and SNL). The reviewer stated that the project team also includes the University of Wisconsin, Madison for characterization testing of fuel injectors.

Reviewer 3:
The reviewer remarked that the project may have suffered some loss of momentum due to the withdrawal of one of the original participants. The reviewer noted that the use of an "alliance" of partners, drawing from domestic OEMs, may not be as effective due to their level of engagement and differing needs and approaches. The use of Umicore and ORNL for aftertreatment development is very appropriate, but the reviewer acknowledged that their influence does not appear adequately reflected in the design of the aftertreatment system.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the Delphi team appears to have identified a sound approach to developing a GDCI engine, i.e., of designing and developing an engine along with the combustion system, fuel injection system, and aftertreatment system. The reviewer remarked that subsequently, they install the engine in a vehicle to optimize the control system for the vehicle. The reviewer concluded that the approach that the Delphi team is taking cannot be any more ideal.

Reviewer 2:
The reviewer noted that engine development is very clear and appears well thought out. The reviewer stated that the aftertreatment approach that will be coupled with the engine is not as well defined.

Reviewer 3:
The reviewer stated that there is appropriate future work to meet project milestones and targets including: dynamometer calibration for performance and emissions, vehicle controls development, and building Gen 3 GDCI vehicle for testing.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer noted that the combustion strategy and development work associated with the project address the stated need for this type of technology within both the DOE and OEM organization as well as USCAR. However, for this combustion approach to be marketable, the reviewer stated that it must be coupled with an aftertreatment system that is capable of SULEV30. The reviewer remarked that this has not been demonstrated yet.

Reviewer 2:
The reviewer said that the Delphi team is trying to develop a practical engine for LD vehicles that can offer significant fuel savings, as high as 35%, compared to current SI engine technology. The reviewer commented that such fuel savings can aid in reducing the overall petroleum consumption in the United States, which is one of the main objectives of DOE.

Reviewer 3:
The reviewer stated yes, this project supports the DOE VTO's goal to improve the efficiency of LD engines for passenger vehicles through advanced combustion and minimization of thermal and parasitic losses. The reviewer noted that it is also developing aftertreatment technologies integrated with combustion strategies for emissions compliance and minimization of efficiency penalty. The reviewer concluded that a highly efficient engine that meets the emissions standard would significantly reduce LD vehicle petroleum use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that there is a significant amount of funding on this project from both of the funding partners. The reviewer noted that resources appear adequate.

Reviewer 2:
The reviewer stated that the allocated funds are sufficient for the proposed development.

Reviewer 3:
This is a well-funded, nearly $25 million, five-year project that includes the needed partners and resources to complete the project targets.

Presentation Number: acs095
Presentation Title: Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation
Principal Investigator: Pu-Xian Gao (University of Connecticut)

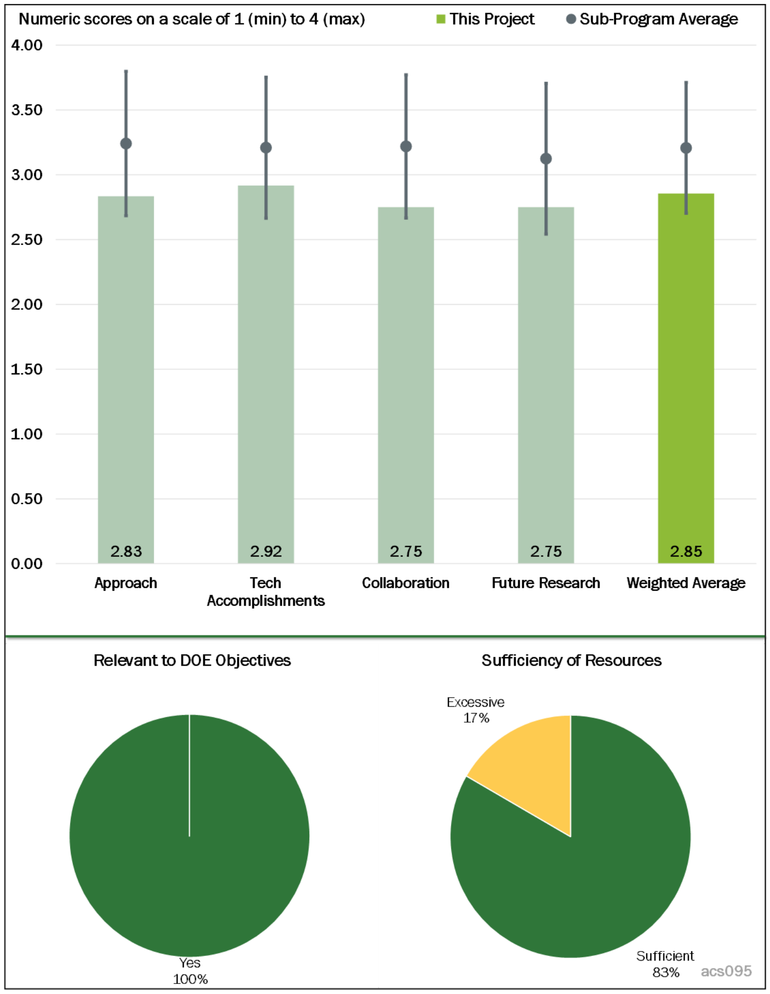

Figure 1-31 - Presentation Number: acs095 Presentation Title: Metal Oxide Nano-Array Catalysts for Low-Temperature Diesel Oxidation Principal Investigator: Pu-Xian Gao (University of Connecticut)

Presenter

Pu-Xian Gao, University of Connecticut

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the steps to test and validate the nano-array seem to have been done. The reviewer stated that the approach is logical and little is left to do to close out the project.

Reviewer 2:

The reviewer commented that the project incorporates lower precious metal loading on a titania support. The reviewer noted that titania is used in rutile phase, so it would seem to be durable for the higher temperatures seen in exhaust. However, the catalyst was incorporated onto a metal support, which is rarely used due to washcoat adhesion issues with thermal cycling in vehicle exhaust. The reviewer went on to state that cordierite was offered as an alternative; the adhesion is presumed to be better but this was not shown (if it was tested). The reviewer observed that there was no direct comparison to commercial DOC under realistic aging conditions. The reviewer noted that 700°C is a degreening.

Reviewer 3:

The reviewer stated that the approach was appropriate.

Reviewer 4:

The reviewer stated that it is a very unique approach, but the value can only be proven if it can be realized in engine dynamometer supported by a vehicle OEM.

Reviewer 5:

The reviewer remarked that the thought process behind the evaluation is fine; however, the execution was flawed. The reviewer noted that the comparisons of catalyst appear to be apples and oranges.

Reviewer 6:

The reviewer commented that the goal of the project is indeed targeting some of the key barriers, namely LT conversion, but it is not clear that the approach undertaken in this project will actually get there, especially because 80% of the project is complete now.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer acknowledged that it was impressive that the project got to engine testing this year.

Reviewer 2:

The reviewer remarked that the key here is to show that the nano-array geometry offers significant benefits over standard washcoated methods, and opined that it seems so. The reviewer stated that relative to washcoated samples with the same platinum (Pt) loading on TiO_2, the nanoarray delivers 50°-100°C lower light-off temperatures. The reviewer noted that this is impressive. The reviewer commented that hydothermal aging is done, as is S tolerance- both are acceptable. The reviewer expressed that the only thing missing is long-term durability like erosion and ash impacts. The project mentions back pressure benefits but does not give data.

Reviewer 3:

The reviewer remarked that more realistic testing conditions were used this year. The reviewer noted that more realistic aging conditions are needed, such as 800°-850°C. The reviewer stated that desulfation also needs to be more realistic, as in high O_2 without hydrogen present and higher temperatures. The scale-up efforts were not clear to the reviewer.

Reviewer 4:

The reviewer commented that the project showed that Pt dispersion was stable after 700°C at four hours. The reviewer went on to state that going to 100 hours, T90 increases less than 40°C.

Reviewer 5:

The reviewer stated that progress has been made in aging and S poisoning. The reviewer observed that hydrothermal aging shown in Slide 14 is good, but it seems not too encouraging even though the performance may be still on par. It would be clearer to the reviewer if comparisons can be made between aging and fresh results on Slide 14. The reviewer remarked that it is not clear why both structural and catalytic performance got better after desulfation, which is interesting but needs a better explanation.

Reviewer 6:

The reviewer pointed out that this project followed too many simultaneous paths. The reviewer expressed that the project made minor progress in a number of areas rather than any significant progress in one area.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the testing collaboration with ORNL and Umicore is good. The reviewer pointed out that fabrication and characterization work is done in-house which is sufficient collaboration for this type of study.

Reviewer 2:

The reviewer identified Corning, Umicore, and 3D Array Tech. as partners.

Reviewer 3:
The reviewer noted some collaboration, however, the frequency of contact and closeness of the relationships was not really explained.

Reviewer 4:
The reviewer remarked that collaborations with ORNL and Umicore are important to this work.

Reviewer 5:
The reviewer pointed out that the National Energy Technology Laboratory (NETL) is not a collaboration. The reviewer stated that NETL is a project management arm of DOE (distributes funding).

Reviewer 6:
The reviewer stated that the program can have meaning if it can have vehicle OEM involvement in terms of DOE objectives. The reviewer noted that lack of industrial partner is one of the issues of this program after many years of development.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the work plan is appropriate. The reviewer suggested that the project compare the 800°C aging to the commercial version, if possible.

Reviewer 2:
The reviewer commented that the project has reached the end of its lifespan.

Reviewer 3:
The reviewer noted that the project is ending this calendar year.

Reviewer 4:
The reviewer stated that future work should focus more on engine dynamometer tests and try to get vehicle OEM involvement.

Reviewer 5:
The reviewer remarked that the true test will be a sample tested apples-to-apples on the engine dynamometer. The reviewer noted that the team chose the Pt-titanium dioxide (TiO_{2f}) system; however, a standard washcoated DOC with the same PGM and washcoat ought to be compared. The reviewer stated that the nano-array seems perfectly suited for a GPF wherein the ash might be kept from contacting the catalyst; and back pressure might be reduced.

Reviewer 6:
The reviewer stated that scale-up feasibility and cost was not addressed very clearly. The reviewer asked if the assumed increased cost of manufacture be offset by precious metal savings or if this technology can ever be mass-produced.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that yes, improving catalyst efficiency will promote better fuel efficiency.

Reviewer 2:
The reviewer noted that yes, advanced aftertreatment allows for more efficient engines.

Reviewer 3:
The reviewer commented that reducing light-off of oxidation catalysts will be critical to enabling efficiency LTC engines.

Reviewer 4:
The reviewer stated that oxidation catalysts are needed for engines that run lean and are more fuel efficient.

Reviewer 5:
The reviewer stated that this can only be proven relevant if the technology can be recognized by industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer mentioned that although the remaining budget is not shown, it appears dynamometer testing is the main next step to close out the project, and that this is done by partners.

Reviewer 2:
The reviewer remarked that only 20% of the project remains.

Reviewer 3:
The reviewer answered that it seems appropriate.

Reviewer 4:
The reviewer concluded that the funding seems excessive for the progress made.

Presentation Number: acs097
Presentation Title: Affordable Rankine Cycle (ARC) Waste Heat Recovery for Heavy-Duty Trucks
Principal Investigator: Swami Subramanian (Eaton)

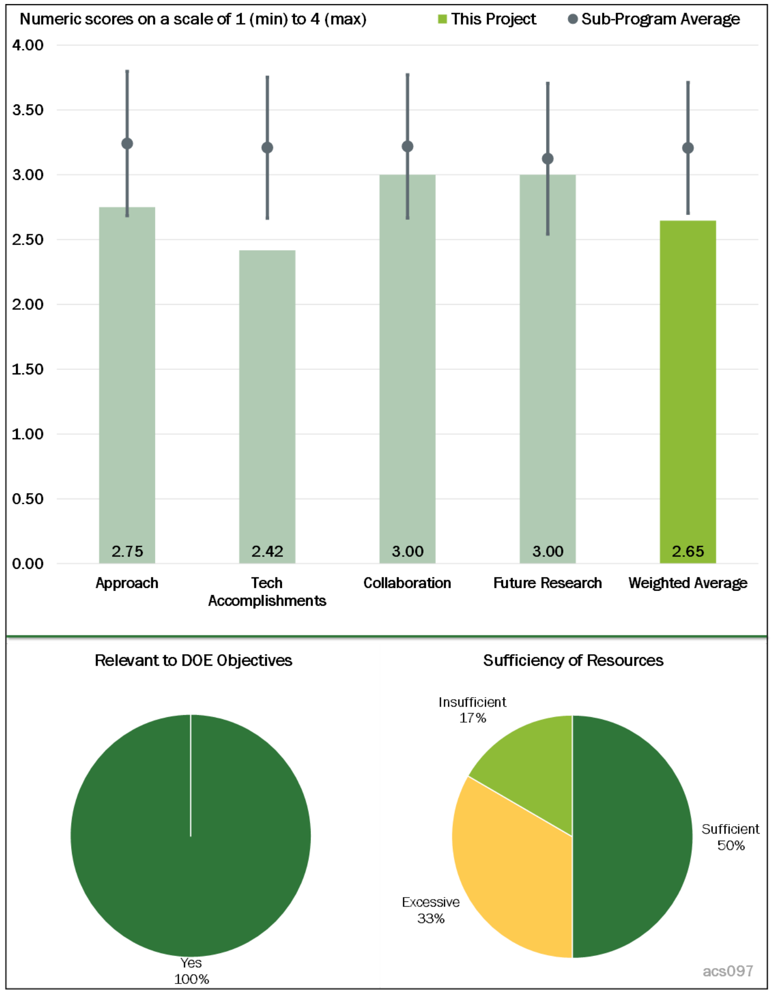

Figure 1-32 - Presentation Number: acs097 Presentation Title: Affordable Rankine Cycle (ARC) Waste Heat Recovery for Heavy-Duty Trucks Principal Investigator: Swami Subramanian (Eaton)

Presenter

Swami Subramanian, Eaton

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that using engine coolant in a waste heat recovery (WHR) system with Roots expander was an innovative idea toward lower cost and good performing WHR systems.

Reviewer 2:

The reviewer remarked that the approach is to use a low-cost working fluid (engine coolant) for the Rankine cycle to increase overall engine system efficiency. This reviewer stated that this approach is worthy of research and investigation. The reviewer said that the project has been carried out with multiple collaborators and partners. Appropriate research plans have been conducted with suitable attention to critical parameters of interest for determining feasibility of the approach.

Reviewer 3:

The reviewer was impressed that this project got to a go/no-go point and chose the no-go. The reviewer noted that that happens very infrequently. The reviewer stated that it appears as if the engineering requirements were made without a thorough analysis of the system. The reviewer noted that the project was not at all clear as to why the 5% efficiency point was such a hard target—4% seemed reasonable. The reviewer wondered why the character of the engine coolant played such a crucial role. The reviewer inquired why the team could not work with a coolant which did not have such a limiting degradation point, and asked why the other WHR-using engine coolant not have this problem.

Reviewer 4:

The reviewer stated that the project's approach is technically sound, however, achieving its target of a 5% fuel economy gain will be dependent on the efficiency of the base engine from which they start. The reviewer remarked that as the base engine gets more efficient the amount of "waste heat" goes down; and as the waste heat available goes down there will likely be design changes that need to be made to maximize the recovery of the WHR system. That is, the development of a WHR systems needs to be done in conjunction with development of a specific engine. The reviewer commented that this seems to be consistent with the assessment of the researchers and offers a concise explanation for why they have stopped the program.

Reviewer 5:
The reviewer stated that the potential efficiency improvement of the project could be increased by challenging the assumptions that are constraining the performance.

Reviewer 6:
The reviewer stated that the program objective in Phase 1 is good if and only if the project can achieve the program goal, which proves to be unachievable.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the project did a nice analysis of the WHR system and what is needed.

Reviewer 2:
The reviewer remarked that analysis was conducted with satisfactory detail to determine the limitations and issues with this type of system.

Reviewer 3:
The reviewer observed that it seems as if the coolant feasibility analysis should have been done prior to the project initiation. The reviewer pointed out that it feels like the technical accomplishments were just to prove the concept could work instead of finding a way to do it.

Reviewer 4:
The reviewer stated that technical accomplishments were not well described by the presentation. It is difficult for the reviewer to tell what was done based on the paucity of results presented.

Reviewer 5:
The reviewer commented that technical accomplishments were good in the sense that the research plan was carried out. Unfortunately, the reviewer observed that results were not as positive as desired, but overall, the progress in getting the results and the quality of the data were good.

Reviewer 6:
The reviewer said that there is no surprise that this project fails to achieve the program goal, because fundamentally the approach suffers from a major flaw—using coolant as a working fluid. The reviewer stated that this should be common knowledge.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that regardless of the outcome of this program, it shows that there were a lot of collaboration among the team members.

Reviewer 2:
The reviewer stated that the project had a good group of collaborators.

Reviewer 3:
The reviewer answered that it seems reasonable.

Reviewer 4:
The reviewer observed that a large team of collaborators was involved in the project.

Reviewer 5:
The reviewer commented that perhaps stronger involvement and influence by an engine or system development partner was needed.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the project is finished.

Reviewer 2:
The reviewer remarked that the project is ending. The reviewer learned that the system had some potential but it was not sufficient for the project goals. The reviewer said that stopping is appropriate.

Reviewer 3:
The reviewer commented that the team has chosen to end the research based on the results that did not show suitable performance. The reviewer stated that this is the correct plan of action (thus, the "good" rating). This reviewer recommends publicizing the work in journal or conference papers so that future efforts can reference the research performed here which entailed substantial investment.

Reviewer 4:
The reviewer remarked that if the technical team cannot find a way to make the project a success, then the reviewer sees no reason to continue the project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer acknowledged improved fuel economy.

Reviewer 2:
The reviewer said that even though the project is not proceeding, there was relevant learning that took place.

Reviewer 3:
The reviewer stated that WHR is very solidly known as important for reaching stretch engine efficiency targets.

Reviewer 4:
The reviewer commented that WHR is a pathway to improve vehicle fuel economy.

Reviewer 5:
The reviewer remarked that heat recovery via Rankine cycle can increase fuel efficiency and reduce petroleum use.

Reviewer 6:
The reviewer stated that yes, only if the program can achieve the goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the costs seem high for the progress made before the decision point.

Reviewer 2:
The reviewer thought that the pre-work was insufficient and consequently excessive funds were used.

Reviewer 3:
The reviewer remarked that using engine coolant as a working fluid is a non-starter.

Presentation Number: acs098
Presentation Title: Cummins 55% Brake Thermal Efficiency Project
Principal Investigator: Lyle E. Kocher (Cummins)

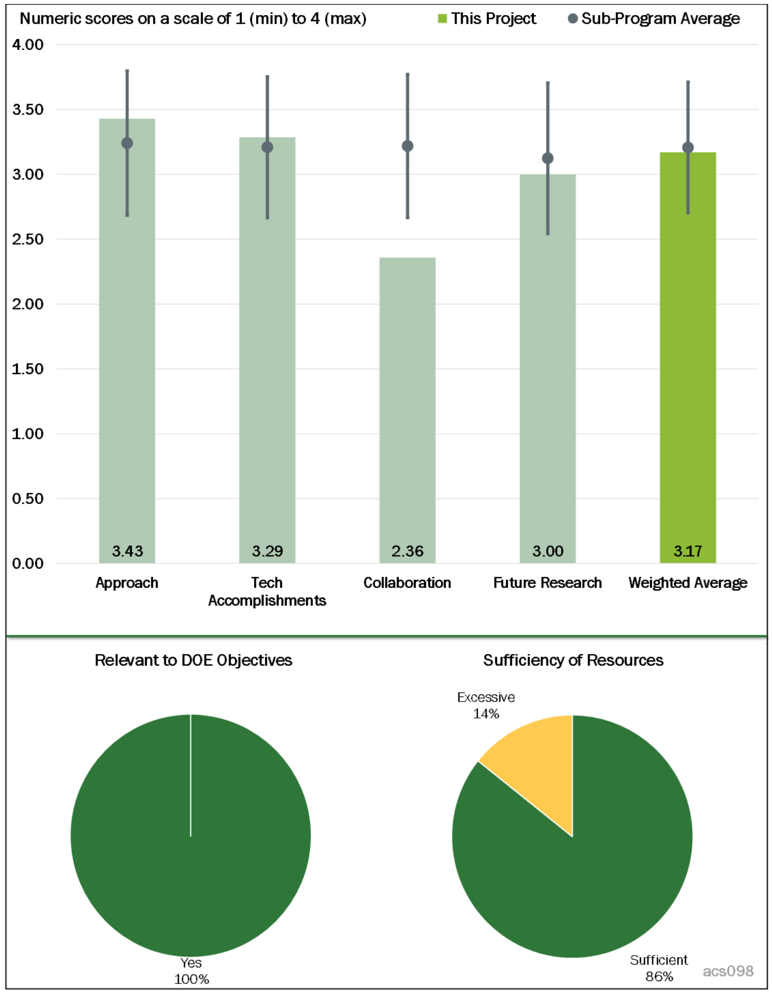

Figure 1-33 - Presentation Number: acs098 Presentation Title: Cummins 55% Brake Thermal Efficiency Project Principal Investigator: Lyle Kocher E. (Cummins)

Presenter
Lyle E. Kocher, Cummins

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer mentioned that this is an exceptionally well thought-out and analyzed approach to achieving 55%, exploiting measures to reduce essentially all of the loss paths in ICEs.

Reviewer 2:
The reviewer remarked that this project exhibits a very high level of technical work; addressing all the energy flows within the engine. The reviewer observed that it is a direct extension of the project's SuperTruck activities.

Reviewer 3:
The reviewer stated that it is good to take a holistic approach to the engine system efficiency; to consider the interactions between all of the different components involved in the engine.

Reviewer 4:
The reviewer said that the technical approach timeline looks to be logical, although the mule engine demo for the go/no-go fell behind schedule.

Reviewer 5:
The reviewer stated that this program pushes the limits that each of the key technologies can achieve. Virtual updates on all sub-systems are certainly helpful; however, the current status only achieves 49.2% BTE. It largely relies on WHR to achieve the remaining in order to reach the goal. In the meantime, it is confusing to the reviewer that in the backup table (Slide 20) only 0.2% BTE can be obtained with newer WHR. As the program states, it is likely that high engine-out NO_x would be used, and then the question for the reviewer is more than just OBD. The key question is whether this engine can pass 2010 emission on NO_x due to the cold part of FTP.

Reviewer 6:

The reviewer observed that this is a system refinement approach. This assumes that there are no low-hanging fruit options, so it is an approach that addresses edges. The reviewer remarked that Cummins has been good at that, but the edges are getting steadily less productive.

The reviewer said that there does not seem to be a desire to go out of the project's standard combustion strategy comfort zone. Mostly the project is sanding off the rough edges. The reviewer is not expecting any revolutionary improvements. This approach is not the high-risk development that the reviewer believed is the mission of the DOE.

Reviewer 7:

The reviewer noted that the challenge for the project (55% BTE) is quite significant. The project team realizes that an array of approaches and technologies/components are needed to achieve this goal. The array of strategies employed is being well coordinated and the project lead (Cummins) has significant expertise to combine the components into an engine system for evaluation. The reviewer noted that there are some high-risk approaches like the new WHR turbine design. The reviewer acknowledged that such efforts are in line with government funded research (which enables industry to perform research that would be too high risk for industry alone).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted excellent progress. The project is even working through the issue of air-handling and turbocharger sizing. The reviewer remarked that the project is close to the start testing.

Reviewer 2:

The reviewer observed that the project has a relatively short time frame overall (2 years). The reviewer stated that very good progress has been shown to date in a project with an aggressive schedule.

Reviewer 3:

The reviewer observed that the project is making progress toward the 55% goal.

Reviewer 4:

The reviewer stated that the project has essentially reached the objectives except for a minor issue with the procurement of the air-handling component. Considerable innovation was achieved in the design and implementation of the new WHR devices, low heat loss pistons, fuel injection, etc.

Reviewer 5:

The reviewer acknowledged that these accomplishments seem to be what OEM's do to improve their product. The reviewer noted that there is not much risk here.

Reviewer 6:

The reviewer noted that very good progress is shown on the injectors and low heat transfer pistons, and parasitic load reduction. The reviewer mentioned that the new WHR expander design seems risky for the small amount of efficiency gain, but it is recognized that the project has to go after everything to get the 55% BTE.

Reviewer 7:

The reviewer stated that not too much progress has been made in hardware in an integrated manner as far as the whole engine is concerned, while it still has 5.8% more in BTE to go.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer acknowledged a very strong industry supplier-based team in addition to core internal Cummins teams of multiple disciplines.

Reviewer 2:

The reviewer observed that all of the collaborations seem to be with Cummins which seems very insular. The reviewer noted that there is no real evidence of outside idea cross fertilization.

Reviewer 3:

The reviewer noted that an answer to this question is not very relevant. The reviewer observed that the project collaborates with their supply base, which also sells components to their competitors. Most of the significant collaborations are with internal suppliers.

Reviewer 4:

The reviewer stated that there was no significant collaboration.

Reviewer 5:

The reviewer remarked that the logic behind the limited collaborators makes sense, but it still does not justify a higher rating considering this is an all Cummins internal team.

Reviewer 6:

This reviewer noted that the project is primarily being performed at Cummins. Suppliers were cited as collaborators during the presentation, but no specific examples were given to substantiate their role as collaborators (as opposed to basic suppliers). The reviewer was wondering what research or new innovation was enabled at these suppliers as part of the project. The reviewer went on to question what contributions for concepts and new approaches were supplied by the suppliers and whether these contributions were the result of Cummins-supplier interactions/collaborations. The reviewer asked how public research funding provides the supplier companies with the ability to perform research or studies that are beyond the capabilities supported by their normal industry operations. The reviewer stated that much more could be done in the area of collaborations in this project.

Reviewer 7:

The reviewer stated that it would be politically incorrect if you run a DOE program without any partner. The reviewer noted that the money is not very well spent. [DOE Program Clarification: There is 50% industry cost share for this project, which was competitively selected.]

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the work to date leaves them with a high level of confidence that the program will be successful.

Reviewer 2:

The reviewer remarked that a good path forward was communicated for the remainder of the project.

Reviewer 3:

The reviewer stated that the plan forward looks sound.

Reviewer 4:
The reviewer pointed out that development engineers have all of the same problems and they do that for internal products. The reviewer is not excited.

Reviewer 5:
The reviewer noted that future work is described as completing the tasks at hand. The reviewer remarked that there was not much detail provided, but all is on a solid path.

Reviewer 6:
The reviewer noted that the future work stated in Slide 16 is in the right direction, but the barriers seems too big, specifically the delay on hardware delivery. The reviewer is unsure if the project can accomplish the program goal in time.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that improving over the road fuel efficiency will have an enormous impact on oil consumption, so this project does strongly support the DOE objective.

Reviewer 2:
The reviewer commented that yes, higher efficiency translates to petroleum displacement.

Reviewer 3:
The reviewer noted that the engines of focus in the project and the ambitious targets support fuel savings in the largest fuel-using segment (Class 8) of HD vehicles. Overall, HD vehicles are the fastest growing fuel user and GHG contributor.

Reviewer 4:
The reviewer stated that improved heavy truck engines can have a significant impact on reducing petroleum consumption.

Reviewer 5:
The reviewer remarked that this work really pushes the limits of pragmatic efficiency of an engine. The reviewer stated that the learning is very beneficial in regards to what can be done, and the cost and complexity of those actions versus the benefit.

Reviewer 6:
The reviewer noted that improving brake thermal (fuel) efficiency, which is the objective of this project, directly reduces petroleum use.

Reviewer 7:
The reviewer remarked that yes, only if the project can achieve the program goal in a timely manner.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that it appears that the project will be able to complete the work within the allotted budget. Of course, the reviewer does not know exactly what Cummins is spending internally. The reviewer stated that the work is very high caliber.

Reviewer 2:
The reviewer commented that resources have been effectively used for such a multifaceted approach.

Reviewer 3:
The reviewer remarked that the project should have what it needs, considering that Cummins is the only OEM that got this program plus SuperTruck II program.

Reviewer 4:
The reviewer stated that it feels like the DOE is supporting Cummins' product development. The reviewer thought that Cummins should be paying for more of this work with internal funds. [DOE Program Clarification: Cummins provides 50% cost share for this project.]

Presentation Number: acs099
Presentation Title: Improved Fuel Efficiency through Adaptive Radio Frequency Controls and Diagnostics for Advanced Catalyst Systems
Principal Investigator: Alexander Sappok (Filter Sensing Technologies, LLC)

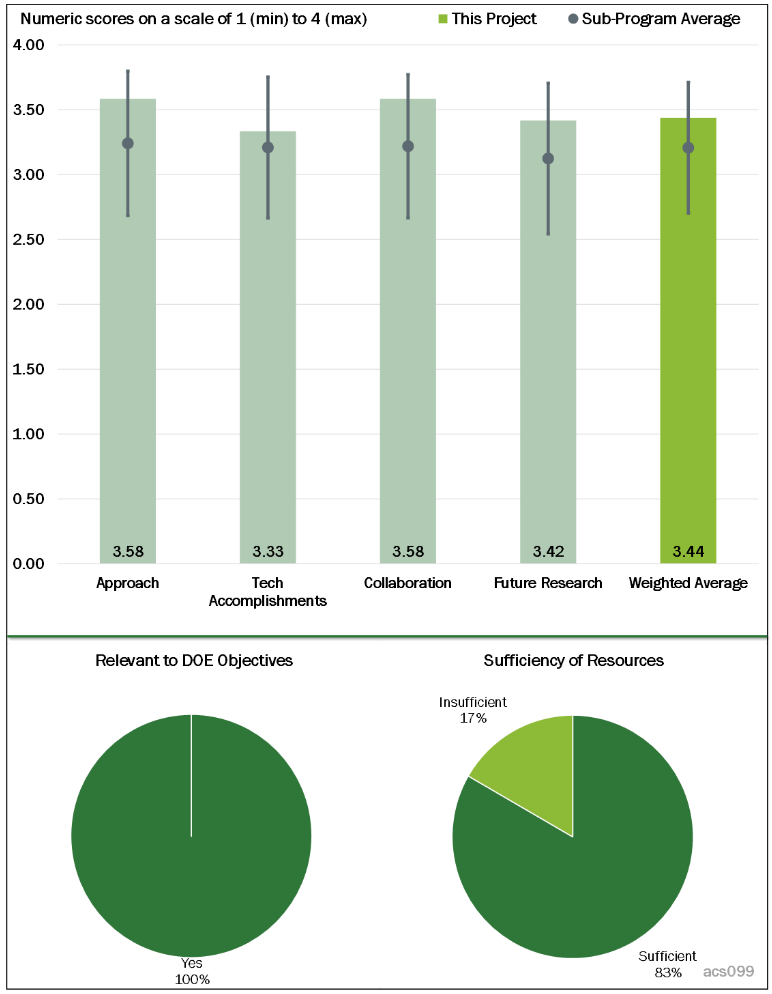

Figure 1-34 - Presentation Number: acs099 Presentation Title: Improved Fuel Efficiency through Adaptive Radio Frequency Controls and Diagnostics for Advanced Catalyst Systems Principal Investigator: Alexander Sappok (Filter Sensing Technologies, LLC)

Presenter
Alexander Sappok, Filter Sensing Technologies, LLC

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked that this is an excellent work plan with significant partners.

Reviewer 2:
The reviewer said that this is a novel approach to catalyst sensing and exactly the type of project that DOE funding should support.

Reviewer 3:
The reviewer commented that one sensor with a radio frequency (RF) concept that works for many kinds of applications (NH_3, O_2, HC and PM) is something really exciting. However, it is not clear to the reviewer if the hardware and software would be the exact same when applied to different measurements. For example, the reviewer questioned whether a RF sensor used for PM could be exactly the same as one used for NH_3, etc. If so, this reviewer suggested to state it, which is a great achievement of this program.

Reviewer 4:
The reviewer remarked that this is an interesting application of sensor development for enabling effective aftertreatment management.

Reviewer 5:
The reviewer noted that the approach builds on past work on the DPF sensor which was mostly successful. The reviewer stated that this is a diverse and highly capable team and generally a novel sensing method.

Reviewer 6:
The reviewer stated that detecting the catalyst state in real time will make engine calibration and controls much more effective. That should improve fuel efficiency and perhaps catalyst thrifting. For TWC systems, the reviewer remarked that calibrators have estimates of the OSC of the catalyst depending on the history of the catalyst. This approach can give them a real-time measure of the OSC. The reviewer noted that the real-time measure of the OSC could refine the calibration on the fly. Refining the engine controls on the fly should fine tune the emissions in order to get better fuel economy. The reviewer commented that essentially, the same is true for the SCR catalyst; however, the effect on the calibration will be different, but should provide the same benefits. The reviewer concluded that this technology provides information for engine calibration that was not previously available.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer stated that significant progress has been made in demonstrating that the sensing approach shows that this technology has potential.

Reviewer 2:
The reviewer noted that the decision point criterion has been met and progress on other fronts also looks very good.

Reviewer 3:
The reviewer remarked that the results are encouraging. The vehicle fleet test is on the way and it would be very interesting to the reviewer to see how the sensors respond to real world driving condition. However, there is no need to the parent company (CTS) in Slide 9. The reviewer remarked that this would make the program too commercial and dilute its excellent achievements.

Reviewer 4:
The reviewer remarked that the project is making good progress. The reviewer also acknowledged that the project is working on a no cost extension due to some difficulties in getting the testing done.

Reviewer 5:
Significant early feasibility established of detection of NH_3 storage on catalyst. Progress is evident for the TWC application, which is significant for a new project.

Reviewer 6:
The reviewer noted that the technical accomplishments are those which are needed to move this technology along. The weakness is the effect of H_2O on the catalyst state. The reviewer stated that this is true for the SCR and TWC. Water storage either left over from the previous use or ambient H_2O will have an effect on the signal. It is unclear to the reviewer if those effects have been appropriately accounted for.

The reviewer said that testing the sensor technology on a range of engines with different displacements is attractive because each of these engines will have different calibration needs. Fleet testing is especially encouraging to the reviewer.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there is an outstanding diversity of partners involved and their roles were clearly defined.

Reviewer 2:
The reviewer noted that there is excellent collaboration with other team members. The project clearly defined their roles and how these members help the program (Slide 22).

Reviewer 3:
The reviewer stated that the project has a good mixture of collaborators which can help take this concept to application.

Reviewer 4:
The reviewer noted that the project is collaborating with the appropriate stakeholders

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the project has moved to demonstration which gives evidence of project success. The reviewer observed that the project will be complete in about seven months and that the future plans seem a bit optimistic for the amount of time left.

Reviewer 2:
The reviewer remarked that the project appears to be on track to complete its tasks within the additional time allotted through the no cost extension. The results of its final round of testing will be the most important data to see.

Reviewer 3:
The reviewer noted that the project has a solid path forward of modeling, bench work, engine validation, and eventually decisions on its commercialization potential.

Reviewer 4:
Regarding efficiency to stay aligned with DOE mission, the reviewer noted that future work should focus on developing estimates of overall system efficiency gains via RF control and quantifying system-level fuel savings.

Reviewer 5:
The reviewer observed that future work is defined in Slide 23. The reviewer stated that it would be better if the project can talk more about control and how this control with open or close loop can help the program.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that sensor development is an important aspect of the total energy flow management within the vehicle. This sensor could be very helpful in terms of optimizing the interface between the engine and the exhaust gas aftertreatment system. The reviewer remarked that the fact that the project is engaged in fleet testing indicates that there is interest in evaluating the technology’s viability in market application.

Reviewer 2:
The reviewer observed that new sensing methods improve function of aftertreatment systems, reduce energy penalty, and possibly reduce cost for better market acceptance.

Reviewer 3:
The reviewer asserted that improved sensing systems can have direct and indirect impacts on vehicle fuel consumption.

Reviewer 4:
The reviewer commented that improved aftertreatment system efficiency is the goal, which aligns with DOE's petroleum displacement objective.

Reviewer 5:
The reviewer remarked that by providing additional data for the engine controls, this project allows tighter control over the emissions and consequently will minimize the fuel economy penalty.

Reviewer 6:
The reviewer stated that yes, if it can show how this program can improve the aftertreatment and engine performance and save fuel. The reviewer observed that it looks very promising, but has not demonstrated that yet.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the project has made good progress at the current funding level and appears to be on track to achieve the overall objectives.

Reviewer 2:
The reviewer noted that it appears as if the researchers will be able to meet the deliverables with the budget supplied.

Reviewer 3:
The reviewer stated that yes, the project seems to have enough resources to meet the program needs.

Reviewer 4:
The reviewer is unsure if the project has sufficient resources and time to complete the fleet testing.

Presentation Number: acs100
Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II
Principal Investigator: Justin Yee (Daimler Trucks North America)

Presenter

Justin Yee, Daimler Trucks North America

Reviewer Sample Size

A total of seven reviewers evaluated this project.

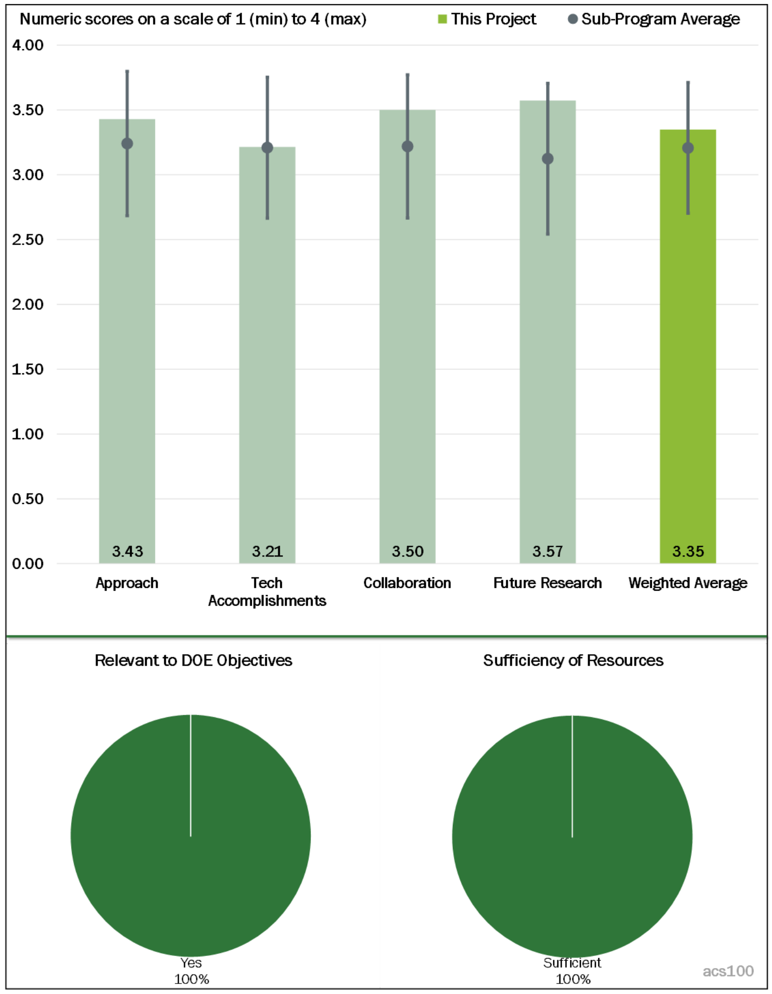

Figure 1-35 - Presentation Number: acs100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II Principal Investigator: Yee, Justin (Daimler Trucks North America)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted the freight efficiency target of 115% over the 2009 Cascadia baseline. As the reviewer understands, the 2017 Cascadia has technologies that leave 34% remaining as indicated on Slide 4. The reviewer stated that it would be reasonable to assume the seven or so vehicle technologies laid out in Slide 5 have a good chance of contributing to the targeted efficiency, as well as the engine and drivetrain approach shown in both Slide 4 and in Slide 12.

Reviewer 2:

The reviewer stated that the plan appears to be sound and should achieve program goals. Though the presentation focused mostly on the powertrain, the reviewer stated that it would have been nice to hear a little more on the vehicle side.

Reviewer 3:

The reviewer noted that even though the project was just getting started in 2017, the project had a solid approach with “Potential Topics for Investigation” mapped, considering mild electrification (48 Volt) and potential electrification of parasitics as well as strong focus on aerodynamics while using tools and approaches from SuperTruck I.

Reviewer 4:

The reviewer noted SuperTruck I had been a very successful project for Daimler reaching 115% of the baseline vehicle. This project is an attempt to exceed that. The reviewer was concerned that some improvements would not be considered because Daimler already has a success with those technologies in the first SuperTruck project.

High fuel efficiency (FE) tires will be used on this project, but there is no collaboration to improve the tires specifically for this application. The reviewer noted that tires have a significant effect on the fuel economy and expected a more aggressive approach would have been taken to refine and improve the tires specifically for this project.

Reviewer 5:

The reviewer noted that this project represents a continuation of the activities of SuperTruck I. It is a more aggressive pursuit of the technologies that were worked on in SuperTruck I, and technologies that were "left on the shelf" during that program.

Reviewer 6:

The reviewer believed that the overall approach to the project was comprehensive. This reviewer noted specifically that the program's goal of a three-year payback time as a guidance demonstrates the project team's strong intention to make the technology commercially viable. However, this reviewer stated that the program is conservative with 115% improvement as a goal, and that this goal had already been achieved in the SuperTruck I program; therefore, the project team should do better under this program.

Reviewer 7:

The reviewer stated that though the project has some potential, though there was only a very minor emphasis on weight reduction.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the plan and preliminary approach established for new project were good.

Reviewer 2:

The reviewer stated the progress is okay considering time since started, and that the project is just getting underway.

Reviewer 3:

The reviewer thought that the program was just getting started and was still in the early stages of defining the sub-program leaderships, organizational structure and timelines. Therefore, the project had shown limited technical progress at this time.

Reviewer 4:

This reviewer questioned if the limited engine improvements on this project were sufficient payback items. The reviewer also noted that the focus is strongly on the peripheral technologies. The reviewer added that reducing engine friction effects in the engine may be a consideration for the project to attain its goals.

Reviewer 5:

The reviewer thought the project was planned very well, however, the stated barriers seem largely internal (budget, resources, etc.). This reviewer also noted that the staged timeline seems reasonable and that the cooperation with ORNL on engine evaluation was impressive.

Reviewer 6:

The reviewer believed that the technical road maps, for example, in Slide 5 for vehicle and Slide 12 for powertrain, should be more specific. The project team mentioning all possible technologies was too vague, which may show lack of confidence. The reviewer noted that the project team's previous SuperTruck I program made striking progresses.

Reviewer 7:
The reviewer stated that it was difficult to evaluate because it was so early in the project (only 5% of the program completed).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the program consisted of a large team with representation from suppliers, national laboratory and universities and that the project was well done in this area.

Reviewer 2:
The reviewer stated that there was a strong team with key members identified at leading Universities, Tier 1 aftertreatment, tire and driveline, suppliers, national laboratories and fleet level.

Reviewer 3:
The reviewer believed the program had very good partnerships and that this would help lead the program to a successful outcome.

Reviewer 4:
The reviewer stated that the project team had engaged many relevant stakeholders.

Reviewer 5:
This reviewer believed that the project has a comprehensive team, which included a large fleet operator.

Reviewer 6:
The reviewer commented that OEM supplier relationships dominated the collaborations for the project and that it was not clear where Ohio State University and UM fit into the project plan.

Reviewer 7:
The reviewer stated that it seemed as though the main collaborations are on the powertrain side as shown in the org chart (ORNL, UM, Bosch). The reviewer then noted that most of the vehicle work was internal to Daimler Trucks North America, adding that this was not a concern at this stage in the project. The reviewer commented that the diversity of partners was adequate for the project, and hoped that these partners are leveraged as the project proceeds; not only to achieve project success, but to enhance technology transfer, which is a key objective of a publicly financed program like this.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the future plan for the program was excellent—continue scoping to lay out the game plan. The reviewer further noted there were many opportunities in this program and the reviewer was confident the stretch goal would be reached.

Reviewer 2:
The reviewer commented that the research activities as planned were carefully thought out and integrated so that the program would look for synergistic opportunities. The reviewer then summarized that the project team was building on the experience gained from SuperTruck I.

Reviewer 3:
The reviewer believed that there was a solid preliminary roadmap for future plan, considering the January 2017 start.

Reviewer 4:
The reviewer stated that the future work described in the presentation (Slide 8 and Slide 9 for vehicle and in Slide 16 and Slide 17 for powertrain) clearly identified the barriers and the future research needed.

Reviewer 5:
This reviewer believed that the plans were well-described and comprehensive.

Reviewer 6:
The reviewer said that nearly everything presented was future research because the project just started. The reviewer added that the pathways forward look to be clearly defined, though the presentation felt like the reviewers were basically reviewing the proposal.

Reviewer 7:
The reviewer believed that Daimler has clearly learned from earlier SuperTruck I experience and had a clearly defined path for SuperTruck II. This reviewer was concerned that "out of the box" thinking will suffer because of that.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer believed that demonstrating another 25% reduction in fuel consumption (84%-115% freight efficiency) was certainly relevant to the DOE mission. The reviewer stated that many of these technologies would hit the market within the EPA Phase 2 HD GHG timing (2027).

Reviewer 2:
The reviewer commented that the program goals of 115% freight efficiency improvement and 55% engine BTE directly target the DOE petroleum displacement objective.

Reviewer 3:
The reviewer stated that the project scope to meet SuperTruck II goals was in alignment with DOE objectives.

Reviewer 4:
The reviewer noted that this program clearly supports DOE primary objectives

Reviewer 5:
The reviewer stated that the SuperTruck II program clearly addresses the reduction of reliance on oil. The reviewer also commented that to make the project successful, the OEMs will need to incorporate the technologies developed from the project into their commercial product.

Reviewer 6:
The reviewer noted that there was the potential for much learning to occur in terms of how advanced technologies interact when used together on a vehicle, and the potential and possible timelines for introducing these technologies into market products.

Reviewer 7:
The reviewer believed that this project focused on largest fuel use sector of freight movement, which is also the fastest growing GHG contributor in transportation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer was concerned if the funding would be sufficient to be able to compete for resources within each of the companies included in the program.

Reviewer 2:
The reviewer believed that this was a good level of funding to achieve more than incremental improvement, and that the project had substantive funding and goals.

Reviewer 3:
The reviewer commented that the project team had all they need to achieve the program goals

Reviewer 4:
The reviewer believed that it was too early to see issues.

Reviewer 5:
This reviewer noted that if was difficult to evaluate (so early in the project).

Reviewer 6:
The reviewer said that it is a lot of money, and expectations will be high.

Presentation Number: acs101
Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency
Principal Investigator: Pascal Amar (Volvo)

Presenter

Pascal Amar, Volvo

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

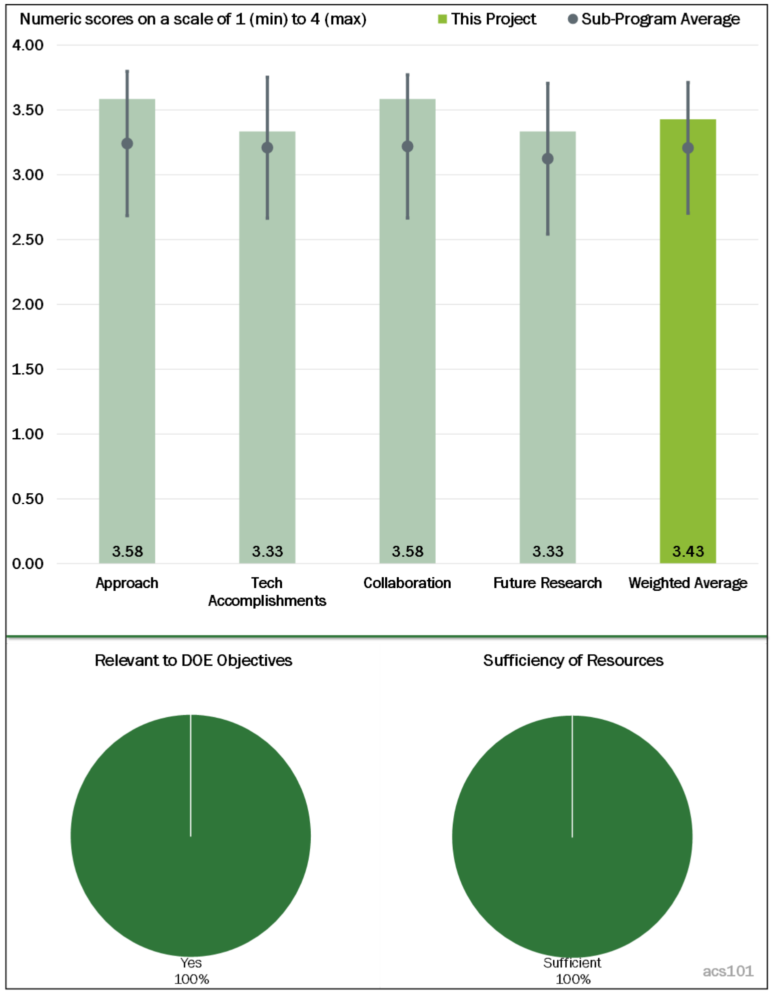

Figure 1-36 - Presentation Number: acs101 Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Amar, Pascal (Volvo)

Reviewer 1:

The reviewer commented that learning curve from SuperTruck I has had a major impact on the approach for SuperTruck II and that the approach to this project was much more like a new vehicle development program than an exercise in engineering learning. This reviewer further noted that the strong focus on predictive energy management was a strong plus for this program. This focus has shown that a downsized engine allows the project team to operate within the “sweet spots” defined by the energy management system.

The reviewer stated that there was no apparent plan to leverage the hotel batteries to improve the cruising fuel economy. This reviewer would have liked to have seen projections of when the hotel batteries would reach full charge and if the batteries were charged before needed. This reviewer noted that if the hotel batteries were at full capacity before needed, then there is energy being wasted.

Reviewer 2:

The reviewer stated that this project was similar to the other SuperTruck II programs, and is building on the project team’s previous successes and trying to push further product efficiencies.

Reviewer 3:

This reviewer noted the Interesting and likely effective emphasis on energy management and weight reduction. The reviewer also commented that there was not much emphasis on aerodynamics R&D, which may be at diminishing returns. The reviewed noted that though several options were still under consideration for 55% path, it was good to see that a couple have been downselected.

Reviewer 4:

This reviewer recognized that in addition to the typical powertrain and vehicle improvements, the team had captured another project focus, which is that of energy management. The reviewer further noted that though the other project teams have versions of energy management, Volvo set the energy management focus aside as a separate item, indicating a greater emphasis would be placed on this topic. Also, the reviewer saw that the analysis of hotel load and drivability was unique.

Reviewer 5:

This reviewer stated that the program plan was clearly laid out. Then the reviewer stated that because the project is in the early stages (15% completion), evaluation of the approach was difficult.

Reviewer 6:

This reviewer stated that though the overall approach taken was technically sound and comprehensive, there was no clear identification regarding what kind of the engine would be used for the program (as indicated in Slide 22). The reviewer then raised a level of concern due to his opinion that there was no reason to believe that, at this stage, a novel engine can bring any value to the program.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the analyses were well underway, with downselecting in progress. The energy management analyses are impressive, as is the lightweighting. This reviewer summarized that the analyses that have been performed have been applied to balancing the vehicle loads with a downsized powertrain, and that this approach seems more advanced than the other SuperTruck II projects.

Reviewer 2:

This reviewer stated that SuperTruck I was clearly a success, and now there is a clear plan to project the technologies from SuperTruck I into new applications, though those technologies will need to be refined to reach the goals for SuperTruck II.

Reviewer 3:

This reviewer noted that because the program was just beginning and that currently the project leaders were developing the teams, timelines and organizational structure.

Reviewer 4:

This reviewer stated that the project had interesting and effective use of SuperTruck I efforts for exploratory work on SuperTruck II.

Reviewer 5:

This reviewer stated that it was too early in this project to properly evaluate the accomplishments.

Reviewer 6:

This reviewer questioned why Volvo would still spend time on a novel engine development. This reviewer then commented that the introduction of solar panel on the roof of cab was something new, but it was not clear if the trailer would use the energy from the solar panel as well.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer noted that the project had very well-developed team/partnerships.

Reviewer 2:

The reviewer commented that the team consisted of all key partners from suppliers, national laboratories to universities, and that the team was impressive.

Reviewer 3:

The reviewer stated that the team was in place with an impressive list of players, and that some work on the project has started.

Reviewer 4:

This reviewer noted that this was an OEM plus supplier development project and did not understand what input UM would have to this project.

Reviewer 5:

As a minor point, this reviewer recommended explaining partners and their roles early in the presentation or at each point in the description instead of near the end. The reviewer commented that the fleet partner, the ultimate customer and user of the truck, could be making contributions and is perhaps doing so. The partners are not really mentioned in the plans or progress.

Reviewer 6:

This reviewer noted that there was an overlap between the collaborators in this project with another SuperTruck II team. When this was pointed out the audience was told that program management is aware of the overlap of partners with other projects, and that DOE was monitoring the situation for potential conflicts.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that because this project had just begun, most of the presentation was on future work, and the future work looked like a good, comprehensive plan. This reviewer then commented that the concept downselect process looks to be working well to define the pathway forward for this project.

Reviewer 2:

This reviewer noted that the project was well laid out, and that it was now time for the work to start.

Reviewer 3:

The reviewer summarized that this project has a clear direction and very definable deliverables though the reviewer was worried that the project had a development structure that was too rigid and could lose the benefit of unexpected technology opportunities.

Reviewer 4:

The reviewed commented that the discussion of future work was a bit disorganized and clouded with ongoing technical progress. The reviewer stated that the future work would basically follow a good plan, but the presentation should have been more explicit on major future decisions and outcomes. This reviewer was surprised that aerodynamic improvement was essentially not discussed, but was interested to hear more on the details of connectivity exploitation. Finally, this reviewer noted that the advanced novel engine was not discussed this time.

Reviewer 5:

This reviewer commented that the downselecting process had started, and that it was most critical to choose an engine approach, because in the reviewer's opinion everything else is dependent on this. This reviewer would like to see a unique approach with significant downsizing.

Reviewer 6:
The reviewer commented that although Slide 22 provided a sense of the future work, the program does not provide a specific section to talk about the future research. Also, this reviewer was surprised that the future work still considers a novel engine design as a possibility because the effort for this change would impact the overall project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that SuperTruck programs are targeted to significant fuel savings for materials transport by Class 8 trucks, and because over-the-road freight hauling consumes approximately 20% of the oil consumed in the United States, improving freight hauling efficiency can have an appreciable payback.

Reviewer 2:
The reviewer referenced comments made for the other SuperTruck programs.

Reviewer 3:
The reviewer noted that the project strives to achieve higher freight-moving efficiency, and that HD vehicles are fastest growing fuel user and GHG source.

Reviewer 4:
The reviewer commented that SuperTruck II was key to reducing freight energy demands, and that Volvo has some unique approaches that feed into reducing freight energy demands, with an emphasis on commercialization.

Reviewer 5:
The reviewer stated that a 55% engine BTE demonstration and 120% stretch goal on vehicle efficiency improvement are directly aligned with the DOE petroleum displacement objective.

Reviewer 6:
This reviewer confirmed that the program specifically targets the program objectives defined by DOE.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer assumed because Volvo has developed a project plan that the project team must find the budgeting sufficient.

Reviewer 2:
This reviewer stated that the project team should have sufficient funding to achieve the program goals.

Reviewer 3:
This reviewer believed that because no issues were brought up in the presentation, there must be sufficient funding.

Reviewer 4:
The reviewer said big money, high expectations.

Reviewer 5:
The reviewer stated that it was difficult to evaluate at this very early stage of the program.

Reviewer 6:
This reviewer had no comment.

Presentation Number: acs102
Presentation Title: Cummins/Peterbilt SuperTruck II
Principal Investigator: Michael Ruth (Cummins)

Presenter
Michael Ruth, Cummins

Reviewer Sample Size
A total of seven reviewers evaluated this project.

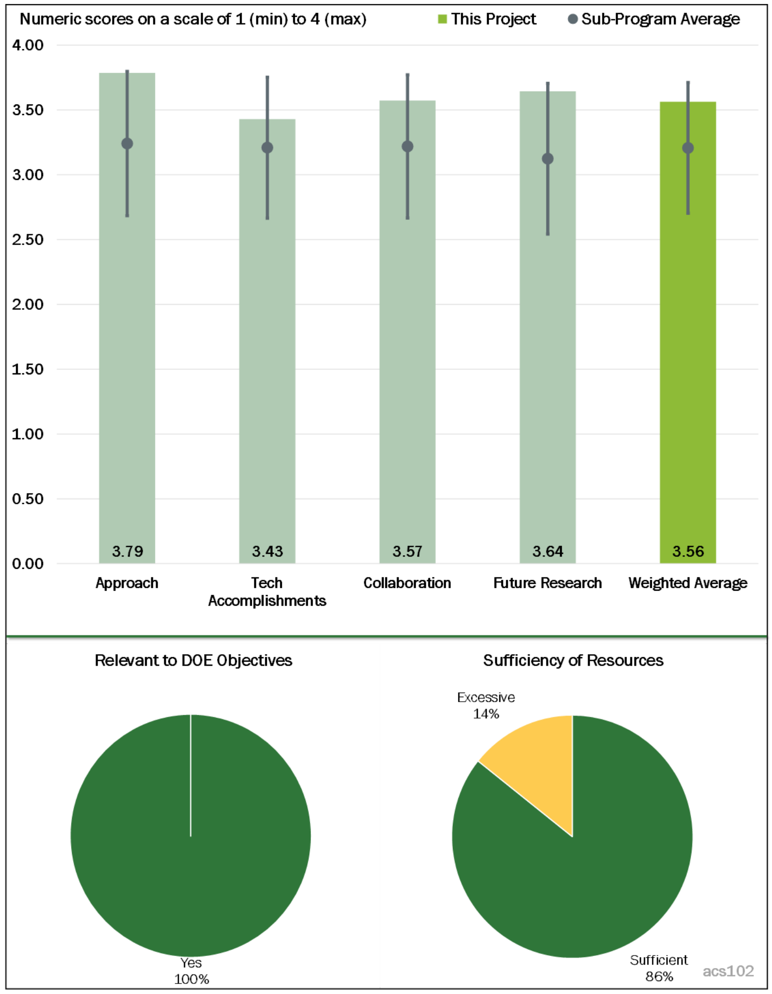

Figure 1-37 - Presentation Number: acs102 Presentation Title: Cummins/Peterbilt SuperTruck II Principal Investigator: Ruth, Michael (Cummins)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer appreciated that the project team separated the powertrain development from the aerodynamic development. The reviewer commented that this approach gives a fresh set of eyes and opinions to balance the project. Further, the reviewer recognized that Cummins is "world class" in powertrain development and rightfully is focusing on that part of the project. The reviewer stated that Cummins had presented justification for each of the engine development choices, and that was confidence building for the success of the project.

This reviewer also recognized that the Peterbilt aerodynamics portion of the project was equivalently well justified. The reviewer noted that the yaw mitigation portion of the project was not one the reviewer had been previously exposed to; however, it was a reasonable approach and is clearly an appropriate target for fuel savings. The reviewer noted that the focus on reducing tire loss was also important, and that the partnership with Bridgestone brings in a high level of expertise to reduce the overall rolling resistance.

The reviewer summarized that there was a clear understanding of regulatory requirements in both parts of the program. Though it was not clear to the reviewer that each of the improvements would benefit equally short haul and long-haul applications, it would have been helpful to categorize the focus areas into long hauler short haul improvement areas.

Reviewer 2:
The reviewer noted that the approach was very thorough, including an analysis of routes and drives cycles and essentially every reasonable aspect of truck technologies and systems for reducing fuel consumption. Further, the reviewer recognized that work on tires, where one might have concluded a point of diminishing returns, was commendable. The reviewer stated that inclusion of weight reduction is on target, where this part of

project is sometimes mistakenly assumed to be of no value except for weight-limited situations. Finally, this reviewer commented that the fleet/customer partnership was a strong addition to the project.

Reviewer 3:

This reviewer noted that the project had just started in 2016. The reviewer believed that there was an excellent management approach to promote cost effective solutions considering three-year payback and customer feedback for payback considerations. The reviewer viewed the project team's technical approach as excellent with engagement of key suppliers to develop productive solutions (transmission, driveline, WHR). The reviewer also appreciated the aggressive approach to integrate a WHR system as the cooling system.

Reviewer 4:

The reviewer commented that the Cummins/Peterbilt team has done impressive analyses to achieve another 56% freight efficiency improvement to get to 115% over the original baseline. The reviewer recognized that the effort on the base engine was a good start, and quantification of the opportunity with the HEV analysis was impressive. Further, the reviewer stated that on the vehicle side of the project the aero, tire resistance, and speed control work efforts provide excellent opportunities for further improvements.

Reviewer 5:

The reviewer stated that the project had a well-defined approach, with a good tie into the 55% engine BTE enabling technologies efforts. However, the reviewer noted that was too early (10% completed) to determine if any course corrections are appropriate.

Reviewer 6:

This reviewer stated that the project team's approach was comprehensive, and provided a fairly detailed technical scope, road map with quantitative measurements. The reviewer further noted that targeting a minimum of 125% improvement was impressive, if the project can achieve it. The reviewer recognized that prioritizing the solutions with three-year payback is encouraging, and summarized that this was a very strong program.

Reviewer 7:

This reviewer simply commented that this project was a continuation of efforts from SuperTruck I.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that progress had been reported in the tire and chassis portions of the vehicle, and also that the energy recovery, friction reduction, and engine design/analysis were competed. Further, the reviewer commented that this effort was completed in just the first few months of the project, so the reviewer believed that the project was off to a very good start.

Reviewer 2:

This reviewer noted excellent progress with clear definition of program goals, reasonable allocations of improvements to subsystems and initial analysis to support.

Reviewer 3:

The reviewer noted that though the technical accomplishments were mainly analytical, the analysis provided excellent direction. The reviewer noted that breaking down the engine opportunities shows high probability of demonstrating 55% BTE, and that the results on HEV requirements (electrical storage and motor requirements) and ring friction reduction are excellent starts. The engine layout plan is complete. The route evaluation focuses the effort on bang for the buck. On the vehicle side, the reviewer commented that the aerodynamic analyses were very impressive, especially concerning the impact of vehicle yaw with respect to air flow. The reviewer believed that the weight reduction goals seem reasonable (500 lbs. from the tractor, 500 lbs. from the trailer), and the results and initiation of the tire side of the project were also impressive.

Looking at the HEV aspect, the reviewer recognized that engine braking was chosen for slowing the vehicle in steeper slopes and wondered if the team evaluated ultra-capacitors (UC) teamed with a smaller battery, as part of the 3-4 kWh storage requirements. The reviewer noted that UCs can soak up that high power for more efficient storage.

Reviewer 4:
The reviewer believed that the SuperTruck I project was a solid success, and that the direction this project was headed has been well defined. The reviewer saw that establishing the direction in the early stage of the project was a significant accomplishment.

Reviewer 5:
This reviewer noted that with less than a year of work, the project team had performed analysis, developed some tools, and conducted preliminary designs. However, the reviewer also commented that because the program has spent nearly $1 million spent, this reviewer expected a little more achievement.

Reviewer 6:
The reviewer recognized that the program was just starting and had establishing the teams, organizational structures, time lines, and procuring parts.

Reviewer 7:
The reviewer noted that progress has been made on the new engine platform, and that the expected benefits shown on Slide 10 were detailed. However, the reviewer was confused on the WHR benefit, which only shows 0.2% benefits, and the reviewer believed that this benefit needed to be larger in order to achieve the program goals.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent collaboration with a vehicle OEM, an engine OEM, transmission supplier, Tier 1 suppliers and fleet.

Reviewer 2:
The reviewer said that the team is off and running. The route evaluation with the NREL and Walmart is exceptional and guides the program for most impact. Bridgestone has started on tire improvements. Eaton is part of the drivetrain team, and Johnson Matthey on aftertreatment. Peterbilt is well-equipped to do the vehicle side and coordinate the efforts.

Reviewer 3:
The reviewer stated that the project seems to have a good team.

Reviewer 4:
This reviewer noted that Walmart’s participation was a strong feature because Walmart had been exploring advanced technologies themselves.

Reviewer 5:
The reviewer noted that Purdue University and NREL were mentioned in the presentation, but are not listed as partners/collaborators. The reviewer questioned if there was a reason for this, such as the size of their role. The reviewer summarized that the rest of the team looks strong, and including a trailer manufacturer in SuperTruck II is an excellent addition.

Reviewer 6:
The reviewer believed that the collaboration seemed to lack participation from academic institutions and national laboratories, and was concerned that this might limit the innovation elements of the technology development.

Reviewer 7:
The reviewer believed that the team only consists of industrial partners, and there are no partners from universities or the national laboratory system shown on Slide 2, although Purdue University was mentioned in Slide 18.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the plan was in place and looks excellent. The reviewer recognized that the project was focusing on the big items, such as combustion, aerodynamics, and rolling resistance, and believed that the HEV part was also exciting, and the layout and approach seems reasonable.

Reviewer 2:
The reviewer noted that specific plans for work are already in place, for both the powertrain and the vehicle. The reviewer summarized that the project team seems to be well on their way to identifying specific technological approaches, and have made estimates of the expected benefits.

Reviewer 3:
The reviewer noted that the technical plan was comprehensive and paths appear sound. The reviewer also commented that there was good attention to commercialization potential, and this was where regulatory issues were often involved.

Reviewer 4:
This reviewer noted that most of the presentation was on work started and future work because this project just got started. The reviewer then stated that the proposed future work looks good.

Reviewer 5:
This reviewer stated that the project had a solid preliminary roadmap of future activities to achieve targets.

Reviewer 6:
This reviewer questioned how well coordinated the two research projects would be.

Reviewer 7:
The reviewer noted that the entire presentation did not provide a specific section to talk about future research, even though future work direction can be interpreted from some of slides. Therefore, the reviewer believed that the presentation was not very well organized in this sense.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer believed that the project was absolutely relevant with the clear program road map to achieve the program objective.

Reviewer 2:
The reviewer noted that there would be a lot of learning about the interaction between different technologies when integrated onto a vehicle from this project, as well as the technologies' potential benefits, and the potential for getting those technologies into the market.

Reviewer 3:
The reviewer commented that demonstrating 36% fuel consumption reduction from the SuperTruck I program certainly would be relevant to DOE objectives, and that the team has a good start in commercializing the technologies.

Reviewer 4:
The reviewer believed that the project planning seemed to be complete and there was no evidence that there were insufficient funds.

Reviewer 5:
This reviewer noted that 55% engine BTE and 125% FTE improvement are directly in line with DOE's objective for petroleum displacement.

Reviewer 6:
The reviewer identified that this project pertains to Class 8 trucks, which is the category of largest freight fuel consumer and overall HD vehicles are fastest growing fuel use sector.

Reviewer 7:
The reviewer noted that the project scope to meet SuperTruck II goals which has been engineered to meet DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer believed that both the DOE and OEMs have the SuperTruck I experience in hand so that the cost of the project should be well understood.

Reviewer 2:
The reviewer commented that these projects are heavily cost shared by the industry partners, so the achievement potential per government dollar is satisfactory.

Reviewer 3:
The reviewer commented that no requests or issues have been raised by the project team regarding project funding.

Reviewer 4:
The reviewer noted that the project had a large amount of funding and that the expectations for success would be high.

Reviewer 5:
The reviewer believed that the project had a good level of funding to achieve more than incremental improvement, and that the project had substantive funding and goals.

Reviewer 6:
The reviewer pointed out that Cummins also has another DOE program on 55% BTE, making this program resource significantly more as compared to their competitors. In addition, the engine program also shows that Cummins has all they need to achieve the program goals.

Presentation Number: acs103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer–SuperTruck
Principal Investigator: Russ Zukouski (Navistar)

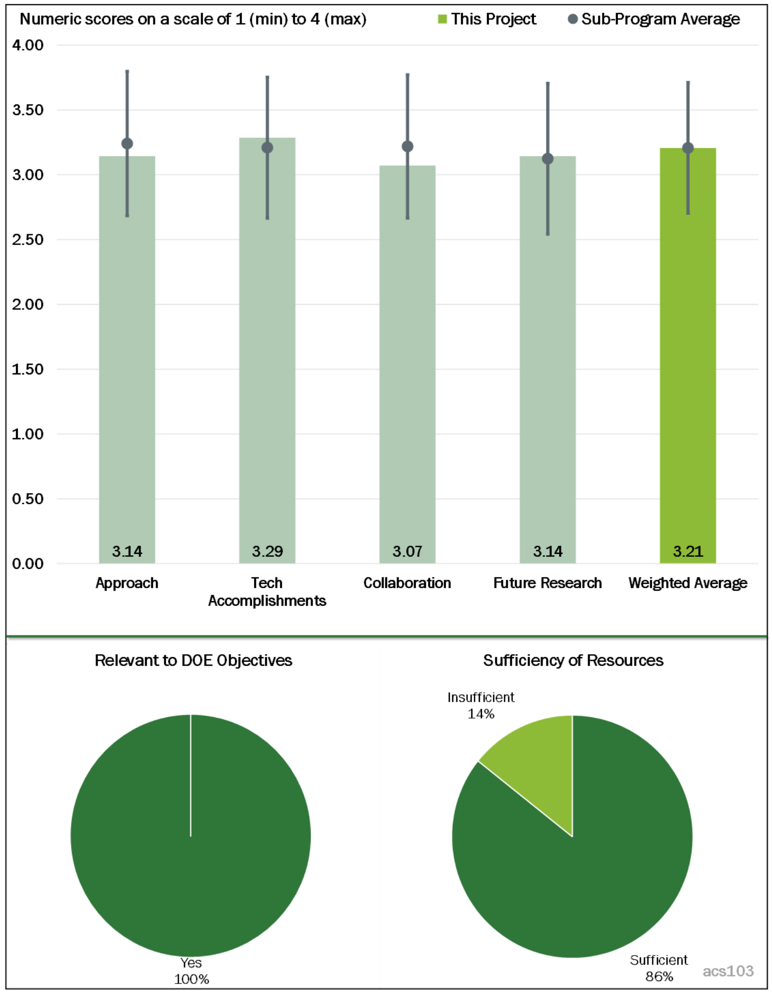

Figure 1-38 - Presentation Number: acs103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer—SuperTruck Principal Investigator: Russ Zukouski (Navistar)

Presenter

Russ Zukouski, Navistar

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted a good approach to fuel efficiency improvement through the scope of this project. Standard areas of combustion efficiency, friction, down-speeding for turbo efficiency and aero on target list. The reviewer further commented that is was a novel and potentially promising approach to consider a kinetic recovery system (KERS) for energy recovery in this application. The reviewer also noted that GCI development was new for industry so the value proposition and benefit should have preliminary characterization. (i.e., eliminate SCR, eliminate DPF, or efficiency gains greater than diesel).

Reviewer 2:

The reviewer believed that the approach presented was a systems approach, where multiple technology improvements and additions are utilized to meet the challenging goals of this SuperTruck II project. The reviewer noted that the multiple strategies were well coordinated by the project team, and that the team had diverse set of expertise which would be required for a project like this.

The reviewer noted that the presenter did not use the format for the VTO AMR presentation, and because of this, there are several aspects of the project that were unclear relative to the review criteria.

Reviewer 3:

The reviewer believed that the program had all of the key components to achieve the program goals, but was not sure why a GCI concept shown on Slide 10 was needed for this program. The reviewer was concerned that the GCI effort may divert the program focus and resources. The reviewer said that transient control and durability are two of many concerns; these can be extremely challenging to bring the concept into potential market place. The reviewer also noted that the program did not identify what the stretch goal was and listed only "XXX%." The reviewer stated that the project team should be more specific.

Reviewer 4:

The reviewer noted that going after a new approach GCI engine is very intriguing, unfortunately the approach presented by the project team appears to be a "kitchen sink" approach (i.e., put everything in that you can think of). This reviewer believed that the project team needed to reference the knowledge gained from the first SuperTruck program or the experiences of the other SuperTruck I programs. Also, this reviewer believed that there was not enough attention given to an improved tire technology, which was concluded as a very important aspect in the other SuperTruck II projects.

Reviewer 5:

This reviewer believed that the work listed for this project was a continuation and extension of the work the project team did for SuperTruck I.

Reviewer 6:

This reviewer was concerned that low-pressure EGR would be adequate on its own for meeting prevailing emissions regulations, and noted the need for some consideration and mention of after-treatment strategy, which would strengthen the presentation/project. This reviewer was also concerned that it was not clear whether GCI was a prime path or an alternative path to have ready.

Reviewer 7:

The reviewer noted that the project team approach to 100% freight efficiency improvement did not show the starting point (SuperTruck I final results), but the opportunities were defined for the engine and vehicle. This reviewer commented that unique approaches, like GCI, more light-weighting than others, stop/start, and integrated starter/generator HEV would be desirable and have interesting application paths. This reviewer noted that a comparison between the Navistar approach to HEV and the Cummins approach would be of value and that the technology choices seem to fit well with the North American vehicle market. This reviewer also commented that there was no mention of the MAN developments in Class 8 technologies and how MAN might participate.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the project team was off to a good start with advances in analyses, and that the engine friction analyses, air system, and WHR point the way for the project. This reviewer remarked that GCI was a different approach from the other projects and it would be interesting to see how GCI impacts the project. The reviewer also said that the vehicle analyses on aero, cooling, HEV, and axles was a good start.

Reviewer 2:

This reviewer stated that a good plan and preliminary approach had been established for this new project.

Reviewer 3:

The reviewer noted that the project was in the beginning stages; thus, not much progress has occurred. But, the reviewer remarked, what progress had occurred (mostly planning and implementing the team) has been good and thorough.

Reviewer 4:

The reviewer stated that though the project just starting, a good plan had been compiled.

Reviewer 5:
The reviewer commented that the project had just started, and that the effort to date has been largely organizational and managerial. The reviewer also noted that efforts to reduce the rolling resistance of the vehicle's tires was not listed a part of the team's effort to reduce fuel consumption.

Reviewer 6:
The reviewer noted that the project team had put together a project plan, but the plan seemed a bit hap hazard. Additionally, this reviewer commented that there was no budget shown on the slides.

Reviewer 7:
The reviewer commented although the program shows progress with modeling on the engine side, the project has a lack of specific details with quantitative and measurable results/milestones which should be shown on the roadmaps; milestones which are required to achieve the overall program goals.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer noted an excellent team had been assembled with a wide range of technical capabilities and commercialization potential.

Reviewer 2:
The reviewer noted a very solid and diverse team has been assembled, though a tire company would add strength.

Reviewer 3:
The reviewer remarked that the partners in the collaboration were interesting, but the coordination for the project seemed a bit loose.

Reviewer 4:
This reviewer was surprised that the project team did not have a tire company among their collaborators.

Reviewer 5:
This reviewer remarked on the progress of specific team members; ANL has started some GCI analyses, LLNL was doing aero, Bosch was doing the fueling system and Dana seemed to have started on axle evaluation with TPI doing some weight reduction. The reviewer noted that given the role of WHR in meeting the objective, perhaps the project team might want to find a participant in that area.

Reviewer 6:
The reviewer noted good coordination with national laboratories, a body fabricator, and an axle manufacturer. This reviewer further commented that collaboration could be improved with clear mapping of electrification function responsibilities for the project and that expertise in system implementation for KERS, hybrid, and 48 V areas were not implicitly obvious and would be important for project success.

Reviewer 7:
The reviewer noted that there was no university involvement in the project, which was a concern.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that an excellent plan had been compiled, and referenced prior comments on emission control path.

Reviewer 2:
The reviewer noted a solid preliminary roadmap/future plan to achieve targets.

Reviewer 3:
The reviewer commented that the approach was sound for addressing the challenging project goals.

Reviewer 4:
The reviewer stated that though the initiatives were very interesting, there was not much justification given for the selection of each initiative.

Reviewer 5:
The reviewer remarked that the project plans were still being formulated, but for those steps that were solidified the work has started. Then this reviewer questioned whether MAN would play a future role in the project.

Reviewer 6:
The reviewer noted that the description of the plans was very general, much more so than the other SuperTruck II teams, which had specific detail.

Reviewer 7:
The reviewer noted that the presentation did not provide a specific section to discuss future research. Although some future work can be sensed, piece-by-piece, from different slides, it was not a very well-organized presentation.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the project team was looking at advanced concepts in composite frames and significantly enhanced electrification on the vehicle, such as totally electrified heating, air conditioning, and ventilation, and coolant etc., and noted that this would be important learning.

Reviewer 2:
The reviewer affirmed that reducing fuel consumption from HD trucks will directly reduce petroleum use in the United States.

Reviewer 3:
The reviewer stated that the project supports the overall DOE program objectives when achieving DOE BTE and vehicle freight efficiency goals.

Reviewer 4:
The reviewer compared this project to SuperTruck I, with additional emphasis on affordability, which should help ensure real-world fuel savings.

Reviewer 5:
The reviewer said that if any of the individual parts are successful, it could be a breakthrough. That would be an enormous benefit and would take the project out of the straight forward engineering development that we are seeing from the other SuperTruck II projects.

Reviewer 6:
The reviewer observed that Navistar has a big vocational vehicle emphasis, and said that much of the technologies from this project could be pertinent there.

Reviewer 7:
The reviewer summarized that the project scope was developed to meet SuperTruck II goals, which has been engineered to meet DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that because the budget for this project was not shared during the presentation, budget related questions were difficult question to answer. However, the reviewer noted, with the high-risk initiatives of this project, it will be very hard to estimate costs and most likely the costs will be estimated low.

Reviewer 2:
The reviewer noted that the project had a large amount of funding and that the expectations for success would be high.

Reviewer 3:
The reviewer was hopeful that resources would materialize and enable the project to be successful.

Reviewer 4:
The reviewer found no funding issues yet.

Reviewer 5:
The reviewer believed that the project had a good level of funding to achieve more than incremental improvement, and that the project had substantive funding and goals.

Reviewer 6:
The reviewer commented that it was unclear how sufficient the resources for the project were, because the budget details were not provided in the presentation, and summarized that the team should provide more funding and budget information in future reviews.

Reviewer 7:
The reviewer noted that the project team should have all they need to achieve the program goals.

Presentation Number: acs104
Presentation Title: Cavitation Within Fuel Injectors: Development and Multiscale Validation of Euler-Lagrange based Computational Methods for Modeling Cavitation within Fuel Injectors
Principal Investigator: Emily Ryan (Boston University)

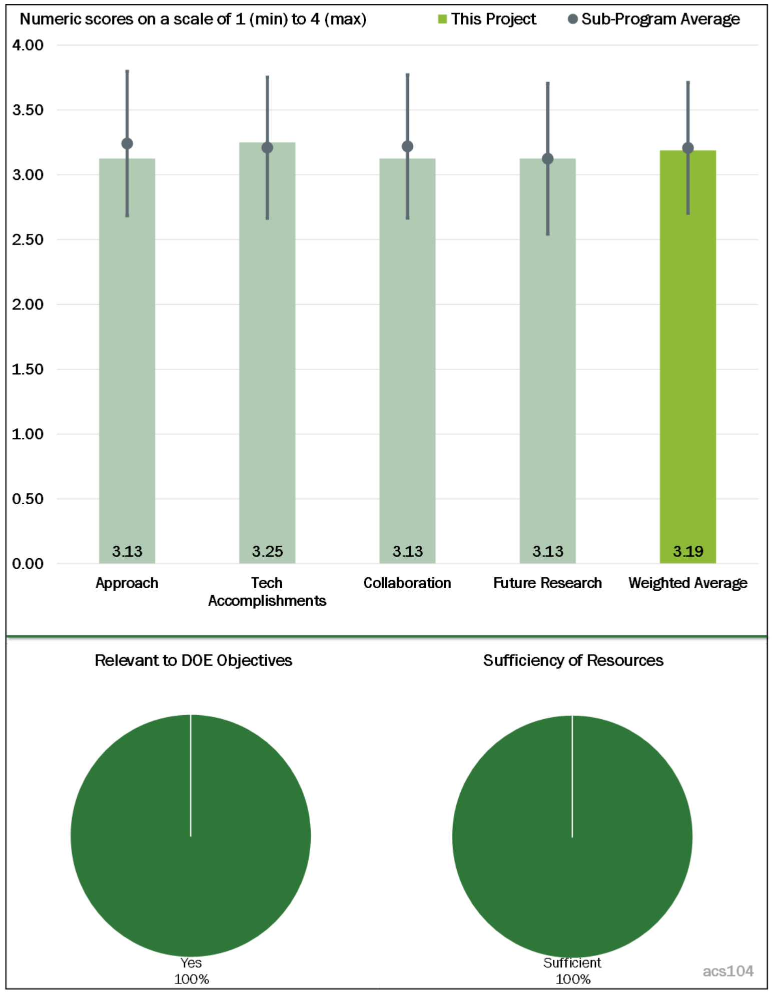

Figure 1-39 - Presentation Number: acs104 Presentation Title: Cavitation Within Fuel Injectors: Development and Multiscale Validation of Euler-Lagrange based Computational Methods for Modeling Cavitation within Fuel Injectors Prin. Investigator: Emily Ryan (Boston University)

Presenter

Emily Ryan, Boston University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that overall, the technical barriers are well identified and addressed milestones are feasible. It is a little unclear to the reviewer why the smooth particle hydrodynamics (SPH) is the method of choice over the conventional approach and what benefit/improvements are expected, given the anticipated computational cost increment.

Reviewer 2:

The reviewer commented that the approach over the past year has been to incorporate some new capabilities in KIVA that would enhance its usefulness. These include various approaches to modeling sub-processes and improving some computational aspects to make the solution to the governing equations more efficient and less time-consuming. The reviewer noted that the view is to improve engine efficiency and reduce harmful emissions.

The reviewer stated that KIVA has been around a long time and its virtue is open-source (e.g., unlike for-profit codes like CONVERGE) along with its significant capabilities. Efforts include employing LES to model engine flows, spray modeling grid generation capabilities, and multistep kinetics using Chemkin-pro. Fuels are multicomponent, especially surrogates. The reviewer commented that some discussion of how multicomponent effects would be addressed should be included. The reviewer asked how confident the PIs are that their property database for mixtures is robust. The reviewer also asked about mixing rules, etc., combustion chemistries of multicomponent liquid mixtures.

KIVA ostensibly relies on certain adjustable inputs (e.g., because it is not an ab-initio solver); the reviewer asked if that is right. The reviewer noted that it would be good to have a concise list of what needs to be adjusted for predictions and data prior to using KIVA.

The reviewer observed that a VOF approach for sprays is mentioned. The reviewer asked if the resulting simulation capability will be at the level of a code like RAPTOR (SNL) which simulates jet injection and its ultimate development into a spray.

Dynamic LES for capturing the transition from laminar to turbulent flow and a move away from the law-of-the-wall is being pursued which the reviewer noted is good.

The PI noted that the team has “validated with experimental data” the dynamic LES. The reviewer stated that this needs to be further discussed. The reviewer asked if this is the backward-facing step and isolated drop configurations mentioned in the proposal and if so, how are these configurations related to in-cylinder processes where KIVA is to be applied. The reviewer also asked what “validated” means, and asked if there is a targeted percent difference between simulation and experiment where “validation” would be considered as having been met, and what the contingency is if the agreement is poor. The reviewer would like the project to elaborate with details.

Reviewer 3:

The reviewer asked how SPH is exactly incorporated. The project mentioned VOF will be used in the simulation, but VOF is for the Eulerian scheme while SPH is a particle method. The method should be stated more clearly. The boundary conditions would appear the most difficult to handle; combining the methods is critical to understanding if this system will be successful.

Reviewer 4:

The reviewer remarked that as another reviewer noted, there are some issues related to the use of H_2O as a fluid in this project. Researchers are strongly urged to consider doing experiments, particularly the simple geometry experiments at Boston University, as well as computations using more realistic fuels or fuel-like fluids. The only other effort this project is aligned with is the neutron imaging at ORNL. The reviewer wonders why this work is not connected to the X-ray measurements being done at Argonne National Laboratory (ANL). It seems like those measurements are better suited to experimental demonstration of cavitation, which would be readily compared with these modeling efforts.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed steady and timely progress on the experimental side. Base setup on the computational side is ongoing. The reviewer is looking forward to seeing validation against the measurement data.

Reviewer 2:

The reviewer noted that progress in the first year seems fine, but efforts need to be ramped up to make the project more productive.

Reviewer 3:

The reviewer remarked that in the past year there are significant advances in improving KIVA’s capabilities. The improvements seem to be in the sub-models for things like turbulence, spray injection, transition from FV to FEM with significant improvements in computational time, grid generation, etc., and comparisons are shown for basic configurations like 3D flow past a cylinder and the pressure field around an isolated droplet. In the end, the reviewer stated that it was not clear how these significant capabilities will fold into the larger scheme of KIVA as an in-cylinder predictor. The reviewer noted that some discussion on this point would help.

The reviewer noted that efforts pursued include validation. For example, the PI notes that a dynamic LES approach is validated with experimental data for pertinent problems. The reviewer asked what problems are used for validation (cylinder, drop, etc.). The concept of validation should be expanded with discussions, but the reviewer asked what is being validated. The reviewer went on to also ask what happens if there are gaps and how the gaps close. The reviewer asked what metrics are used to assess if "validation" has been achieved.

For sprays, the PI notes "true multiphase flow modeling." The reviewer would like the PI to elaborate, and asked if this is like DNS for sprays.

The spray modeling is particularly exciting to the reviewer. The reviewer asked if the spray modeling in KIVA include multi-injector configurations. Other national laboratories are also developing robust computational capabilities for spray (e.g., RAPTOR); the reviewer asked how KIVA's capabilities compare with RAPTOR. The reviewer inquired if there is any collaboration with other national laboratories where their capabilities can further help inform KIVA's development of spray modeling.

The "surface tension test" on a 3D "static drop" seems interesting to the reviewer; however, it was not clear precisely what the PI was simulating. The reviewer inquired if it was evaporation, combustion, convection over the drop, etc. Flow symmetry seems to be assumed as a base case and a pressure field computed around the drop. The reviewer questions what the boundary conditions are. More clarity will help here for the reviewer.

Reviewer 4:

The reviewer noted that the models and experiments have been started. The reviewer observed that there remains a good deal of work to show that coupling SPH methods with an Eulerian Fluid solver is an effective process to incorporate the resolved SPH bubble dynamics into the Eulerian Finite Volume RANS Navier-Stokes solver of OpenFOAM. The reviewer commented that it would be advisable for the PIs to expressly state the mathematical foundation of the models and how the system will work mathematically.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the project is a good collaboration between universities and laboratories.

Reviewer 2:

The reviewer said that the project involves a collaboration with ORNL, but the direct connection between cavitation modeling and the flash-boiling experiments at ORNL is not well demonstrated. In addition, it seems to the reviewer like this project should be closely coupled with other ongoing DOE-funded efforts, such as the work at ANL (as already noted in a previous comment).

Reviewer 3:

The reviewer remarked that the PI has a range of collaborators that include some from national laboratories, developers of CHEMKIN-Pro, universities, and one industry. The reviewer pointed out that perhaps the latter is the problem as there does not seem to be enough interest or collaborative representation of OEMs in KIVA. The reviewer commented that the PI and his team should get some OEMs on boards to establish better relevance and interest to industry's needs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

For this reviewer to understand the proposed work, the precise formulations of the models should be presented.

Reviewer 2:
The reviewer commented that the project feels that it is conservative in setting its goal and driving for it. Maybe once it makes it through the go/no-go decision point, more challenging milestones will be presented.

Reviewer 3:
The reviewer stated that, as noted previously, the work should target other fluids besides H_2O, as well as more realistic injector nozzle geometries. The work should also aim to link up with other efforts (e.g., ANL's X-ray measurements).

Reviewer 4:
The reviewer remarked that the PI has identified a number of challenges for future work. These include turbulence and spray modeling and conjugate heat transfer. The reviewer observed that the PI noted the need for incorporating heat transfer to the engine block which seems to be a move away from correlations for heat transfer coefficient, which is good.

The reviewer stated that a consideration for future work that would separate KIVA from other codes, but not apparently considered, is engine block thermal considerations and materials stress matters associated with significant temperature gradients within the cylinder. Engines may not operate indefinitely at peak efficiency if the materials of which they are fabricated fail. The reviewer remarked that it is time to incorporate this consideration in to robust engine solvers.

The reviewer recommended that the PI include on his team of "partners" at least one OEM with some commitment to adopt KIVA for prototype engine design if certain conditions are met (the PI can work with the OEM to define the conditions). The reviewer stated that doing so will enhance the relevance of the project to DOE's interests.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the project is very relevant at addressing the understanding of the effects of cavitation and turbulence within the injector on the overall performance of the engine, since injection physics highly influence the performance and combustion products.

Reviewer 2:
The reviewer commented that predictive model development is aligned with the DOE objectives.

Reviewer 3:
The reviewer remarked that KIVA is relevant from a broad perspective. The reviewer noted that robust capabilities for predicting in-cylinder performance are needed and that the PI is working toward that end. However, if KIVA is to be relevant to industry's needs, the reviewer stated that some evidence of that is important to demonstrate. There are no OEMs on the PI's team. The reviewer asked if that mean that OEMs have no interest in using KIVA to design engines (at least on a wide-ranging scale). The reviewer said that the PI did note that "...most of the following attributes are those heralded by industry as necessities."

That is great, but if the PI is working to provide more relevance of KIVA's capabilities to OEMs needs, the reviewer asked why the OEMs are not embracing KIVA the way they are other codes (e.g., CONVERGE). The reviewer noted that it would be good for the PI to answer this question in future presentations. Along with the answer will come another answer, specifically, who the audience KIVA is targeted for. If the audience is OEMs, the reviewer remarked that they should be brought in. If it is university researchers, fine. KIVA will then assist in the education of the next generation of computational scientist being trained in simulations and there is nothing wrong with that, but the reviewer thought that it should be known.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that it looks that the budget is sufficient for the plan.

Reviewer 2:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs105
Presentation Title: Turbulent Spray Atomization Model for Diesel Engine Simulations
Principal Investigator: Caroline Genzale (Georgia Institute of Technology)

Presenter

Caroline Genzale, Georgia Institute of Technology

Reviewer Sample Size

A total of four reviewers evaluated this project.

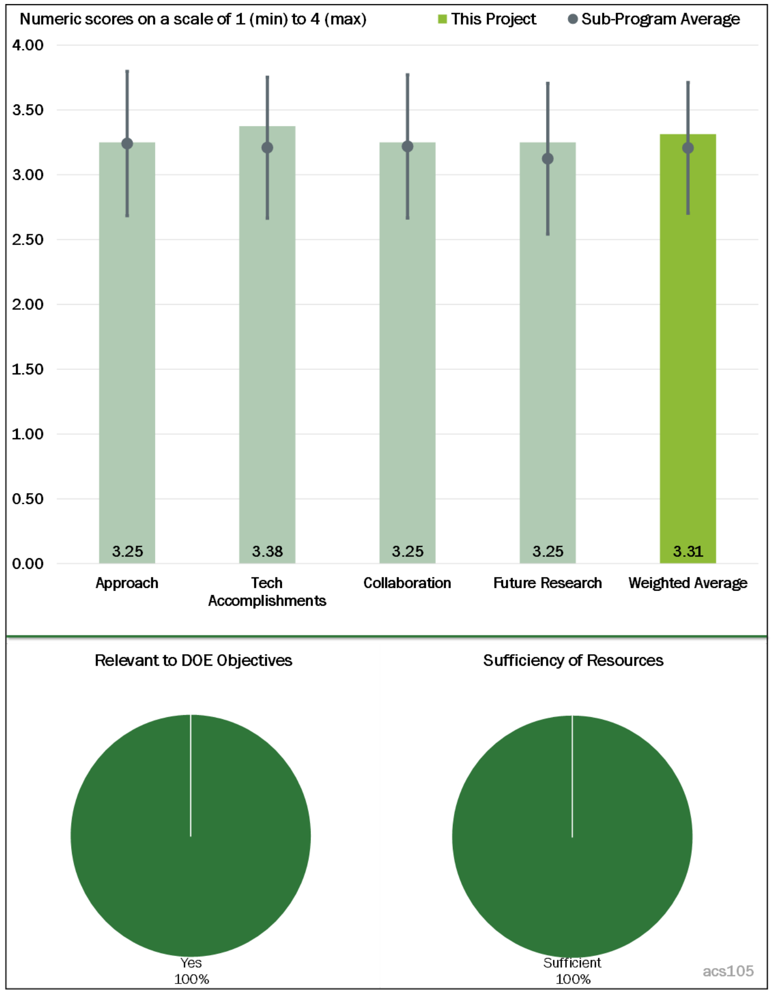

Figure 1-40 - Presentation Number: acs105 Presentation Title: Turbulent Spray Atomization Model for Diesel Engine Simulations Principal Investigator: Caroline Genzale (Georgia Institute of Technology)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that, as highlighted in several other DOE-funded projects, better understanding of spray processes addresses several critical technical barriers to improving engine combustion efficiency and emissions. This project, while only through 1 year, is off to an impressive start and appears to be very well conceived. The reviewer is looking forward to seeing how this work proceeds. In addition, the reviewer noted that the project is collaborating with appropriate researchers conducting other efforts, both directly with ANL and somewhat indirectly through the ECN.

Reviewer 2:

The reviewer commented that the approach is comparatively a new way to measure spray morphology providing quantitative measurements for the spray modeling. The reviewer remarked that the method is well proposed. The reviewer asked why OpenFOAM is only being used to implement this model, not other software, e.g. KIVA. The reviewer is unsure why the Kelvin-Helmholtz Rayleigh-Taylor (KH-RT) model is not being utilized, just the KH model. It could be that the realm of spray condition is not sufficient to show that the RT model is useful. Perhaps the RT part of the KH model is not developed properly in OpenFOAM. The reviewer observed that using a KIVA code would at least solve that problem, by simply adding the KH model or using UW's Engine Research Center's (ERC) version of KIVA which has the KH type Reitz version of spray combined with the RT or use of CONVERGE software. The reviewer stated that the accuracy of the numerical method used in OpenFOAM, in addition to the fact that it is overly complex, requiring re-meshing the topology for moving parts, seems like a better choice over the KIVA codes or CONVERGE.

Reviewer 3:

The reviewer remarked that the project is developed around the (correct) belief that there is a lack of basic knowledge of how sprays impact engine performance. In response, the reviewer said that the PI is developing a predictive capability based on OpenFOAM that will incorporate a new turbulent atomization model relevant to low ambient density.

The reviewer noted that the PI and team are outstanding and the results they are working toward—a validated predictive spray model—will be significant if successful. Some additional comments about the approach are given below.

In framing the approach, it was not quite clear to the reviewer precisely what will be simulated using OpenFOAM and what the experimental data will provide. Many things were mentioned. The reviewer questioned if it is Sauter mean diameter (SMD), density etc.

The reviewer noted that validation is important, though it would be helpful to provide more information about how the model will be validated, and what data would be used in the validation. The reviewer presumes the PI has in mind certain specific properties OpenFOAM will predict, and the Georgia Tech team has the capability to provide data on those spray properties. The reviewer wondered what the properties are (such as SMD, and density) and what the criteria for "validate" is. The reviewer noted that some thought needs to be given to this question.

In the approach, a go/no-go point is indicated that concerns "validation" of benchmark sprays. The reviewer would like the project to provide more details of what is meant by "validation."

The reviewer remarked that the PI notes that mechanisms of atomization are unknown. It might be necessary to modify this claim. Books have been written on this very subject. The reviewer noted that a lot is known about how sprays are formed. Less clear, perhaps, is what happens inside the atomizer itself, which the reviewer presumes is where the ANL collaboration comes in.

The reviewer observed that the approach is to combine data from new diagnostics that characterize sprays and use the data to validate a Lagrangian spray atomization model. The modeling aspect will be performed using the OpenFOAM code. Well characterized atomizers will be used in the experiments which the reviewer noted is good.

It was not clear to the reviewer how the ANL data would be used in the spray validation process. The reviewer noted that some discussion of this should be included in future presentations.

Reviewer 4:

The reviewer commented that the project certainly addresses the technical barriers of having a spray model for a wider range of application with more physics included. The reviewer noted that the content looks a little weighted toward the experimental side. It is not clear to the reviewer where the current models need improvement. It is claimed to be investigated, but the models to be tested have been around for decades. The reviewer stated that it would be nice to have directions for model development described in more detail.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that the PI has done a lot of work in the first year which is impressive. Work at ANL also provided information on liquid volume fraction that allowed determining the distribution of liquid mass with position. Data on SMD were reported at various axial distances and a new diagnostic to resolve diesel sprays was used to infer droplet size, number density, and volume fraction. The main concern for the reviewer is what the PI means by “validation”. The reviewer presumes these matters will be addressed in future presentations.

The reviewer would not consider this a technical accomplishment if carried out, but recommended the PI consider doing an extensive literature search on sprays to ensure that there are no useful data in the literature that can be used in the OpenFOAM validation process. It seems to the reviewer that some of the types of information reported here—SMD in particular—has a rich literature, though with data obtained by different means.

The reviewer noted that the work performed in the reporting period also included simulations using OpenFOAM to predict the evolution of liquid penetration and of SMD with axial distance.

Reviewer 2:
The reviewer noted that although the project has only completed its first year, it seems to be making very good progress toward its objectives. The reviewer went on to comment that the PI also seems to be keenly aware of areas that need to be addressed and honest about the difficulties of doing these measurements and computations.

Reviewer 3:
The reviewer pointed out that the work meets the general technical accomplishments and progress toward overall project and DOE goals. The reviewer noted that if budget period one is the main base for the other two phases, this project is on track to meet the overall goals.

Reviewer 4:
The reviewer remarked that the project’s progress meets milestones. The reviewer has a small concern with the grid convergence. The reviewer asked if the parcel count convergence check was with 0.25 millimeter (mm) and 0.125 mm grids. The reviewer is looking forward to seeing in-depth comparison of the model benchmark results.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project appears to have very good collaboration, particularly considering its budget.

Reviewer 2:
The reviewer noted that there is a good combination of expertise. The reviewer commented that project coordination also looks nice.

Reviewer 3:
The reviewer said that the project collaborations include a direct connection to ANL and participation in ECN, both of which are highly appropriate, however, the work might benefit from collaboration with additional researchers, such as those doing experimental and computation work on cavitation and nozzle geometry. It would seem to the reviewer that spray behavior and characteristics depend on initial and boundary conditions, which would include how the flow passes through and exits the nozzle. The reviewer remarked that perhaps such collaborations could come along in later years.

Reviewer 4:
The reviewer noted that there seems to be one outside collaborator for the project (ANL) who will provide expertise on their X-ray visualization facility. The reviewer remarked that this facility has capabilities to view the regions within an atomizer. The reviewer is unsure if that is what the PI is using the ANL facility for (i.e., get data on the interior atomization process of a nozzle) as it was not clear.

The reviewer stated that the PI should consider bringing another national laboratory in as a partner who is doing detailed LES simulations of sprays (the Oefelein group at SNL). Furthermore, the reviewer commented that it might be worthwhile to reach out to an OEM who has a need for the type of model that PI is endeavoring to develop for sprays.

The reviewer observed that the PI is partnering with colleagues at Georgia Tech University (GT) who have unique facilities to characterize sprays. As the reviewer remarked previously, it is not clear if the PI was able to find some relevant literature data. There is vast literature on sprays. While the GT group has certain capabilities that others might not have, the reviewer stated that the PI should see if there are other groups that can also be brought into her team.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the plan makes sense and is aligned with initial goals. The reviewer asked the project to elaborate on why the correlation by Faeth, et al, is to be evaluated.

Reviewer 2:
The plans for future work seems appropriate and solid, but the reviewer suggests that the PI incorporate existing spray data when comparing to models, and not focus only on new data being taken in the GT flow chamber.

Reviewer 3:
The reviewer recommended that the PI endeavor to search the literature for spray studies that may be relevant. The reviewer noted that perhaps that had been done in the proposal phase, though in the presentation, the way the project is framed, there are no relevant data. If that is correct, the reviewer stated that it would be good to note it.

Reviewer 4:
The reviewer observed that the results shown are still not enough to support the modeling. The reviewer noted that fully concluding budget period one results are needed in order to move on.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the project is relevant from a broad perspective.

Reviewer 2:
The reviewer stated that the project will help the modeling of sprays and injection in engines, give more understanding, and provide a tool for design and research to industry.

Reviewer 3:
The reviewer said that this project will shed light on spray modeling uncertainties. This is to improve the current modeling capabilities and help accelerate future engine development.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the budget is substantial, but so is the work.

Reviewer 2:
The reviewer commented that the resources look sufficient

Reviewer 3:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Reviewer 4:
The reviewer stated that considering the cost of experiments, the resources are low. In addition, the reviewer noted that it would be better if another modeling software is incorporated, such as KIVA or CONVERGEnt. The reviewer said that the project should do a fair comparison and validation for the measurement along with demonstrating how the new model can be incorporated in to industry mainstay tools.

Presentation Number: acs106
Presentation Title: Multi-Component Fuel Vaporization and Flash Boiling
Principal Investigator: Chia-Fon Lee (University of Illinois)

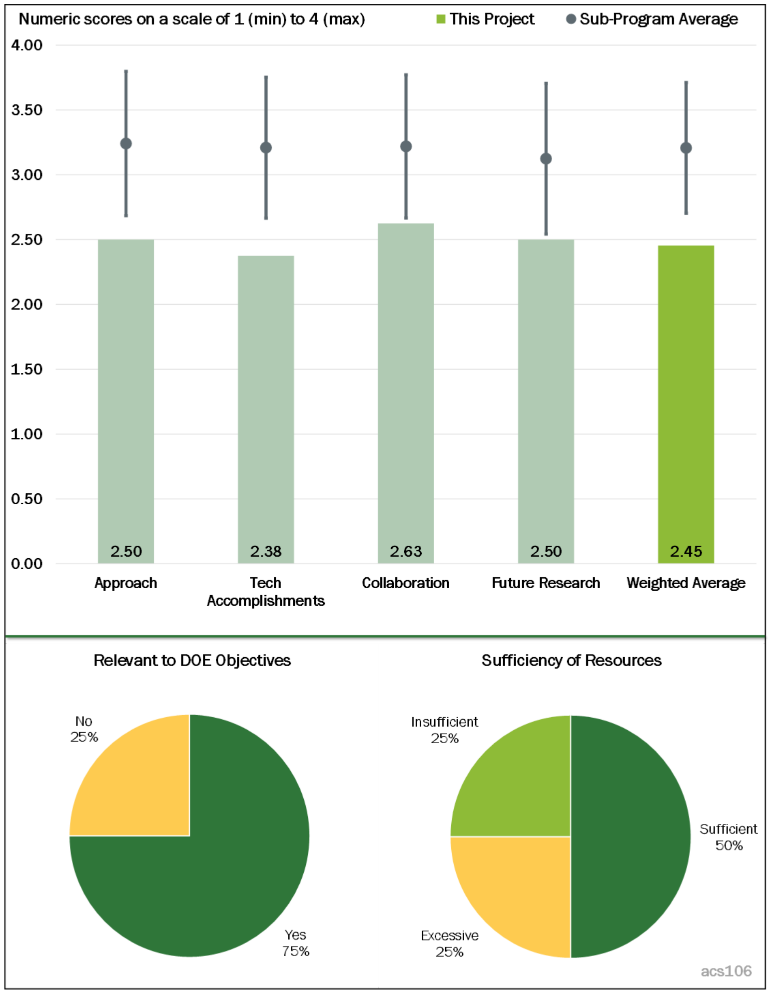

Figure 1-41 - Presentation Number: acs106 Presentation Title: Multi-Component Fuel Vaporization and Flash Boiling Principal Investigator: Chia Lee-Fon (University of Illinois)

Presenter
Chia-Fon Lee, University of Illinois

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
The reviewer commented that this is a good study and very relevant project. However, the reviewer recommended the project needs more focus. The PI is doing a lot, though it is not clear to the reviewer how the elements all connect: droplets, sprays, film, ANL modeling. This person suggested that a better connection should be established for how these parts of the project fit together.

Given that real fuels and surrogates are multicomponent, the project seeks to understand the influence of miscible constituents on the process. The reviewer stated that this fact raises a plethora of issues associated with property predictions, though the project did not touch on the challenges of property predictions especially for more than simple binary systems. To be relevant it is needed, as the title notes, “multicomponent” effects. The reviewer commented that this project could easily turn into addressing the property prediction process, and suggested the PI should come up with a list of properties that dictate flash boiling and focus on trying to predict those.

The PI discussed a droplet and spray set-up. For this reviewer, it was not quite clear precisely what the experiments were intended to show related to flash boiling. The reviewer asked about the expectation for the droplets for flash boiling.

The droplet experimental configuration was somewhat unclear. This individual wanted to see a schematic illustrating precisely what is intended to be derived from the experiments. The reviewer wondered if the droplets are ignited (and how), or if the droplets are evaporating. The reviewer asked what data the modelers want from the droplet and spray experiments. This individual remarked that the PI is right to note the importance of drop temperature in flash boiling and measurement of drop temperature. This is an important variable (though this is the first year of the project and the PI is to be commended for doing a lot).

It was not quite clear to this reviewer how the droplet evaporation data—the D2 profiles reported—related to flash boiling. The reviewer asked whether the PI is trying to connect the D2 profiles with flash boiling; and the origin for the enhancement of the droplet diameter (flash boiling or droplet heating effects).

The reviewer suggested that the droplet configuration perhaps needs more thought to ensure there are no artifacts of the design that can creep into the results. This individual stated the PI notes "floating," "non-convective evaporation" configurations and recommended the PI include a schematic of these configurations to give a sense of what they are and how they are experimentally created.

This reviewer expressed that the spray studies are very useful. This person noted that the fuels systems seem to be single component. This reviewer asked where the flash boiling is triggered in the spray—whether it is downstream of the nozzle. The reviewer further asked how such images will be used to quantify flash boiling and precisely what data from them will be used in any model of flash boiling.

The reviewer offered that there should be some effort, whether theoretical or experimental, that connects liquid composition to variables that related to flash boiling. The approach did not seem to address this matter so in the end it was unclear to the reviewer how the results might be useful to modelers charged with predicting in-cylinder processes where this effect could occur. This reviewer suggested that visualizations on droplet, sprays and films are fine: we just need more quantitative insights about fundamental processes that bring about the flash boiling process.

The reviewer stated that the ANL flash boiling model is unclear, and asked what physics of flash boiling does ANL incorporate.

Reviewer 2:

Clearly stating the models in a mathematical way is needed to understand the approach better for flash boiling of multi-component fuels sprays.

Reviewer 3:

The project aims cutting into a less explored area of modeling, multi-component fuel flash boiling. Modeling of the flash boiling often rely on simple empirical correlation. The reviewer affirmed that comprehensive study with highly relevant measurement data, as planned in this project, would help clear uncertainties.

Reviewer 4:

The reviewer stated that the experiments were poorly designed. This person asserted the experiments do not capture the basic physics of drop and film vaporization in ICEs. While the fundamentals of multi-component droplet vaporization are of interest, the reviewer doubted the models, if validated with these experimental results, will contribute to improving the accuracy of fuel vaporization in ICEs. The project is probably better suited to be funded by the National Science Foundation.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The PI, in the first year, has done a lot: lots of spray experiments to scope out expectations for flash boiling and some droplet experiments that will lead to measurement of the droplet temperature during evaporation.

The PI has made progress on a "droplet liquid phase model," though it was not quite clear what the model was. In particular for flash boiling, precisely how boiling would be initiated and what happens after boiling is initiated, should be better articulated.

The presentation noted that the Peng-Robinson equation of state (EOS) would be used, but the reviewer stated it is not clear what the EOS will be used for. It was not clear how this (or any other EOS) connected with flash boiling. The reviewer asked two questions about EOS: What the role of EOS is in flash boiling (whether it is to set a thermodynamic condition or triggering), and why the Peng-Robinson EOS is being used instead of another EOS.

In the accomplishments, a "current model" is noted in one of the figures (Slide 12), and the reviewer asked what this model is. For the literature data reported, the reviewer asked whether the droplets are evaporating in a high-temperature environment. The reviewer noted that if the droplets are evaporating in a high-temperature environment, precisely how the initial conditions are simulated could influence the subsequent evaporation history. The reviewer stated that the literature experiments are not very clean on this point (initial conditions). Not enough about the model and its relationship to the experiments is provided. The agreement shown is good in some cases and poor others. For either, the question is "why" it is so good or not so good. The reviewer wondered if it is "good" whether that means the model (whatever it is) is proven.

The reviewer asked if flash boiling is expected to occur in a tetradecane/hexadecane mixture.

The ANL simulations reported are interesting. As noted previously, the physics of the boiling process (does it occur within the atomizer for the ANL simulations) are not clear from what was reported, in particular what the criteria used in the model that triggers it.

Reviewer 2:

The model for spray atomization and evaporation is not at all stated. This reviewer recommended that differences in current models should be stated and clear mathematical formulations provided. One might assume the model is generally similar to those used in open source codes such as KIVA with multi-component spray modeling and typically found in commercial codes with some slight modifications. The reviewer re-asserted that clearly stating the models are needed. The reviewer noted that good progress is shown with the experimentation and measurements.

Reviewer 3:

The reviewer is a little concerned about data quality (droplet size measurement), and would like to see improvement next time.

Reviewer 4:

The reviewer observed that the project is only 35% complete with about 50% time left. No plan was presented for 2018. No details presented on how to address challenges and barriers. The reviewer asked what the plan is for integrating into the VOF framework.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The main partner is ANL. They are bringing to the project a capability to simulate engine/flow conditions. Flash boiling processes would seem to be inputs to their simulation, which the PI is providing. More details of ANL's flash boiling efforts (i.e., just what is happening in the model that the liquid knows it is about to cavitate or boil) should be provided in future presentations.

Reviewer 2:

This reviewer stated it is good to see the national laboratory ANL involved, and expressed that the people and co-PI's at ANL need to be named in the report. Credit to particular individuals is important.

Reviewer 3:

The reviewer observed that the PI showed collaboration with ANL, but no details and collaboration plan were presented.

Reviewer 4:
This reviewer stated it is not very clear how the collaborations are coordinated. It looks like the multi-component vaporization model is to be coupled with CONVERGE with which ANL is to attempt flash-boiling calculations. The reviewer asked who is going to perform flash boiling spray experiments.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the future work will include a range of tasks related to droplet and spray experiments.

This person remarked that the work on film vaporization was somewhat unclear, and asked how it relates to the project.

For the spray experiments, the reviewer asked what the PI hopes to derive from phase Doppler anemometry (PDA) and planar droplet sizing measurements, and how ANL will use the spray information.

The reviewer offered that the greatest effort should be directed to the two-color temperature measurements. That alone is a significant undertaking. If the PI pulled back from other tasks (e.g., film studies noted above) and put more effort into tracking droplet temperature, it would be a more fruitful and useful undertaking.

Reviewer 2:
The reviewer expressed that the work on the modeling is hard to judge, because the presentation should have supplied precise detail in references and technical slides. The work in the experimental arena is good. It would be good to see an open source code being used as well for the modeling, something proven in the spray-modeling arena for engines. This would assure that public funds being used would be available to all. DOE funds work on the CFD open source codes for engines, so that using those codes, such as OpenFOAM and KIVA, would demonstrate multiplier on the DOE support. Simply demonstrating the models being developed will work in the open source codes would be sufficient to assure general use of work being developed.

Reviewer 3:
The reviewer desired more details of flash boiling spray experiments.

Reviewer 4:
The reviewer stated that it is poorly presented, lacking details on how to address barriers and risk mitigation plan.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes, from a broad perspective. The reviewer stated that flash boiling is an important problem. Its development dictates to an extent the efficacy of multi-hole injectors in which several liquid jets are directed into the combustion zone. If it occurs, the jets merge due to their expansion from internal bubble nucleation and growth, which will defeat the purpose of the multi-hole concept. Hence, conditions are avoided that would lead to this outcome. Additionally, flash boiling can also occur within a nozzle due to cavitation processes if the fluid pressures within the atomizer drop below some critical value (the cavitation pressure) that could influence the quality of the atomization process itself. The triggering physics are the same.

The reviewer observed that the project addresses this problem from a somewhat fundamental perspective in that engine studies themselves are not specifically studied but rather experiments and analysis are pursued on sprays and droplets to try to understand the basic physics involved. The reviewer asserted that this is the right approach as other DOE projects are dealing more with engine studies and injector designs. Multiple projects within the DOE portfolio could use the results of this project depending on how the results are developed and formulated into a concise criterion for flash boiling.

Reviewer 2:

This project is relevant to petrol displacement, noted the reviewer, because the work is related to a significant portion of physics affecting engine dynamics.

Reviewer 3:

The reviewer affirmed that this project is to improve the current model capabilities, which is to impact efficiency in developing future engines and understand physics better.

Reviewer 4:

The project could support the overall DOE objectives of petroleum displacement. Better vaporization model is critical for combustion modeling. However, the reviewer remarked that this project is not well designed to achieve this goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that it seems the resources are sufficient.

Reviewer 2:

The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Reviewer 3:

This person noted that without knowing exactly what the models being produced, what is novel over existing models, leaves some doubt about the extent of the model development effort required.

Reviewer 4:

The reviewer remarked that the PI did not provide many details on what facility is available and what will be accomplished. For example, the reviewer wondered when the lasers will be delivered to perform laser diagnostics for fuel characteristics.

Presentation Number: acs107
Presentation Title: High-Pressure Supercritical Fuel Injection at Diesel Conditions
Principal Investigator: Ajay Agrawal (University of Alabama)

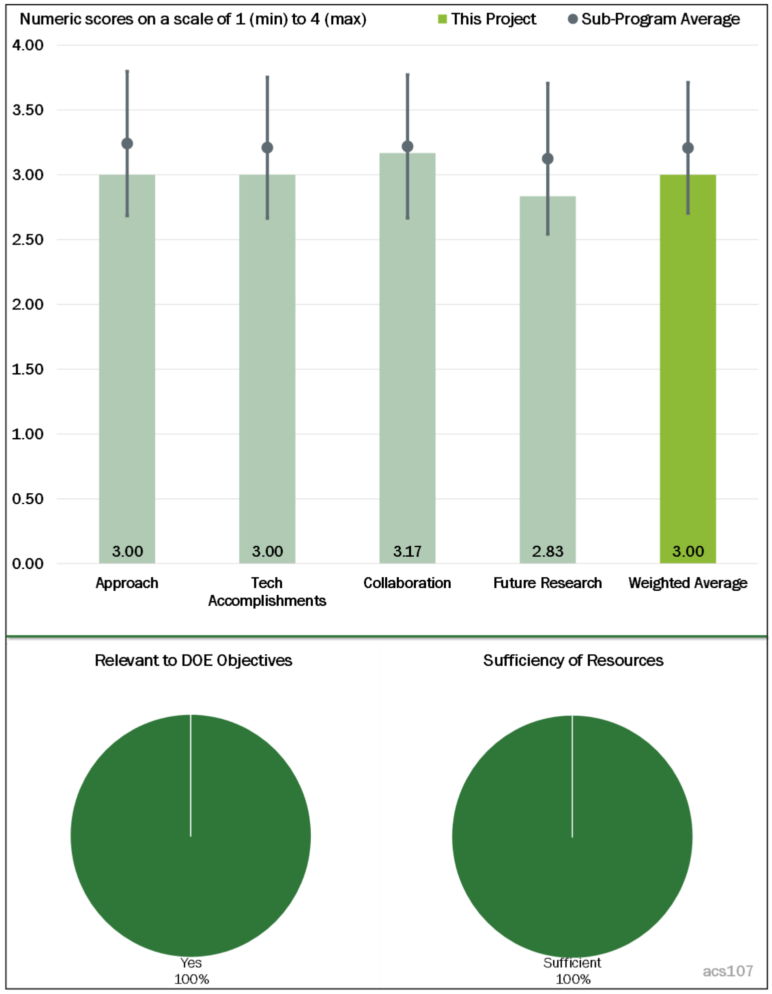

Figure 1-42 - Presentation Number: acs107 Presentation Title: High-Pressure Supercritical Fuel Injection at Diesel Conditions Principal Investigator: Ajay Agrawal (University of Alabama)

Presenter

Ajay Agrawal, University of Alabama

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

The reviewer comments that the approach is good, well designed and feasible. It could be integrated more with other efforts if an open source code were used that had similar capability. But if the models are available in open source after completion of the project, then using public tax dollars is warranted. But if the models only enhance a private sector CFD modeling capability then the approach should be modified to include open source code work too.

The reviewer believes it should have been mentioned in detail how the Eulerian-Eulerian method will work in mathematical statements. The supercritical liquid fluid and the gas fluid in Eulerian phases is feasible and others are working on this type of problem, it is essentially a form of the VOF method. However, the reviewer believes discussion on the interface dynamics between the phases of the fluids must be presented. The species going from one phase to another is a scalar flux calculation requiring a surface reconstruction between the supercritical fluid and the gas phase, as this is essential where the flux of liquid species needs to be accounted for across the phase changes within a computational element. More discussion or references for the ELSA model in CONVERGE code would be good to present.

Reviewer 2:

The reviewer is not sure if the diesel fuel in the injector is at the supercritical condition. The pressure is higher than critical pressure (P_c), but the temperature is usually lower than critical temperature (T_c). Some light components might vaporize causing cavitation, but most will be at liquid phase before leaving the nozzle. Sufficient fuel-air mixing is needed to elevate the fuel temperature above T_c. But, in that condition, it is a mixture of fuel and air, and no longer pure fuel anymore. Fuel liquid was very clearly observed by optical engine experiments.

The reviewer stated it is still valuable to further advance our knowledge of diesel spray and mixing process. However, the reviewer would like the PI to better explain the definition of "supercritical fuel injection" in future, and asked what the major difference is between this experiment and fuel spray experiments.

Reviewer 3:

The reviewer affirmed that supercritical diesel injection does have a potential for great reduction of engine out emissions, so it is worth taking a look. The model and measurement data to be collected will serve the community for developing advanced combustion concept.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

This reviewer remarked that the accomplishments for the term are sufficient, moving toward the goal well. Good headway and accomplishment have been made on both the experimental work and on the EOS work. The team should be moving well along soon.

Reviewer 2:

This reviewer noted that overall, the PI made good progress.

Reviewer 3:

Overall good progress, commented the reviewer. In Slide 10, density against temperature is from the National Institute of Standards and Technology data in high pressure. The reviewer would like to see the PI elaborate on why and whether this is a problem.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that this project has a good mix of team members from academia and a national laboratory.

Reviewer 2:

This reviewer remarked that the collaboration with ANL is sufficient to implement the models in CFD software.

Reviewer 3:

The reviewer stated that it is doubtful to have the commercial code vendor involved. It is not very clear what their role in the project is, while they are not an official partner.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

This reviewer stated that future research is planned in a logical manner.

Reviewer 2:

The reviewer suggested that mentioning which open source codes this work will be created in would have been helpful, would demonstrate the team has been considering this for a period and knows the effort required to put the work in open source. I believe that open source is required if taxpayer's money is being spent, so that good work and good funds benefit all researchers and not just a single private commercial software.

Reviewer 3:
This reviewer observed that it is not very clear which open source CFD code is to be used for validation of the new model and to what extent. It is also not very clear about the target "supercritical" condition for test/model.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this work explores the realm of fuel injection physics not yet well characterized and which could well be useful to improving engine efficiency and reducing impact of burning hydrocarbons.

Reviewer 2:
This reviewer stated that yes, this project supports the overall DOE objectives of petroleum displacement. The research will provide a better understanding of fuel spray and provide better models for diesel combustion.

Reviewer 3:
The reviewer noted that this project does serve the DOE objectives in the context of data/model readiness for advanced engine combustion concept development.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer indicated that there are sufficient resources for this project to achieve the stated milestones in a timely manner.

Reviewer 2:
The reviewer noted that the resources look sufficient for the planned activities.

Presentation Number: acs108
Presentation Title: Spray-Wall Interaction at High-Pressure and High-Temperature Conditions
Principal Investigator: Seung-Young Lee (Michigan Technological University)

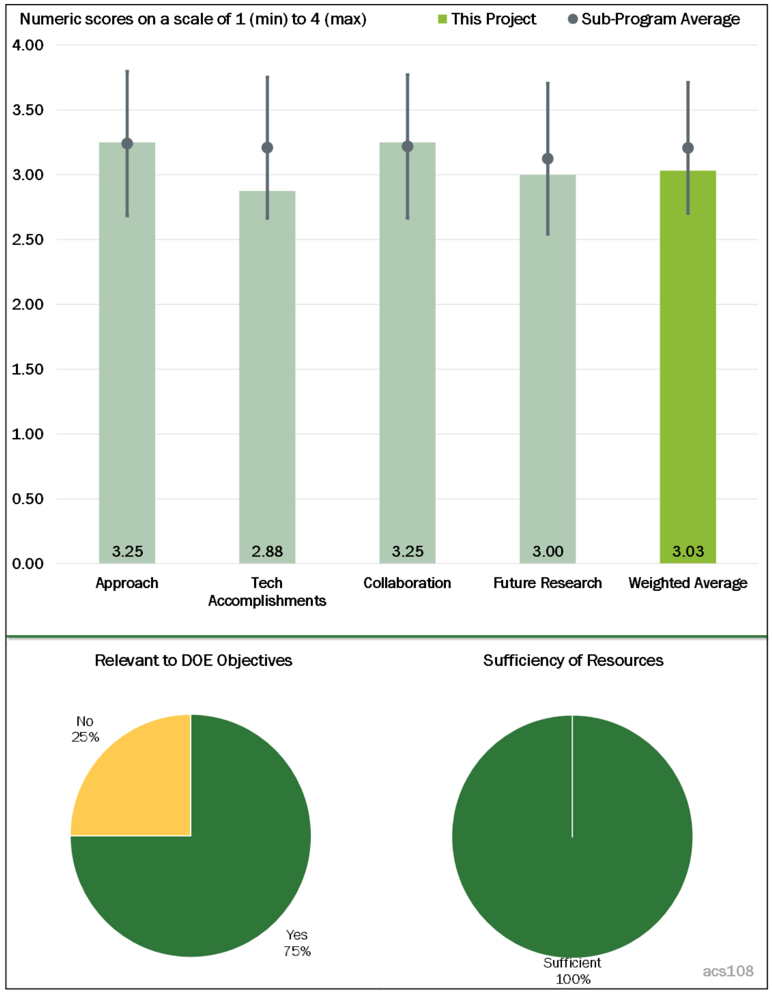

Figure 1-43 - Presentation Number: acs108 Presentation Title: Spray-Wall Interaction at High-Pressure and High-Temperature Conditions Principal Investigator: Seung-Young Lee (Michigan Technological University)

Presenter

Seung-Young Lee, Michigan Technological University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

The reviewer commented that fuel filming and subsequent evaporation of the fuel pool is critical to understanding portions of the combustion process that generally lie outside the desired combustion regime. Hence, understanding the effects of film formation, evaporation, and even lubrication solvency, is important to predictive simulation of engine dynamics and engine out emissions. This reviewer remarked that the approach is solid although specific details of how the DNS simulations and experimental data will be incorporated into a CFD sub-model is not developed in detail. Knowing which RANS equations methods will be used and what wall model will be present is important, as most turbulence RANS require a law of the wall model and certain assumptions for not only fluid boundary layer but heat and mass transport processes.

Reviewer 2:

The reviewer commented that the project plan is well designed to address the technical barrier. The reviewer reiterated the PI’s statement that the spray-wall interaction model has been under a shade for a long time with the excuse of less importance in conventional engine operating conditions. However, as software platforms and other sub-models are improved, its relative uncertainties are increasing.

Reviewer 3:

This reviewer noted that the approach is very standard. This type of approach has been taken by many others to derive the existing sub-models. Therefore, it is not clear why this work, using the similar approach (perhaps the diagnostics is a bit better) can yield much better knowledge or sub-models.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
This reviewer stated the project is on track to meet the overall project goals and DOE's goals. Indicators show good progress.

Reviewer 2:
The reviewer commented that the progress has been made to meet the goals. One thing that this reviewer noted is that typical diesel engines have complex bowl geometry. The reviewer suggested that it would make sense to include the spray-wall angle as a parameter in text matrix.

Reviewer 3:
This reviewer noted that the spray-wall interaction results are very "global." The usefulness of such global spray results remains to be seen.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
Regarding collaboration and coordination, the reviewer stated it is an excellent arrangement. It covers from fundamentals to application, experiment to computation. This represents a very nice example of collaboration.

Reviewer 2:
The reviewer stated that this project has a good mixture of academics and the national laboratory system on a difficult problem to model and understand. It is not always possible to entertain an industry partner, particularly during early phases of work. As the model becomes solidified validation or demonstration of usefulness of the effort on an industry problem, engine could be beneficial.

Reviewer 3:
This reviewer noted that the project collaboration is reasonable.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the plan for proposed future research is reasonable.

This reviewer stated that in particular, the VOF based evaporative system for mass and heat flux will require a good interface reconstruction system and likely an iterative method to converge the flux per time step. The reviewer wondered whether, alternatively, the scheme will be an engineering model, similar to droplet evaporation, and use a Spalding number that is currently done in O'Rourke and Amsden, with interface reconstruction performed mostly for visualization of film thickness. This reviewer said details on the how the future methods are to proceed would be helpful.

Reviewer 2:
This reviewer said it is not clear if two-way thermal interactions between the film and the wall is to be taken into account in the model.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer stated that yes of course, all portions of fuel delivery and thermodynamic conditions properly modeled will quickly go toward petroleum displacement.

Reviewer 2:
The reviewer noted that this project is about model improvement and validation data generation. The project meets the objectives.

Reviewer 3:
The reviewer stated that this project is not about using non-petroleum fuels.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources are reasonable.

Reviewer 2:
The reviewer had no comment.

Presentation Number: acs109
Presentation Title: Predictive Models for In-Cylinder Radiation and Heat Transfer
Principal Investigator: Dan Haworth (Pennsylvania State University)

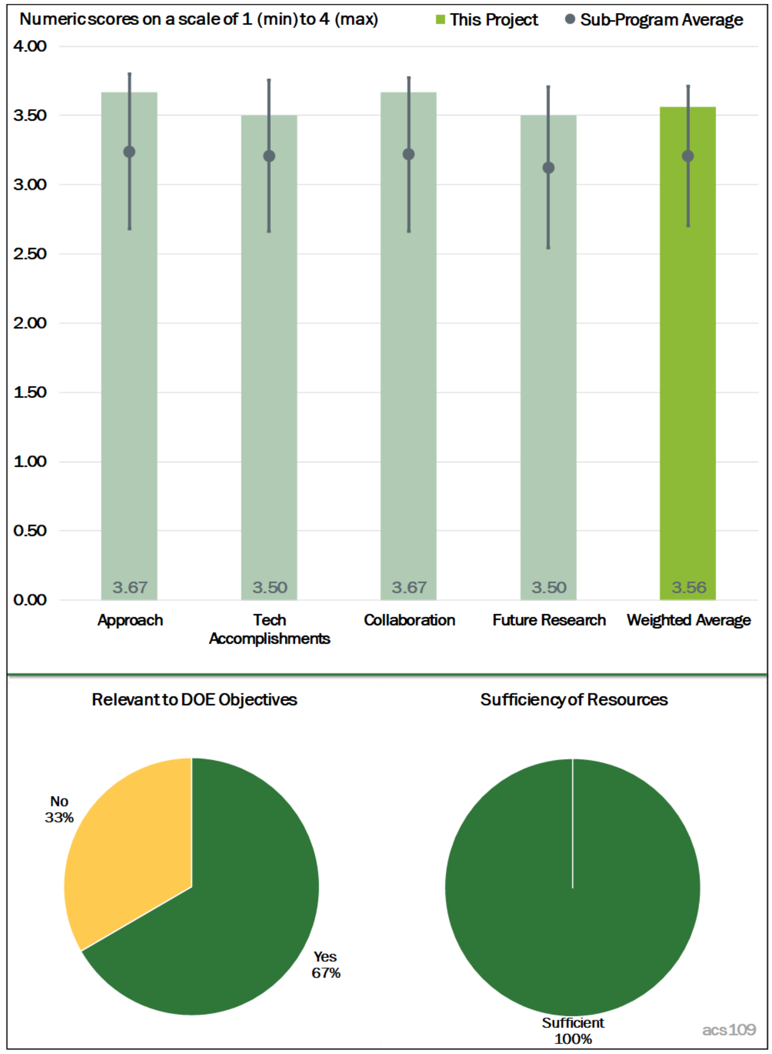

Figure 1-44 - Presentation Number: acs109 Presentation Title: Predictive Models for In-Cylinder Radiation and Heat Transfer Principal Investigator: Dan Haworth (Pennsylvania State University)

Presenter

Dan Haworth, Pennsylvania State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

The reviewer expressed no major concern with the plan and approach. Figuring out how important the radiation portion in the total heat transfer budget has been a challenge. The project has well defined layers of approach that are supplementary systematically.

Reviewer 2:

The reviewer remarked that it is a very nice approach.

Reviewer 3:

This reviewer noted that the approach is well designed, first to find the radiation influences on what and from what species to ascertain the overall effects of radiation heat transfer in engines and in particular, effect on boundary layer heat transfer is excellent to see. The reviewer wondered just how the current boundary layer modeling might need changed could be conjectured at this point as perhaps in a general equation form.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

This reviewer noted that the program is progressing well, showing a need to understand the effects of radiation heat transfer in engines, particularly influences of the heat transfer in the boundary layer. The upshot will eventually be going to improved or adjustments in the wall-laws for use with RANS closure methods. Other progress toward objectives is doing well.

Reviewer 2:
This reviewer remarked that there has been good progress.

Reviewer 3:
This reviewer indicated no major concern so far. The progress has been solid and steady. The reviewer was looking forward to seeing the second-year result as a lot of validation test will be attempted.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer remarked the project has great collaboration with two national laboratories and another university partner.

Reviewer 2:
This reviewer noted that the project collaboration is reasonable.

Reviewer 3:
This reviewer commented that the project team represents a classic collaboration model with partners with distinctive expertise.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This reviewer noted that the future research plan is tightly aligned with the milestones. There is no foreseeable risk at the moment.

Reviewer 2:
This reviewer commented that the future research plan is very good.

Reviewer 3:
This reviewer stated that good planning and proper execution is being followed. A little more information on the models that might be employed as an outcome of the research here for general radiation heat transfer in a CFD code would be helpful.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer stated that this project is very relevant to modeling the engine heat transfer processes, which is critical to knowing just what is being missed by not modeling radiation heat transfer.

Reviewer 2:
The reviewer observed that the project is going to shed light on radiative heat transfer which has been under a shade for quite a while. Evaluation of its effect in different engine configurations will help engineers anticipate its behavior better so as to be more effective in future engine development for better fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This reviewer commented that given the scope of the work, and how the work has progressed, the funding is sufficient.

Reviewer 2:

The reviewer said the resources are reasonable.

Reviewer 3:

This reviewer said that the budget seems to be sufficient to meet the goal in comparison with other projects.

Presentation Number: acs110
Presentation Title: Engine Knock Prediction
Principal Investigator: Seung Hyun Kim (Ohio State University)

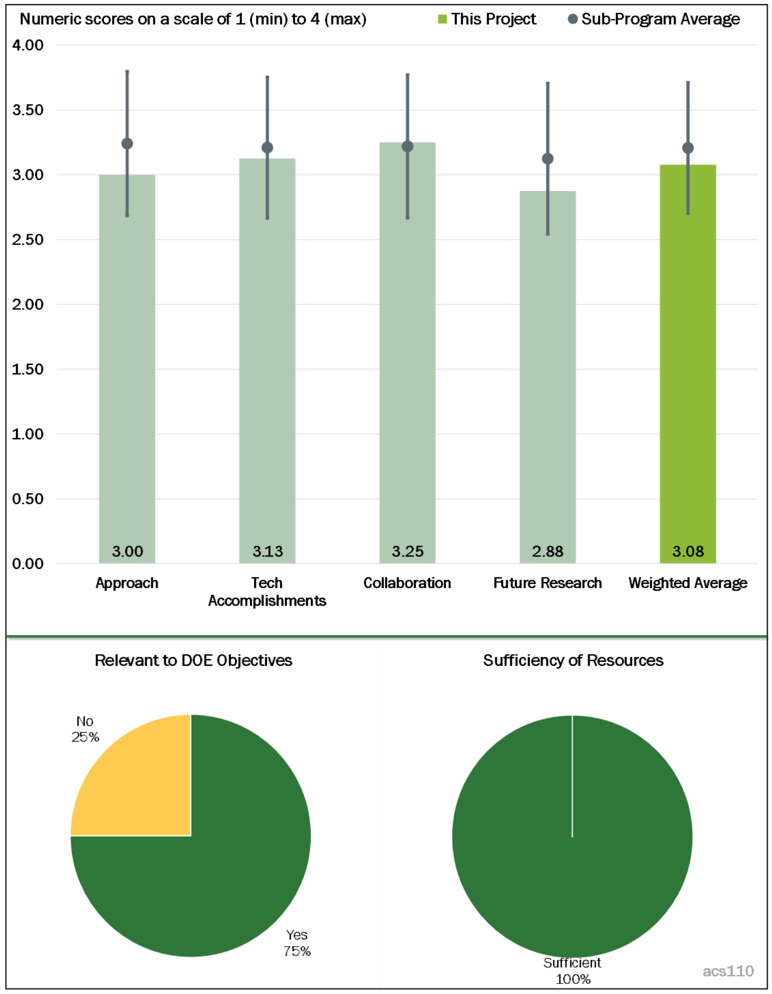

Figure 1-45 - Presentation Number: acs110 Presentation Title: Engine Knock Prediction Principal Investigator: Seung Hyun Kim (Ohio State University)

Presenter

Seung Hyun Kim, Ohio State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

This reviewer stated that the team seeks to provide a detailed insight to turbulence chemistry interaction during engine knock. The approach brings a physics model based on LES to capture cycle-to-cycle variations, prediction of HRR. Benchmarks and validations are done through DNS and engine experiments.

Reviewer 2:

This reviewer noted that the burn models compare well with DNS, yes and that is an admirable goal. The reviewer recommends that the PI provide more detail on the LES model itself to understand the resolutions involved, and wondered whether the LES is so fine that it is essentially DNS. This person recommended that presentation of how the surface averaging proceeds with mathematical statements are required, at least in the technical slides. The reviewer also wondered how these models are applicable to less resolved engine modeling problems, more URANS systems.

Reviewer 3:

This reviewer commented that the project uses a very standard and idealistic approach. It is not very novel, but it is hoped that the approach can lead to desirable results.

Reviewer 4:

The reviewer stated that this project is going to add details in conventional computational approach. However, it is not very clear if turbulence-chemistry interactions are critical in predicting engine knock. The reviewer wondered what benefit the PI expects over the current approach.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer remarked that there has been excellent progress on this project toward the overall goals and DOE goals as shown in the presentation.

Reviewer 2:
This reviewer noted that progress has been made without any foreseeable obstacles.

Reviewer 3:
The reviewer commented that the accomplishments and progress are reasonable.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that collaboration and coordination is reasonable.

Reviewer 2:
This reviewer remarked that the project has nice coordination and collaborations.

Reviewer 3:
This reviewer stated the project has a good mix of academia and national laboratories. The reviewer is curious as to why Convergent Science Inc., was chosen to be used versus codes available in the open. The reviewer wonders whether Convergent brings expertise in developing the methods, and if so, whether the public funds being used will make available the models to any code.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the proposed future research plan is reasonable.

Reviewer 2:
This reviewer stated that it would be nice to see the engine experiment plan for year two with operating conditions in detail.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer noted the project helps researchers and industry with tools that provide for overall better understanding of spontaneous ignition, while also providing for good burn modeling with LES.

Reviewer 2:
The reviewer noted the project is to improve and add details in the current modeling approach.

Reviewer 3:
The reviewer had no comment.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer commented that the resources are reasonable.

Reviewer 2:
The reviewer stated there is nothing to comment yet.

Presentation Number: acs111
Presentation Title: Lagrangian Soot Model Considering Gas Kinetics and Surface Chemistry
Principal Investigator: Sage Kokjohn (University of Wisconsin)

Presenter
Sage Kokjohn, University of Wisconsin

Reviewer Sample Size
A total of three reviewers evaluated this project.

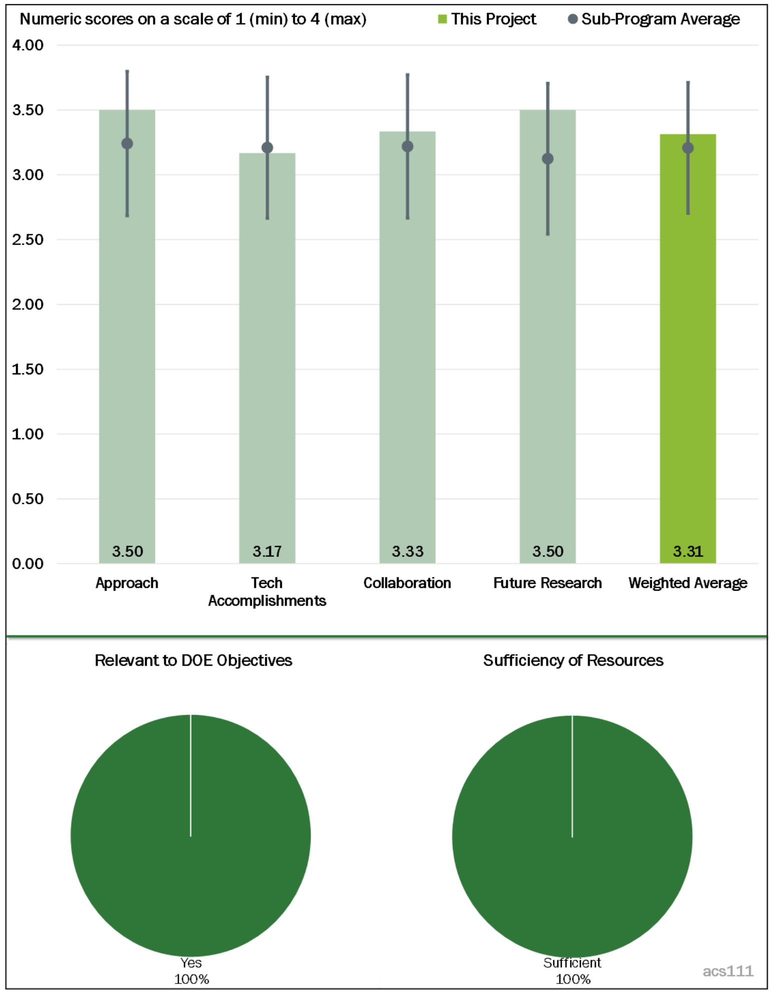

Figure 1-46 - Presentation Number: acs111 Presentation Title: Lagrangian Soot Model Considering Gas Kinetics and Surface Chemistry Principal Investigator: Sage Kokjohn (University of Wisconsin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
The reviewer remarked that the approach is good, certainly a big step forward to predictive modeling for soot formation and transport. It is good that the effort is going into a code of open source origin, ERC's version of KIVA, and not just being tailored for a commercial software vendor. As such, this increases the integration with other efforts being pursued by DOE.

Reviewer 2:
This reviewer commented that project has a very nice approach.

Reviewer 3:
The reviewer noted that soot prediction has been a big challenge for modeling. The project is aiming the technical barrier effectively in collaboration of partners with proper expertise.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer stated the progress is quite good. The authors should include specific references for the soot models used such as the moments method and provide mathematical details in the technical slides for the Monte Carlo method.

Reviewer 2:
This reviewer said the progress is very good.

Reviewer 3:

The reviewer noted this project has well-paced progress and accomplishments. There is no major concern in meeting the goals. It would be nice to have the in-house research code and the commercial code side by side and compare validation/calibration against the measurement.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer noted the project has a good mix of partners from lab, academia and software providers.

Reviewer 2:

The reviewer stated that collaboration is very good in this project.

Reviewer 3:

This reviewer suggested that it would be nice to invite other software vendors as partners for even better impact/penetration to industrial use of the new model.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked the project has a very good plan.

Reviewer 2:

This reviewer commented that further activities are planned nicely. The reviewer looked forward to seeing model performance/cost trade off.

Reviewer 3:

The reviewer observed that the work is proceeding in a reasonable and logical manner. The results of the effort will be very beneficial. The work should be made available in open source if public funds are used, and ERC's KIVA code is not an open source code to this reviewer's understanding of the KIVA codes. Showing how the effort is linked into KIVA in the end and how one might link it into other open source code should also be included in the effort.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said that soot prediction has been one of the biggest challenges. The project is sharply focused on exploring an improved approach.

Reviewer 2:

This reviewer noted that soot modeling and understanding the formation of soot is critical to finding the best regimes under which to operate and engine and hence goes toward petroleum displacement.

Reviewer 3:

The reviewer stated this project can be applied to biofuel combustion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer affirmed that this project has very good resources.

Reviewer 2:
This reviewer said it looks like the resources are sufficient.

Presentation Number: acs112
Presentation Title: Integrated Boosting and Hybridization for Extreme Fuel Economy and Downsizing
Principal Investigator: Chinmaya Patil (Eaton)

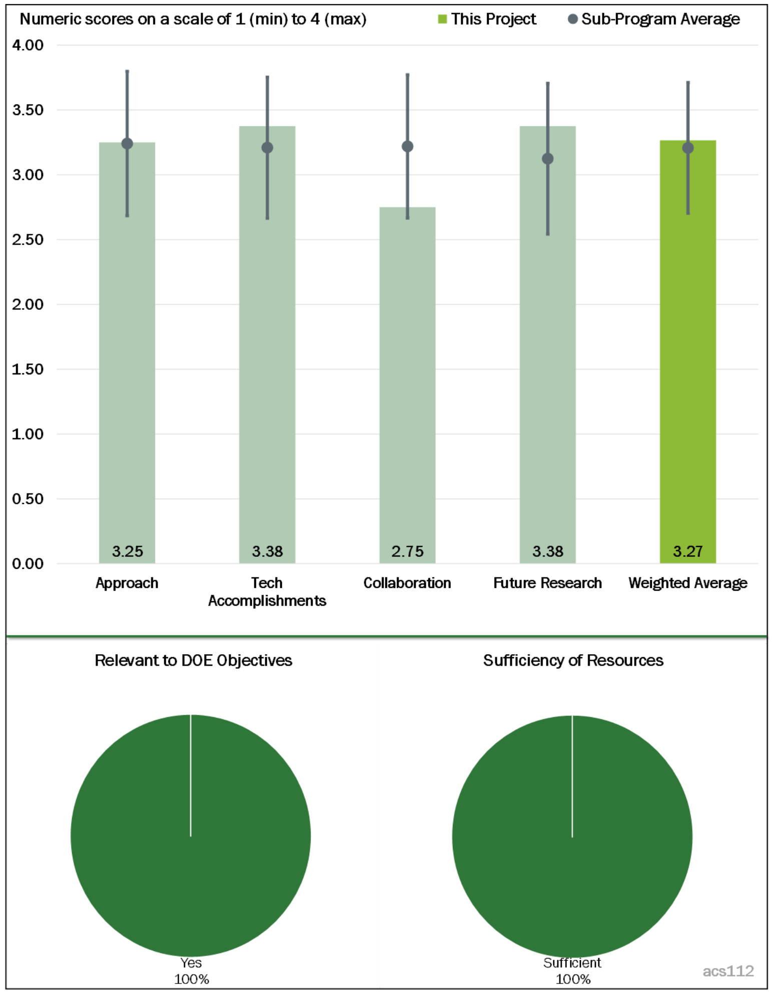

Figure 1-47 - Presentation Number: acs112 Presentation Title: Integrated Boosting and Hybridization for Extreme Fuel Economy and Downsizing Principal Investigator: Chinmaya Patil (Eaton)

Presenter
Chinmaya Patil, Eaton

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
This reviewer stated that the Eaton team proposes development of an electrified expander to perform WHR in engine exhaust, and also use an electrified supercharger (EAVS). These two also aid with torque assist, braking and engine start/stop and potentially could result in 20% fuel efficiency improvement in diesel engines. Overall, these concepts being novel merit evaluation by prototyping.

The approach comprises of system modeling to size the components, which is followed by prototype electric WHR (eWHR) and EAVS development for a downsized diesel engine. Engine performance evaluation will be followed by performance evaluation on a vehicle. The reviewer said that overall, the team has identified the technical barriers and component level design targets through a modeling effort, and then laid out a very logical scope of work.

Reviewer 2:
The reviewer asserted that trying to get similar performance from a 1.8 L diesel with added components to a 2.6L diesel appears to be a reasonable approach.

Reviewer 3:
This reviewer noted that, based on the presentation, which is all we have for 2016 and 2017, the model and simulation of the entire system at the powertrain or vehicle level needs some further detail in the presentation. Perhaps a comparison at the powertrain or engine level, such as showing an engine map, would be helpful along with global vehicle simulation. The traditional fuel economy drive cycles should be presented. As the components are developed, and perhaps the system configuration is adjusted, it would be advisable to update the simulations and present updated results each year.

Reviewer 4:
This reviewer commented that this is an interesting idea. It is not clear that the researchers have done the basic thermodynamic analysis—for the available energy within the exhaust, the regenerating braking efficiency, the efficiencies of the energy exchanges between the electricity generation, power electronics and the battery—in order to demonstrate that this approach is indeed feasible. The researchers should at least bench mark what performance that will be necessary for the individual subsystems of their system.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
This reviewer remarked that the project team appears to be making good progress. The reviewer would be more comfortable if a thermodynamic analysis had been presented to demonstrate feasibility.

Reviewer 2:
The reviewer observed good progress on component designs and starting component builds, as well as progress on control system design and models. It is not clear how the Isuzu engine control unit is in the program without Isuzu being formally under contract.

Reviewer 3:
This reviewer expressed that the technical progress appears to be on track. So far, the Eaton team has identified the design targets for the eWHR and EAVS components through a system model. Subsequently, these systems were designed confirming two architectures: Mule 1 and Mule 2. Currently, the associated control schemes have been developed and the Mule 1 components have been evaluated. They will be integrated into an engine and a system level performance evaluation will commence soon. Additionally, the Eaton team has partnered with Isuzu as the OEM partner. An Isuzu engine of appropriate size has been set up in an engine test cell to serve as the test platform.

Reviewer 4:
The reviewer stated that the team has now designed the necessary components for EAVS and eWHR and have moved to the testing stage as planned in project

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that Eaton has partnered with Isuzu, who specialize in LD diesel engines. Additionally, the project team has partnered with SwRI to evaluate supercharger and eWHR component performance under EGR conditions. Overall, the team is cohesive with individual partner expertise being complementary and leveraged fully.

Reviewer 2:
This reviewer observed that according to the presentation, Isuzu is not yet a collaborator. If they are, or when they become one, their collaboration will be excellent,

Reviewer 3:
The reviewer noted that the auto company partner seemed a little late to join the project, but that it is good to see them under contract now. The reviewer also noted the status of SwRI participation does not appear to have changed since last year. The inclusion of SwRI would address a potential show-stopper. The reviewer commented that it should have been further along early in project, and needs a backup plan.

Reviewer 4:
The reviewer observed that the project is now 50% completed but the project is still in the contract stage with a vehicle supplier. This reviewer remarked that they appear to be behind.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the proposed future work comprises evaluating the performance of their Mule 2 architecture and is a logical extension of the work performed so far. This will be followed by integration with a vehicle and its subsequent evaluation.

Reviewer 2:
This reviewer commented that the outline of future work testing system for functionality and durability is logical.

Reviewer 3:
The reviewer indicated that their plan for future work seems sound. The reviewer highlighted however, that no discussion of cost targets was presented.

Reviewer 4:
The future work includes vehicle integration in addition to resolving or understanding the potentially significant issue of EGR deleterious effects on the roots devices. The future work is appropriate, but appears very daunting to achieve in the last 15 months of the effort. A time extension may be needed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer expressed that if this works and is cost effective, it could offer significant improvement in engine overall efficiency.

Reviewer 2:
The reviewer commented that the potential application to HD engines and vehicles is interesting and important.

Reviewer 3:
This reviewer stated that the proposed technology, if proven successful, would result in a reduction of petroleum use in transportation vehicles, specifically those using diesel engines, by 20%. As a result, this project aligns with the DOE goal of reduced petroleum use in the United States.

Reviewer 4:
The reviewer affirmed that downsized boosting is a logical strategy to reducing energy consumption and vehicle weight. This project moves in this direction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that it appears the research will be able to meet their program objectives within their budget constraints.

Reviewer 2:
The reviewer said that the allocated funds are commensurate with the projected scope of work.

Reviewer 3:

The reviewer remarked that the team has demonstrated the capability to design, build, and develop control systems for their system. The team has also contacted an independent team, Southwest Research, to study the durability.

Reviewer 4:

This reviewer offered that the resources are perhaps adequate for a first level of vehicle validation, but not likely adequate for full optimization. The reviewer suggested considering resources for medium or HD vehicles after go/no-go point in 2017.

Presentation Number: acs113
Presentation Title: DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics
Principal Investigator: Kambiz Salari (Lawrence Livermore National Laboratory)

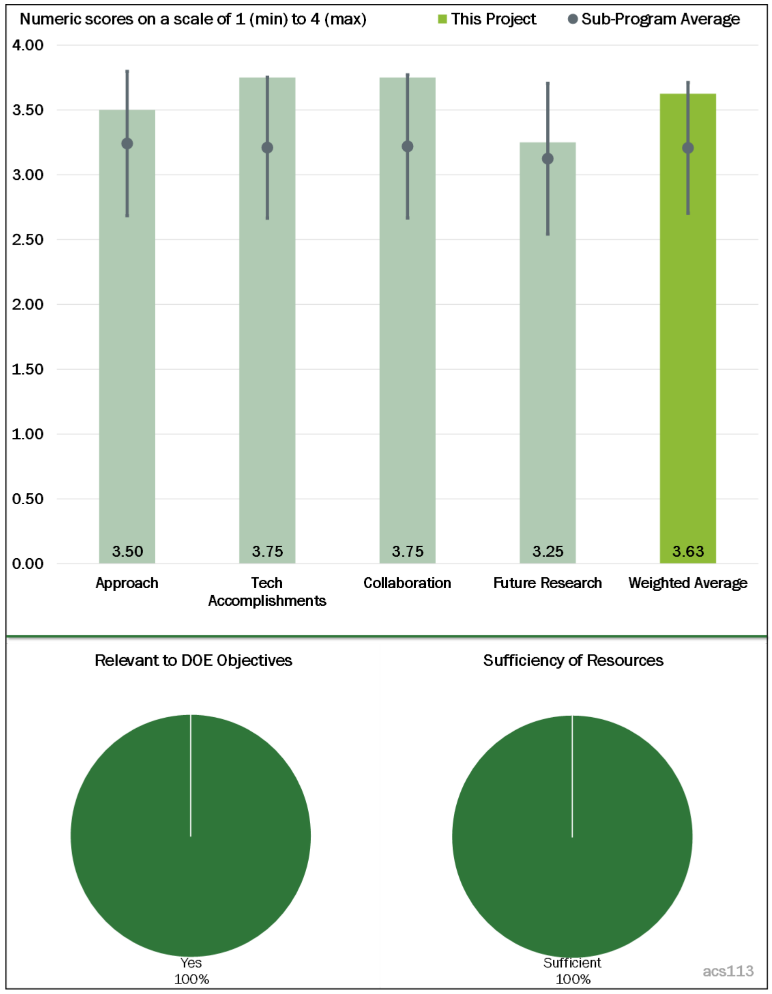

Figure 1-48 – Presentation Number: acs113 Presentation Title: DOE's Effort to Improve Heavy Vehicle Fuel Efficiency through Improved Aerodynamics Principal Investigator: Kambiz Salari (Lawrence Livermore National Laboratory)

Presenter

Kambiz Salari, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project approach continues to be very well-thought-out and carefully aligned to DOE goals and industry needs. The generalized information on commercial vehicle aerodynamics adds greatly to the public discussion about how far to push aerodynamic drag reduction. The reviewer observed that the generic speed forms are a good way to start "the conversation" about aerodynamics advances by demonstrating the potential drag reduction.

The reviewer recognized that tanker trailers are a good place to focus activities and that this project would be addressing a low fuel economy sector with relatively simple technologies that should be well-received. The reviewer stated that little work has been focused in recent years on technologies for dry van trailers, so this work was an excellent area for DOE to help push drag reduction technologies even further.

The reviewer said that this project was a good focus on early-stage research using government facilities that industry cannot access otherwise. The researchers on the project team have many years of experience in this field and can use that experience to take advantage of the computational and wind tunnel resources available to the team.

The reviewer summarized that the science-based approach of this project lends credibility to the results and creates defensible and logical outcomes. The project team's approach pursues specific technologies and broader focus areas in a logical manner.

Reviewer 2:

The reviewer remarked that the approach included a design, test, validation and then a demonstration phase, which was a solid project approach.

Reviewer 3:

The reviewer commented that the project was taking a systematic approach and making good strides to understand the physics behind the aerodynamic improvements. The reviewer summarized that the project was proving theories through experimentation and physical testing.

Reviewer 4:

The reviewer observed that the project was well designed to evaluate the opportunities for additional aerodynamic drag reduction. The reviewer stated that the project was well integrated with DOE SuperTruck effort (Navistar). The reviewer remarked that a tractor trailer integration approach decreases aerodynamic drag, resulting in up to 40% reduction in fuel use. The same approach applies to tanker trucks as well (tanker trailers account for 1.3% of U.S. petroleum consumption). The reviewer summarized that the project was a good science based approach, starting with virtual test environment before proceeding to wind tunnel and track/road testing with fleets.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that the 2nd generation generic speed form (GSF2) geometry is adding significantly to the discussion of "what is possible" in truck aerodynamics. Performance of this geometry represents a breakthrough that should help OEMs create novel real-world shapes for production vehicles. The reviewer noted that because this configuration performs so drastically different from the standard tractor and trailer combination, both the project and the GSF2 should attract the attention of vehicle and trailer OEMs: indeed, it appears to have already garnered interest from the SuperTruck II teams. The reviewer highlighted that these early-stage research accomplishments should build the case for additional work with both DOE and industry.

The reviewer summarized that the project team has made important accomplishments in vehicle platooning that cover the significant issues such as following distance and offset/misalignment. Aerodynamic drag reduction is one of the key mechanisms for fuel savings for platooning and needs to be explored fully in order to understand how best to implement the technology. The reviewer said that this new work has done a good job in addressing previous concerns raised by NREL research about cooling flow challenges with platooning of vehicles, and that the project team has done very thorough work on separation distance as a key parameter for platooning fuel savings. Interesting findings show that offset does not have big effect on drag but does have big effect on cooling air.

Finally, the reviewer affirmed that the project team has been influential in helping guide the aerodynamics work within the SuperTruck program and that the project team's work with Navistar to validate the performance of their final SuperTruck I vehicle in the full-scale wind tunnel was very important.

Reviewer 2:

The reviewer stated that significant progress has been made in the past year on this project, specifically calling out the platooning work as quite interesting. The reviewer noted that the project partners appear to be in sync and well managed resulting in a good transition of work from one stage to another.

Reviewer 3:

The reviewer commented that the project made great progress in measuring the effects of platooning, and different aerodynamic aids. There was a lot of interest in the theory of platooning, because of the potential fuel savings for fleet operators. The reviewer noted that having quantitative data, from this project would to help drive decisions and promote acceptance and adoption of the project recommendations. The reviewer summarized that this effort helps DOE meet its goals, as fleet operators have a financial incentive (through fuel savings) to implement new technologies. The reviewer affirmed that the measured data had unexpected results and showed benefits over a much wider operating range then was previously understood.

Reviewer 4:

The reviewer observed that the project team conducted scaled experiments to investigate aerodynamic benefits of platooning (first of its kind testing with various two to three vehicle configurations, including vehicle offset). Integrated skirt and tail configurations were evaluated showing an optimal distance between 20 and 60 feet between vehicles. Also, the reviewer noted that the project team had previously supported Navistar SuperTruck I project, which achieved significant freight efficiency improvement in large part due to the aerodynamic drag reduction.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that the project team was well aligned and that each project team member's strengths appear synergistic. The reviewer commented that the project team needed to discuss each industry partner's contributions to the project (Navistar, Kentucky Trailer, Freight Wing, Frito-Lay, etc.) in greater detail. The reviewer stated that the project members are mentioned on the overview slide but there was no information about what the role each partner performed this work.

Reviewer 2:

The reviewer stated that the project had a very good team, consisting of vehicle and trailer OEMs, end fleet owners, and multiple government agencies and research laboratories.

Reviewer 3:

The reviewer applauded the project team for having very good collaboration with seven industry manufacturers and suppliers, three large user fleets, as well as other research laboratories (NREL, National Aeronautics and Space Administration [NASA], U.S. Air Force, and U.S. Army). Further, the reviewer noted that it was nice to see truck and trailer manufacturers as well as other suppliers (tires and aerodynamic devices) collaborating on this project.

Reviewer 4:

The reviewer stated that the Navistar SuperTruck collaboration was very good and that the collaboration was important to demonstrate how the LLNL work and researcher expertise can connect theory and practice. The reviewer affirmed that the project team's work on platooning shows a very good collaborative effort with NREL, as this project addressed areas of concern in platooning that initial NREL research had identified (e.g., cooling air supply). The also commented that the collaboration with NASA, Air Force, and Army was essential to give the team access to wind tunnel facilities at a range of scales.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the additional research was good, but the presentation required more information on what deliverables were being created that industry could pick up and implement. The reviewer then noted that no capital costs of the proposed changes were discussed, and that caused difficulty in understanding the true financial benefit from this project and whether the results dictate that the return on investment was sufficient for trucking companies to implement the proposed technologies. The reviewer summarized that information regarding how the fabrication costs of the new components compare to the savings was required for future reports. The reviewer expressed that the wind tunnel and validation data was good, and that a good deliverable for industry might be some final design specifications or requirements.

Reviewer 2:

The reviewer stated that the tasks listed were appropriate for the project in general, but the tasks was not tied to a timetable (other than sometime during the remainder of the project), and also that the decision points, barriers and risk mitigation pathways were not listed.

Reviewer 3:

The reviewer observed that the project had good future plans for tractor trailer integration shape design and design of the next generation of highly aerodynamic tankers. Also, the reviewer commented that the continued investigations of truck platooning aerodynamics and collaboration with NREL as connected and autonomous vehicles would likely be a key contributor to minimizing the energy use in future freight mobility systems.

Reviewer 4:

The future research plan appears to be a very logical and reasonable extension of the current work and builds upon the areas of greatest success and future opportunity. Because of the great interest in platooning as a fuel saving opportunity, the future research in this area was essential for ensuring these systems maximize fuel economy improvement and thus their marketability. If the team's concepts for next generation tanker trailers were as advanced and successful as those for the van trailer, they should advance the state-of-the-art in this sector considerably.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer surmised that because tractor-trailer freight operations represent a significant portion of the petroleum consumption in the United States, reduction in tractor-trailer fuel consumption has the potential to impact petroleum displacement.

Reviewer 2:

The reviewer commented that the testing and suggested improvements to truck and trailer aerodynamics presented by this work directly reduces petroleum required in truck operations.

Reviewer 3:

The reviewer stated that Class 7-8 tractor trailers are responsible for 11% of the U.S. petroleum consumption, and that tractor trailer integration can radically decrease aerodynamic drag reducing fuel consumption up to 40%. The reviewer concluded that a 15% reduction in fuel use was equivalent to 4.2 billion gallons of diesel fuel saved per year and 42 million tons of CO_2 emissions, which aligns with DOE's goals.

Reviewer 4:

The reviewer noted that aerodynamic drag was a major contributor to commercial truck fuel use and addressing drag was extremely important for meeting DOE petroleum displacement objectives. Therefore, the reviewer concluded that reduction in aerodynamic drag for commercial vehicles was directly related to decreasing petroleum use through efficiency improvement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that the project team has done great work with the resources made available and that the project team has extended their reach by collaborations with others (e.g., NASA). The reviewed stated that the freight hauling community receives quite a bit of exceptional work with the funds DOE invests in this team.

Reviewer 2:

The reviewer observed that nearly $1 million per year funding for this project over the past few years has been money well spent because tractor trailer aerodynamics play such a large role in Class 8 long haul truck fuel consumption. The reviewer concluded that contributions from this project were evident in the DOE SuperTruck program outcomes, and that funding was appropriate given the number and complexity of presented milestones.

Reviewer 3:

The reviewer noted that the project team was making great progress on the funds provided.

Reviewer 4:

The reviewer commented that the project appears to be progressing well.

Presentation Number: acs114
Presentation Title: Improved Tire Efficiency through Elastomeric Polymers Enhanced with Carbon-Based Nanostructured Materials
Principal Investigator: Georgios Polyzos (Oak Ridge National Laboratory)

Presenter
Georgios Polyzos, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

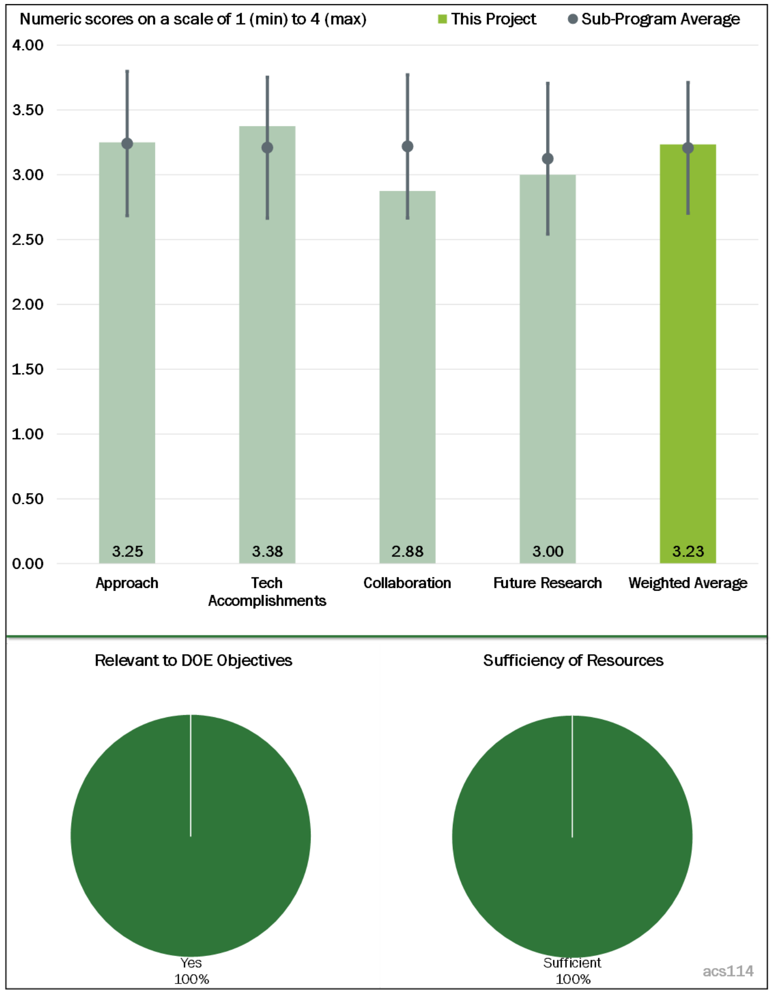

Figure 1-49 - Presentation Number: acs114 Presentation Title: Improved Tire Efficiency through Elastomeric Polymers Enhanced with Carbon-Based Nanostructured Materials Principal Investigator: Georgios Polyzos (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
This reviewer remarked that the approach being used for this project is excellent and provides a good method to address the barriers of the development of new technologies with parallel paths and the development of cost competitive options.

Reviewer 2:
This reviewer said the overall approach is excellent. Paths to overcome most technical barriers are addressed. Further follow-on discussion/elaboration regarding the commercialization and production-scale-up potential of the graphene nano-platelet filler material would be beneficial as significant challenges could exist here.

Reviewer 3:
The reviewer noted that the approach is focused on the materials characteristics needed to improve tire efficiency. The project is relatively short-term in length (less than 2 years total). Therefore, ORNL’s approach had to focus rather specifically on only a few materials changes to be explored, both composition and structures.

Reviewer 4:
This reviewer indicated there are some questions that are not answered in the presentation that may be better suited for a paper. The first question that could be addressed is what evidence suggests the new fillers will be a better substitute than carbon black in terms of meeting the objectives. The second question is why the 50 gigapascal target was chosen.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
This person remarked that the accomplishments shown in this project to date have been excellent. The accomplishments have provided necessary information to allow the project to successfully meet its FY 2016 and FY 2017 milestones and has put the project in a position to complete the remaining milestones which will lead to a successful completion of the project later this year.

Reviewer 2:
This reviewer noted that the project team seems to have moved its way through the evaluation of candidate materials in 2016. Later last year, the project focused on the processing conditions, including a look at the structures resulting from different approaches. In addition, ORNL established baseline characteristics based upon samples from the industrial partner. Most recently, the project has focused upon moving through refining material designs, and then evaluating performance. The results appear to indicate that it is feasible to obtain a 4% fuel savings through this approach to tire efficiency improvements. The reviewer remarked that in fact, the results appear far better than the target values originally identified.

Reviewer 3:
The reviewer stated that Effort Milestones are on track. A 4% fuel savings potential has been demonstrated. The reviewer noted that this project advances the DOE goal of significantly reducing life-cycle energy consumption via the production/use of advanced technology.

Reviewer 4:
This reviewer highlighted that the dispersal issues were achieved without demonstration of performance with or without the desired target, which was not defined. The reviewer further highlighted that there is no demonstrated description of why 50 GPa target was chosen for the silica nanofibers. This reviewer questions how prototype materials are manufactured for mechanical testing to verify hysteresis reduction targets and what standard test methods are applied. The reviewer also asks what the impacts of the Tan delta values at low temperatures are on potential tire performance.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that ORNL is collaborating with a major tire manufacturer, which is exactly the type of organization needed to complete this project (tire expertise). The industrial partner itself will not move forward with what is learned under this project because it produces tires and not the tire materials, so material manufacturers are now being sought for moving forward.

Reviewer 2:
This reviewer said a key relationship is established with a major tire OEM industrial partner. Developing collaboration relationships with industrial graphene and silica suppliers would be ideal for follow-on efforts.

Reviewer 3:
The reviewer noted that the "industrial partner" was not identified, which could cause a perception of potential bias. The reviewer recommended using an industry association that represents multiple manufacturers.

Reviewer 4:
This reviewer observed that the only reference to collaboration is that there is work with a major tire manufacturer. The reviewer suggested that it would be good if the project could indicate what kind of input the tire manufacturer has made to the work, if any.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

This reviewer remarked that the proposed future work in this project will provide very good information which will provide for a successful completion of the project. It is especially good that the project will find suitable industrial partners for the scale-up for the developed fillers.

Reviewer 2:

The reviewer said future project work is effectively planned in a logical path with appropriate milestones. The approach contributes to overcoming most barriers. The reviewer suggested that additional barriers/concerns that may warrant further discussion could include; maintaining (not-degrading) tire ozone resistance and further elaboration on the commercialization and production scalability of the new proposed fillers (especially the functionalized graphene nano-platelets).

Reviewer 3:

This reviewer noted that it does not appear that there is much left to complete this year—the key item seems to be to finding an industrial partner to move forward with the production of the new materials. The current industrial partner makes tires, not the materials. The rest of the activities are focused on finishing off the efforts underway, such as fully curing tires made from materials identified.

Reviewer 4:

The reviewer observed that due to the lack of prototype material fabrication and mechanical testing results, along with the identification or description of the industrial partner, there is some risk that the proposed approach can be achieved toward the goals of the project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer affirmed that this project definitely supports the overall DOE objective of petroleum displacement by achieving a 25%-30% reduction in rolling resistance that will translate into fuel mileage increase of up to 4%. The objective of the project is to improve tire efficiency and meet DOE's fuel consumption reduction target of 4%, while maintaining or improving tire wear characteristics which supports DOE's objectives.

Reviewer 2:

This reviewer noted that the project's focus is on reducing the impact of rolling resistance on fuel consumption, clearly within VTO's objectives.

Reviewer 3:

This reviewer asserted that yes, this project most definitely supports the overall DOE objective of petroleum displacement. A 4% improvement in fuel efficiency is achievable.

Reviewer 4:

The reviewer commented that, provided there is incentive for manufacturers to bring the "improved" tire technology to market on a large, fleet-wide scale, then yes, this project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that resources appear to be sufficient to complete the project this year.

Reviewer 2:
This reviewer said that no indication was made that funding is not sufficient.

Reviewer 3:
The reviewer remarked that this question is difficult to determine without seeing the complete experimental protocol. For example, the reviewer wants to know what the metrics are for mechanical testing and quality assurance in manufacturing.

Reviewer 4:
This reviewer suggested that additional funding could be helpful to formalize the relationship with the unknown tire OEM industrial partner and potential filler manufacturers. The reviewer noted that currently the cost/benefit economics are unknown for a full-scale production scenario. That is, the cost of the new technology versus the fuel economy benefit. Perhaps it is premature at this stage, but it would be good to better understand the potential financial benefits at play.

Presentation Number: acs115
Presentation Title: Advanced Bus and Truck Radial Materials for Fuel Efficiency
Principal Investigator: Lucas Dos Santos Freire (PPG)

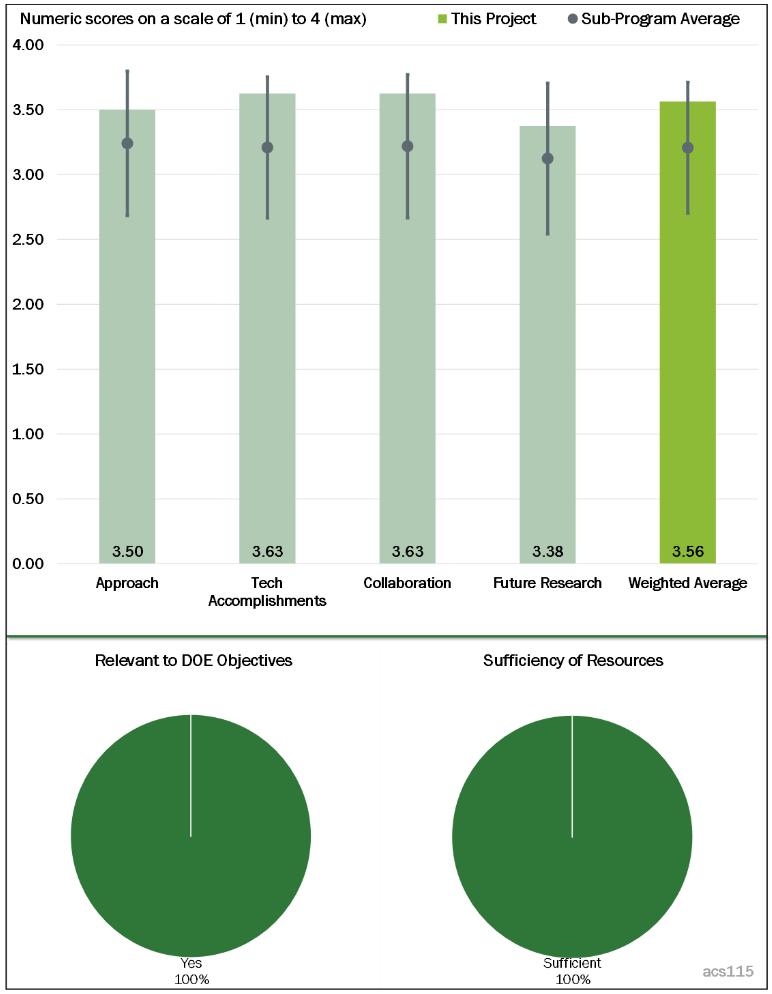

Figure 1-50 - Presentation Number: acs115 Presentation Title: Advanced Bus and Truck Radial Materials for Fuel Efficiency Principal Investigator: Lucas Dos Santos Freire (PPG)

Presenter
Lucas Dos Santos Freire, PPG

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
This reviewer affirmed that the project includes a reasoned approach for accomplishing desired goals, through first focusing on tread compounds, then tire production, and finally tire testing for validation of results.

Reviewer 2:
The reviewer remarked that the overall approach is excellent. Paths to overcome most technical barriers are addressed. Further follow-on iterative efforts are required to meet the rolling resistance target and slightly improve wear and abrasion resistance.

Reviewer 3:
This reviewer stated that the approach to extend the rolling resistance benefits of silica from passenger car tires to commercial truck tires while retaining the other benefits of natural rubber for truck tires is logical and reasonable. The team has applied a methodical process for identifying the necessary silica surface treatment chemistries and to relate these to the desired performance both with lab tests and full-scale tire production and testing. The inclusion of real-world tire manufacturing and testing is a critical part of the approach that is essential for moving this work from the lab to industry so its benefits can be realized.

Reviewer 4:
The reviewer observed that the project leads identify performance metrics with which to judge future progress. The project team understands the optimization problem with regard to lower hysteresis and tire performance

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer observed that the project appears to have been making progress in line with the plan for the project. A number of candidate materials have been evaluated, with a downselect initially to two compositions. They then conducted a number of compound studies to evaluate these candidates, to determine optimized composition. They also found that the production conditions were very important. Two prototypes compounds were produced for comparison to the control (baseline) composition. The reviewer commented that results were promising, exceeding or close to goals for all performance criteria.

Reviewer 2:

This reviewer stated that effort Milestones are on track. A 4%-6% fuel savings potential is achievable. This project advances the DOE goal of significantly reducing life-cycle energy consumption via the production/use of advanced technology.

Reviewer 3:

The reviewer remarked that the team has achieved a significant amount of work in the timeframe of the project to date. The team has completed all of the treated silica parameter evaluations, developed bench-scale processing evaluations, and built real tires for standardized testing. The last accomplishment (building tires using the silica-treated compound in a standard truck tire production line) is one of the more important accomplishments as it demonstrates the feasibility of the new material to achieve both low rolling resistance and production feasibility. The team has achieved a significant improvement in rolling resistance tread compound parameters and good improvement in rolling resistance in real tires—the team is very close to the 20% reduction project goal and has a path to achieve the project goal. There is value in the team's work in identifying the important related considerations for incorporating the surface-treated silica into tire rubber (such as mixing conditions and silica loadings) as these will be important in ensuring the surface-treated silica can be used most effectively.

Reviewer 4:

The reviewer noted that the project team holds to their performance metrics and stands with them. The project team approaches their method with self-skepticism and presents the results in an objective manner.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the team has a tire manufacturer as close collaborator and this is very important. They have chosen the largest tire manufacturer in the world and have ensured they are very involved in the material development and process evaluation. The team has responded to previous reviewer questions about customer feedback by embarking on good outreach to some fleets who have shown support and positive feedback. The combination of tire OEM and fleet participation should ensure success.

Reviewer 2:

The reviewer notes that PPG is working closely with Bridgestone. The United States Army Tank Automotive Research, Development and Engineering Center is also serving as an observer. The project team has reached out to several trucking companies for feedback, and has obtained a number of letters of support from these ultimate users of the technologies under development.

Reviewer 3:

The reviewer commented that a key relationship is established with Bridgestone, the largest tire manufacturer in the world.

Reviewer 4:

This reviewer noted the project team describe the specific contributions of their private partners and express concerns regarding potential influence.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer notes that the project team still needs to decrease rolling resistance a bit more, and confirm the wear target. The PI did present ideas for future efforts beyond the project.

Reviewer 2:

This reviewer observed that the team has good plans to address the issue of increased wear and push toward the rolling resistance target. It is good to see that PPG is looking toward using results from this work to expand the benefit to other natural rubber tires—this will expand the impact of DOE work and leverage VTO's investment. The team also has plans in place to improve the wear characteristics of these tire compounds as this will be important for eventual commercialization (better business case for using these tires).

Reviewer 3:

The reviewer noted that the project team provided no discussion of potential economic impacts of the silica formulation to tire manufacturers and their customers. There are no specific descriptions of the test methods that will be used to demonstrate the performance metrics. There are no acknowledgments of related research and how collaboration may synergize efforts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer noted that the project is focused upon increasing vehicle efficiency through better tires, resulting in significant petroleum savings.

Reviewer 2:

This reviewer affirmed that yes, this project most definitely supports the overall DOE objective of petroleum displacement. An approximate 5% improvement in fuel efficiency is achievable.

Reviewer 3:

The reviewer noted that this project provides the opportunity to save petroleum through a four to 6% improvement in fuel efficiency by reducing rolling resistance of truck and bus tires is very relevant and directly addresses petroleum displacement objectives.

Reviewer 4:

This reviewer stated yes, because any slight reduction in fuel per trip will reduce our emissions and increase efficiency, especially if it results in extended tire life.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that funding appears sufficient.

Reviewer 2:

This reviewer observed that the resources of this project appear reasonable for the timeframe and accomplishments to date as well as for completing the project by the end date.

Reviewer 3:

The reviewer stated that it appears the relationship between the DOE, the researcher and their partners are strong enough to fulfill the obligations to the project objectives.

Reviewer 4:

The reviewer provided a general comment that the cost/benefit economics are currently unknown for a full-scale production scenario. That is, the cost of utilizing the new silica technology (in comparison to a baseline carbon-black product) versus the fuel economy benefit. Perhaps it is premature at this stage, but it would be good to better understand and quantify the potential financial fleet benefits.

Presentation Number: acs116
Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires
Principal Investigator: Tim Okel (PPG)

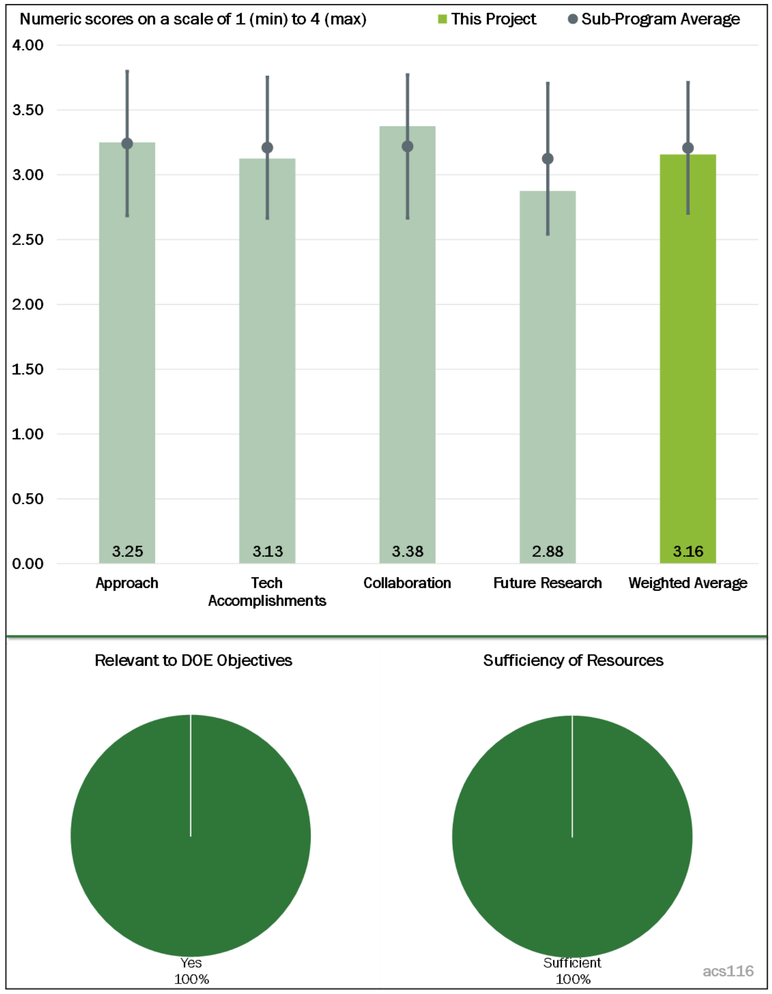

Figure 1-51 - Presentation Number: acs116 Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires Principal Investigator: Tim Okel (PPG)

Presenter

Tim Okel, PPG

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

This reviewer remarked that the approach identified in the three budget periods to document tradeoffs with existing materials, to predict and develop optimal reinforcing filler and finally to optimize compound formulations is excellent.

Reviewer 2:

This reviewer notes that the project is focused on non-tread (particularly sidewall) materials, where little work has been completed to date. This information does not appear in previous studies. PPG believes non-tread component impact on fuel efficiency is equal to that of the tread, and the sidewall is likely 20% of overall tire impact. However, changes in sidewall efficiency must be balanced against performance. The reviewer remarked that the project approach seems rational and focused on desired results.

Reviewer 3:

This reviewer stated that the technical barriers identified are not relevant to the actual work.

The reviewer wondered how the proprietary products used influenced the results and how were they selected in the first place.

This reviewer stated that there does not appear to be any economic aspect to the project. This person wonders whether the tire industry would be compelled to change their formulation with a maximum potential of 2% efficiency gained for their customers.

The reviewer also commented that there does not appear to be any engagement with the Rubber Manufacturer’s Association to get buy-in on future work.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer stated that the accomplishments to date have been adequate. The project has successfully met its scheduled milestones and is on track to meet other milestones described in the project. Accomplishments to date including commercial fillers that have been selected and are currently being tested and other surface chemistries which have been defined will provide for an excellent opportunity to allow future milestones to be met.

Reviewer 2:
This reviewer observed that the accomplishments appear on track so far—the project only started last fall. The project appears to have made interesting progress, including development of tests for some characteristics. Eleven commercial reinforcing filler systems have been selected. Most of testing on these has been completed and data compiled. This testing identified electrical surface resistivity as a property to be monitored. This reviewer commented that overall results to date look promising concerning efficiency improvements.

Reviewer 3:
The reviewer stated that effort milestones are on track. A 2% fuel savings potential is achievable. This project advances the DOE goal of significantly reducing life-cycle energy consumption via the production/use of advanced technology.

Reviewer 4:
This reviewer stated that the accomplishments are on par with the maturity of the project. The reviewer wondered how the researchers justify the relationship between tan delta and fuel efficiency.

The reviewer questioned how economic implications will be weighed against the potential for project objective achievement. If performance is less than 100% of control, it does not appear that a manufacturer will be on board.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer highlighted the Akron Rubber Development Laboratory as an excellent partner in this project. Their expertise and laboratory capabilities provide additional resources to ensure the success of the project.

Reviewer 2:
The reviewer observed that the project includes the specifically and highly qualified Akron Rubber Development Laboratory as a partner. The project has also reached out to several tire manufacturers (the ultimate users of the materials), and obtained letters of support.

Reviewer 3:
This reviewer noted that a key relationship is established with Akron Rubber Development Laboratory, an industry leader in tire testing and research/development. Ideally, tire manufacturer interest (perhaps Goodyear and/or Bridgestone) can be obtained for industrial partnership in follow-on task efforts.

Reviewer 4:
This reviewer highlighted that although the partners are identified, not all of their roles have been. This person wondered what roles the proprietary products manufacturers are playing, and how they were selected.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer expressed that the proposed future work is adequate. A major challenge that was identified is to gain tire manufacturers' interest in pursuing this technology. The reviewer suggested it would be useful if the project team could identify a method to meet this challenge.

Reviewer 2:
This reviewer noted that the plan for addressing remaining challenges and barriers is logically developed, focused on predictions, compound development, and testing/validation.

Reviewer 3:
The reviewer commented that there is not enough description of how the work will be performed, by what method and by whom.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the objective of this project to develop new silica filler that increases fuel efficiency by 2%, while maximizing performance properties in non-tread tire components compared to current filler systems, definitely supports the DOE objective of petroleum displacement.

Reviewer 2:
This reviewer commented that the project is focused on increasing vehicle efficiency due to improved tires through modifications to non-tread materials. A 25% improvement in sidewall efficiency is projected to result in an overall 1% fuel efficiency increase for the vehicle.

Reviewer 3:
The reviewer said yes, this project most definitely supports the overall DOE objective of petroleum displacement. An approximate 2% improvement in fuel efficiency is achievable.

Reviewer 4:
The reviewer said this project does support the DOE objectives of petroleum displacement; however, there is no explanation of the fundamental differences between the formulations that make up non-tread vs. tread component and how the researchers are or are not collaborating with other DOE research projects.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the funds provided by DOE for the completion of this project appear to be sufficient.

Reviewer 2:
The reviewer noted there was no indication of funding concerns.

Reviewer 3:
This reviewer commented that additional funding could be helpful to formalize the relationship(s) with tire OEM industrial partner(s) to produce prototype tires for testing.

Reviewer 4:

The reviewer remarked that the resources appear to be sufficient provided that the proper buy-in is achieved from the RMA and other stakeholders.

Presentation Number: acs117
Presentation Title: HD Powertrain Optimization
Principal Investigator: Paul Chambon (Oak Ridge National Laboratory)

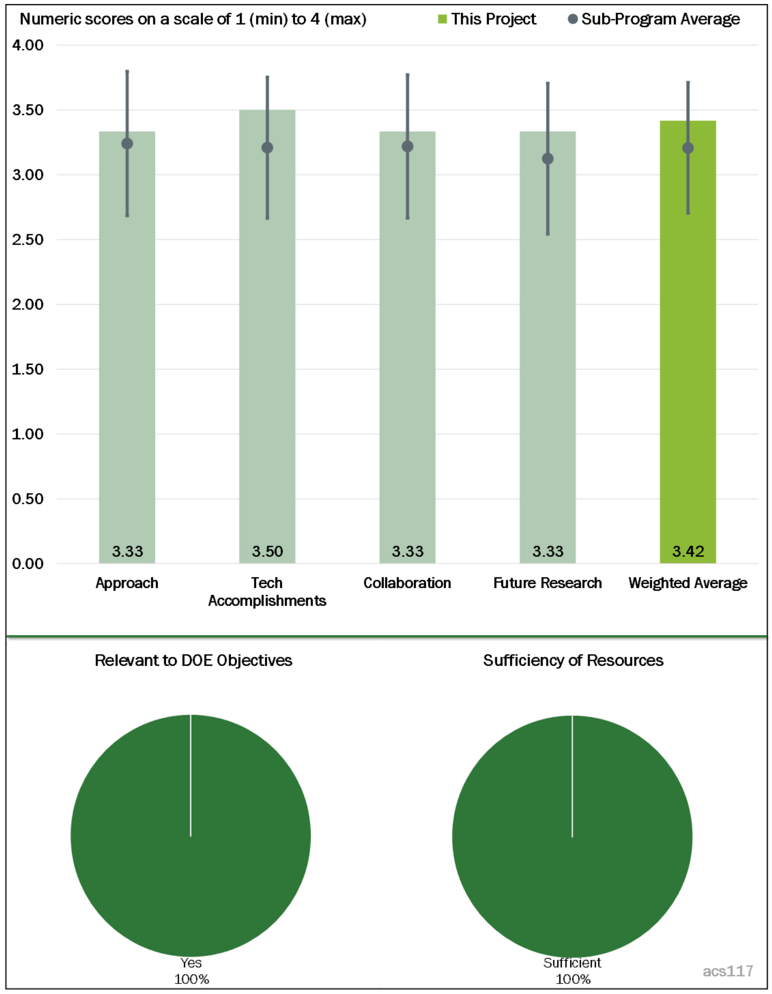

Figure 1-52 - Presentation Number: acs117 Presentation Title: HD Powertrain Optimization Principal Investigator: Paul Chambon (Oak Ridge National Laboratory)

Presenter

Paul Chambon, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

This reviewer said it is a very creative approach to re-use data previously collected for Phase II EPA rulemaking for the optimization assessment of the Cummins + Eaton powertrain. This will be done at a precompetitive R&D component and system-level, to ensure all OEMS/Tier 1 suppliers have access to the results.

Reviewer 2:

The reviewer suggested that the project team define the roadmap for improving fuel economy and form a hypothesis for this work.

Reviewer 3:

This reviewer noted that the project uses special equipment to optimize powertrains. This is close to development work.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer stated that the PI is doing excellent work in optimizing powertrains

Reviewer 2:

This agile approach using existing laboratory capabilities is flexible and can be modified on the fly—in fact, this is the case as Cummins' newest engine (X15) has recently been delivered. This pre-production engine is the latest state-of-the-art technology available. This enables ORNL to test this engine as part of the project in the ORNL HIL test lab.

Reviewer 3:

This reviewer noted that the project seems to be just starting. The reviewer suggested making the baseline clear. This person believes that this is the 2012 version and the SmartAdvantage version. This will make it easier to understand.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that there is good collaboration with industry

Reviewer 2:

This reviewer said that the project has a good spread of industry participation (Cummins, Eaton). The reviewer suggested that the project could integrate an academic institution to help round out the team.

Reviewer 3:

This reviewer recommended clarifying who the partners are in this DOE project, and asked whether all the organizations listed on Slide 2 are project partners.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the project has well laid out metrics and milestones. Project has a definitive end date and a target set of accomplishments.

Reviewer 2:

This reviewer suggested determining what knobs have been left unturned on SmartAdvantage, which the reviewer thought is the focus on this work.

Reviewer 3:

The reviewer noted that future research is more optimization of powertrain technologies.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said yes, this project improves fuel economy by making the engine and transmission more efficient.

Reviewer 2:

This person noted that the project results in improved fuel economy of HD vehicles.

Reviewer 3:

This reviewer stated that optimizing the powertrain will result in efficiency gains.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said yes, and noted that the PI changed jobs before the review. The reviewer suggests that the project needs to be transferred to another person.

Reviewer 2:

The reviewer remarked that the funding level appears adequate to complete the project.

Presentation Number: acs118
Presentation Title: Advanced Emission Control for High-Efficiency Engines
Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

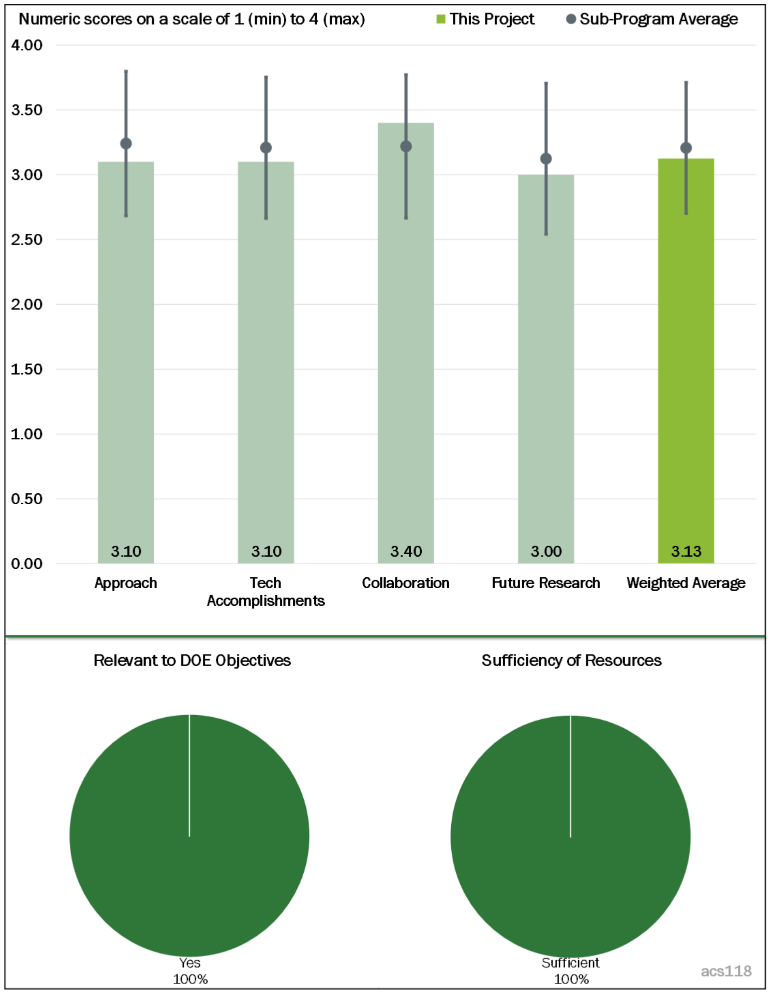

Figure 1-53 - Presentation Number: acs118 Presentation Title: Advanced Emission Control for High-Efficiency Engines Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:

This reviewer said the project has an outstanding approach to work with practical pathways (catalysts, systems, durability) for lean NO_x aftertreatment identified, mapped and status provided, including cost considerations and input from OEMs for most practical pathways.

Reviewer 2:

The reviewer expressed that there are three projects here. Each is relevant for the DOE. The PNA work is relevant and the use of the PNNL characterization technology is a big plus. For the CNG work, the reviewer saw no advances in this work beyond what the suppliers have already done. The reviewer said the particulate work is relevant and interesting.

Reviewer 3:

This reviewer noted that effort is focused on three separate areas of research and development. The PNA development plan and collaboration is very appropriate for advancing material development in this area to address the need for LT NO_x control. Developing materials that will couple with the LT capture of NO_x with release at the right temperature for efficient downstream NO_x reduction is important for lean systems. The reviewer remarked that duplicating efforts of catalyst washcoaters in this area should be minimized. This reviewer commented that CNG methane oxidation catalyst research is also required to achieve more stringent emissions standards. However, the relative market addressed by this research is much smaller than the gasoline and diesel markets the PNA work is addressing. The reviewer concluded that much effort has already been applied to filter/particle characterization and overlap of activities with other labs and suppliers should be closely monitored.

Reviewer 4:
The reviewer commented that the project appears to address the major issues with advanced lean emission control (NO_x, small alkane oxidation, PM).

Reviewer 5:
This reviewer noted that the project addresses three distinct topics (NO_x storage, saturated HC oxidation, particulate properties), each of which is relevant to emission control for high-efficiency engines. However, the reviewer suggested that the technical issues/barriers involved and the approaches to tackle the problems are so different in nature that it seems difficult/unlikely to expect synergy among the three areas under investigation here. (Almost like three independent subprojects within the project.) This may likely create a situation where resources are spread thin, potentially slowing down progress significantly. Also, the work plan described in the "milestones" slide includes the "standard" items pretty generic in nature, not providing enough uniqueness or novelty of this project in terms of the technical issues to tackle, the approaches used and the significance/ultimate goals of this work.

The reviewer observed that for both the NO_x adsorber and methane/ethane oxidation studies, S resistance and thermal stability are planned to be tested last, but such a work plan may not be efficient because some materials that look promising at their fresh state can turn out to be unacceptably poor performers when tested under more realistic conditions. (Detailed kinetic/spectroscopic studies on such materials would, then, become a waste of time/effort/resources.) Thus, it is recommended that steps 1.3 and 1.4 as well as steps 2.2 and 2.3 be integrated to a certain degree rather than being carried out sequentially (one step after another), as indicated in the current plan.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
This reviewer said that excellent results were presented, showing capability to meet the targets and a practical system solution to execute in a cost-effective manner.

Reviewer 2:
The reviewer said that given this project essentially started in 2016, the technical accomplishments shown seem okay.

Reviewer 3:
This reviewer commented that this is a relatively new project so it is a bit hard to judge the technical progress. The work on the PNA portion leverages a generic study done in CLEERS on Pd/zeolites. The progress seems adequate for 1 year given that there are two industry partners.

Reviewer 4:
The reviewer remarked that the PNA project mostly just showed that the catalysts are sensitive to H_2O. This person did not find that surprising. The summary had substantially more information than was in the talk. The summary information is helpful.

The reviewer expressed that there is not much helpful in the methane catalysis work. The reviewer noted that for the analysis of engine produced particles, the project team did not give us much information about the engine. Consequently, it is hard to understand the meaning of the results. The results are interesting, but difficult to extrapolate to engines with somewhat different combustion configurations.

Reviewer 5:
This reviewer said that the technical progress in the area of PNA development appears on time and in a direction that is consistent with advanced work occurring in the catalyst supplier area. Duplication of effort should be minimized, while PNNL characterization efforts will better serve the development need in this area.

Progress in the methane catalyst development area is providing interesting catalyst solutions. New materials in the PNA and methane catalyst area of R&D, that address LT activity, are very important to both the LD and HD OEMs. Particle characterization, although useful, is also being addressed at other research and development centers globally. Some results are already known.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer remarked that the team has a good range of collaborators with different perspectives on the projects.

Reviewer 2:
The reviewer said that overall, this project has a good coupling between PNNL and appropriate OEM/suppliers. Although the work in the PNA and filtration is HD centric, it would also benefit from a LD OEM in this area. Similarly, CNG applications are present in both HD and LD programs.

Reviewer 3:
This reviewer noted that there is a very clear partnership with Cummins and Johnson Matthey.

Reviewer 4:
The reviewer observed that the project team has good collaboration with auto OEMS, catalyst suppliers and national laboratories to develop an integrated system with solid results.

Reviewer 5:
The reviewer stated that the plan to take advantage of strengths from the partners involved makes sense. However, it appears that full collaboration between the partners has not happened yet.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the planned future work addresses the three technologies in the project directly, and is aimed at further understanding.

Reviewer 2:
The reviewer said that few remaining pathways to consider are included in future work plan as is assessment of risk and durability.

Reviewer 3:
The reviewer referenced prior comments.

Reviewer 4:
The reviewer noted that the PNA future plans seem to imply there is a down select to the Pd-alumina. Certainly, knowing the aging effects and poisoning effects is the next step.

This reviewer did not understand the reason for the selection of alloys for evaluation for the methane oxidation, and therefore suggested the project team provide background information on why the alloys were selected.

The reviewer observed that the proposed particulate future work was a laundry list of perhaps more than they can accomplish. The reviewer suggested one focus for the future work.

Reviewer 5:
Both the PNA and methane catalyst characterization work will help illuminate deactivation mechanisms that these catalyst technologies will be exposed to under operating conditions. This is useful information for others in this area of R&D. Developing novel catalysts in these areas will also supports the need for new materials active at lower temperatures. However, the researchers should continue to monitor progress in this area by others to avoid duplication of effort. Activities in the area particulate characterization are not increasing the level of understanding as much, because other work in this area is also well advanced. A better use of resources may be to focus on two projects instead of the three reported here.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that all three of the projects are emission related and can contribute to higher fuel economy vehicles that meet emission standards.

Reviewer 2:
The reviewer said the LT PNA and methane catalysis are consistent with the need in the aftertreatment community.

This reviewer does not believe the particulate work is of high value.

Reviewer 3:
This person noted that the project includes catalyst and filter technologies that are important for highly efficient powertrains.

Reviewer 4:
The reviewer expressed that lean (primarily NO_X) aftertreatment solutions can enable substantial fuel savings by facilitating production solutions for various lean combustion regimes. This nearly fully developed system solution can enable aggressive lean operation with critical systems, cost and durability considerations considered or addressed.

Reviewer 5:
The reviewer affirmed that this project addresses the areas of critical importance in petroleum consumption reduction via fuel efficiency improvement and utilizing alternative fuels.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that it is a good level of funding for work generating outstanding results extremely useful at OEM level.

Reviewer 2:
The reviewer stated that the resources seem sufficient.

Reviewer 3:
This reviewer noted that the project has 50/50 cost share with Cummins.

Reviewer 4:
The reviewer noted that the resources seem to be sufficient to carry out the planned work.

Reviewer 5:

This reviewer observed that funding in this area appears sufficient. However, the reviewer commented that resources to cover the needs of the three different projects appears marginal. The reviewer suggested that perhaps focusing on two projects is a better use of resources.

Presentation Number: acs119
Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF Aftertreatment System for Heavy-Duty NO_X and Soot Emission Reduction
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

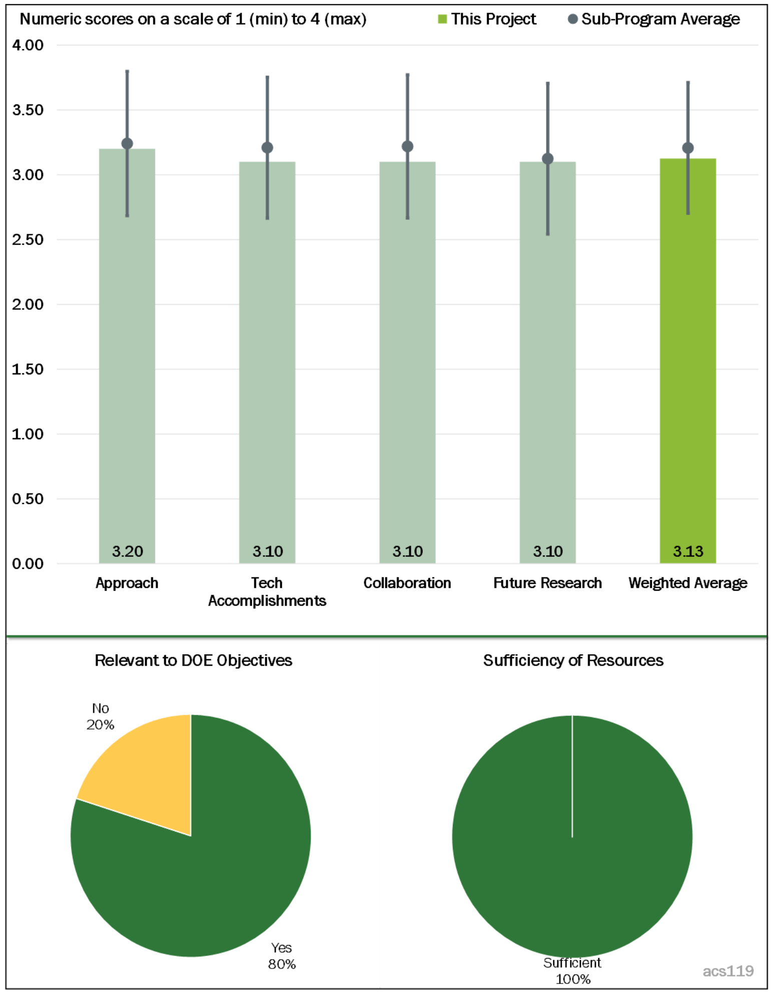

Figure 1-54 - Presentation Number: acs119 Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF Aftertreatment System for Heavy-Duty NO_X and Soot Emission Reduction Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter
Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other

Reviewer 1:
The reviewer noted that this is the number one issue on SCRF implementation in HD, loss of passive regeneration. The approach is novel and the reviewer thought nearly impossible. The reviewer wondered how the project team oxidized NO with minimal impact on NH_3. As such other approaches utilize SCR architecture with modest results like in Slide 13. The reviewer said the project team has proposed a novel approach using a weak oxidation catalyst located upstream of the SCR catalyst that might increase NO_2 in proximity to the soot, without oxidizing NH_3. This reviewer applauded the approach and hoped that the project team's concept works.

Reviewer 2:
This reviewer affirmed that investigation of SCR on DPF is valuable for the industry. This person remarked that the project has a good approach—broken up by phase using building blocks commencing with full scale demonstration. The reviewer also noted the following: The project is looking at scalability and minimizing the amount of SCR development, although there will be some SCR.

The reviewer commented that the distribution of SCR catalyst across the substrate/filter is not well defined, but the PI went to great lengths to describe the problems in NO/NO_2 conversion if the catalyst is in a DPF wall. The reviewer is not sure how the control of this loading is effecting the performance of the system.

Reviewer 3:
This reviewer observed that this CRADA project is working to develop a SCRF system for HD applications. The approach seems to be mainly driven by the CRADA partner. Incorporation of an oxy-cat into the SCR is

designed to promote oxidation of NO to NO_2 to improve the passive oxidation of PM, thereby improving the backpressure in the SCRF. The reviewer remarked that the Milestones seem to have already gotten off-schedule with the February 2017 milestone still marked in progress as of April.

Reviewer 4:
This reviewer commented that the approach seems naive. This reviewer stated that it will be extremely difficult, if not impossible, to balance high SCR conversion with high soot oxidation. The SCR performance as presented was not state of the art. The reviewer said that relying on NO_2 is not a viable long-term strategy.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that there is incredible progress in only 1 year. The reviewer noted that the project team has screened selective catalytic oxidation (SCO) catalysts, as indicated by the fast SCR reaction and NO_2 generation for various catalysts (Slide 10). This slide shows high NO_2 generation (inset) and impact on SCR performance, with the strong SCO showing the slowest SCR and highest NO_2 emission. This seems to imply a moderate catalyst is best, and if you go too high on NO_2 oxidation, you risk NH_3 oxidation (worst SCR and higher NO_2 emission). The reviewer acknowledged the project showed that optimization involves a holistic approach with Cu and SCO. The impact on passive regeneration is modest (drops T approximately 30°C) at around 500°C. Thermodynamic NO_2 levels are very low at this temperature, but generate much NO_2 at the lower temperatures. This indicates the concept does not seem to impact passive regeneration at the typical temperatures used in "active-passive regen" (increase T to activate passive regen) of about 45°C. The reviewer offered that CO_2 might not be a good metric for passive regeneration, as CO is the main product.

Reviewer 2:
This reviewer affirmed that it was good to show the effects of the fast and standard SCR reactions.

Reviewer 3:
The reviewer noted that the project is on schedule and the current data look promising. It is early in the project and the reviewer looks forward to seeing how the performance of the system is optimized.

Reviewer 4:
The reviewer observed that this project is in the beginning stages (approximately 15% complete) and to date, has shown that the NO_2 balance is impacted by the oxy-cat addition, and shown the impact of particulates on the SCR reaction.

Reviewer 5:
The reviewer said that work with Cu-ZSM-5 was not relevant. The reviewer noted that it is unclear how the filters are being coated.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer remarked that the project has good collaboration with PACCAR and component suppliers.

Reviewer 2:
The reviewer suggested that due to the nature of the CRADA, the collaboration is good, though it would be nice to have an academic partner who might focus on some of the characterization work.

Reviewer 3:
The reviewer noted that there is one partner in this CRADA, which is not surprising but also not very collaborative.

Reviewer 4:
The reviewer commented that it is difficult to see how the team behind PACCAR is involved, but this person does not see any miss-steps with the PNNL-PACCAR relationship.

Reviewer 5:
This reviewer observed that it is not clear who PACCAR is collaborating with. No other companies were named except Corning.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that it is obvious from the proposed future research that the researcher has a plan for reaching the project objective.

Reviewer 2:
This reviewer said that the continuing optimization and evaluation seems logical.

Reviewer 3:
This reviewer stated that many in the industry use an aggregate SCR NO_x conversion efficiency. The reviewer suggested combining the fast and standard SCR NO_x conversion data into an aggregate (with assumptions), as this will be valuable to the industry.

Reviewer 4:
The reviewer opined that work on ZSM-5 is a waste of time. This reviewer affirmed that moving to SSZ-13 is correct. The reviewer further remarked that the most important part of the project is the durability study, and S effects need to be included.

Reviewer 5:
The reviewer observed that the proposed future work is an appropriate, but daunting list. This person suggested that if possible (not sure if it is given the CRADA status)—it might be useful to bring in a university partner to help with the characterization work, because there is a lot to do and the impression that this reviewer gets is that things are already starting to fall behind.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer said yes, SCR NO_x conversion improvements will yield better engine plus after-treatment fuel efficiency.

Reviewer 2:
The reviewer stated that diesel engines are inherently more efficient than spark ignited engines. Their drawback are emissions. This person affirmed that if this project plays out and NO/NO_2 emissions are more efficiently reduced, the technology will allow for petroleum displacement.

Reviewer 3:
The reviewer commented that SCR filter regeneration in the SwRI California Air Resources Board low-NO_x program costs a cycle-average nominal 1%-3% fuel penalty. This is approximately one BTE point.

Reviewer 4:
This reviewer said that expecting high SCR performance on a washcoat limited part and also expecting passive soot oxidation is unrealistic to meet any goals for higher efficiency powertrains.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that there has been much progress in 1 year. The budget to take next steps seems reasonable.

Reviewer 2:
The reviewer said yes.

Reviewer 3:
This reviewer noted that the PACCAR cost share is 50%.

Acronyms and Abbreviations

3D	Three dimensional
ACEC	Advanced Combustion and Emissions Control
AEC	Advanced Engine Combustion
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ATP	Advanced Technology Powertrain
BES	Basic Energy Sciences
BMEP	Brake mean effective pressure
BSFC	Brake-specific fuel consumption
BTE	Brake thermal efficiency
C	Celsius
CA50	Crank angle position at which 50% of heat is released
CDC	Conventional diesel combustion
Ce	Cerium
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression Ignition
CLEERS	Cross-cut Lean Exhaust Emissions Reduction Simulations
CN	Combustion noise
CO	Carbon monoxide
CO_2	Carbon dioxide
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
CRF	Combustion Research Facility
Cu	Copper
CuOH	Copper hydroxide
CuZ	Copper sulfanide

dBA	A-weighted decibels
DEGR	Dedicated exhaust gas recirculation
DI	Direct injection
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
EAVS	Electrically Assisted Variable Speed
ECN	Engine Combustion Network
EGR	Exhaust gas recirculation
EOS	Equation of state
EPA	U.S. Environmental Protection Agency
ERC	Engine Research Center
eWHR	Electric waste heat recovery
FCA	Fiat Chrysler Automobiles
FE	Fuel economy, fuel efficiency
FEM	Finite element modeling
FIE	Fuel injected engine
FRESCO	Fast and Reliable Engine Simulation Code
FTP	Federal Test Procedure
FV	Finite volume
FY	Fiscal year
g	Gram
G	Giga
GCI	Gasoline compression ignition
GDCI	Gasoline direct compression ignition
GDI	Gasoline direct-injected
GHG	Greenhouse gas

GM	General Motors Corporation
GPF	Gasoline particulate filter
GPU	Graphics processing unit
GSF	Generic speed form
H_2O	Water
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HCl	Hydrochloric acid
HD	Heavy-duty
HECC	High efficiency clean combustion
HEV	Hybrid electric vehicle
HIL	Hardware-in-the-loop
HPC	High-performance computing
hr	Hour
HRR	Heat release rate
ICE	Internal combustion engine
ID	Ignition delay
K	Kelvin
KERS	Kinetic recovery system
KH-RT	Kelvin-Helmholtz Rayleigh-Taylor
kW	Kilowatt
L	Liter
LD	Light-duty
LDD	Light-duty diesel
LES	Large eddy simulation
LEV	Low-emission vehicle
LLNL	Lawrence Livermore National Laboratory
LNT	Lean NO_x trap

LT	Low temperature
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTGC	Low temperature gasoline combustion
m	Meter
MIT	Massachusetts Institute of Technology
mm	Millimeter
MOU	Memorandum of Understanding
ms	Milliseconds
MW	Megawatt
NASA	National Aeronautics and Space Administration
NETL	National Energy Technology Laboratory
NH_3	Ammonia
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NVO	Negative valve overlap
O_2	Oxygen
OBD	On-board diagnostics
OEM	Original equipment manufacturer
OH	Hydroxide
OpenFOAM	Open source Field Operation And Manipulation
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity
P	Phosphorus
*P*c	Compressed pressure
Pd	Palladium
PEV	Plug-in electric vehicle

PGM	Platinum group metals
PI	Principal Investigator
PM	Particulate matter
PN	Particulate number
PNA	Passive NO_x adsorber
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
R&D	Research and development
RANS	Reynolds-Averaged Navier Stokes
RCCI	Reactivity controlled compression ignition
RCM	Rapid compression machines
RF	Radio frequency
RON	Research octane number
RPM	Revolutions per minute
S	Sulfur
SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SI	Spark ignition
SIDI	Spark ignition direct injection
SMART	Specific, measurable, achievable, relevant, and time bound
SMD	Sauter mean diameter
SNL	Sandia National Laboratories
SOI	Start of ignition
SPH	Smoothed particle hydrodynamics
SULEV	Super ultra-low emission vehicle
SwRI	Southwest Research Institute
T50	Temperature at which 50% conversion occurs

*T*c	Compressed temperature
TFM	Thickened flame model
TWC	Three-way catalyst
U.S. DRIVE	United States Driving Research and Innovation for Vehicle Efficiency and Energy sustainability
UC	Ultra-capacitor
UM	University of Michigan
UQ	Uncertainty quantification
USCAR	United States Council for Automotive Research
UW	University of Wisconsin
VCR	Variable compression ratio
VERIFY	Virtual Engine Research Institute and Fuels Initiative
VOF	Volume of fluid
VTO	Vehicle Technologies Office
VVA	Variable valve actuation
VVT	Variable valve timing
W	Watt
WHR	Waste heat recovery

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2. Electric Drive Technologies

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Electric Drive Technologies R&D subprogram funds programs with partners in academia, national laboratories, and industry. The subprogram emphasizes material, device, and component innovations to significantly reduce the cost, weight, and volume of electric drive systems. The subprogram supports material and process innovations to achieve significant cost reduction in power electronics, electric motors, and integrated electric drive systems by supporting two areas: Electric Drive Technologies Research and Electric Drive Technologies Development.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE Vehicle Technologies Office (VTO) subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: edt000 Presentation Title: Overview of the DOE VTO Electric Drive Technologies R&D Program
Principal Investigator: Steven Boyd (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer asserted that the program area was adequately covered. The various technology areas and their long-term progression and impact on overall performance targets have been covered.

Reviewer 2:
The reviewer agreed that the program area was adequately covered in the presentation.

Reviewer 3:

The reviewer stated yes.

Reviewer 4:
The reviewer commented that this review covered the electric vehicle power electronics, electric drive system, and charging infrastructure. The reviewer noted that the electric drive (ED) area was adequately covered.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer stated that there is a very good balance and a clear roadmap in terms of developing and maturing the different technology areas to meet the various performance targets.

Reviewer 2:
The reviewer observed that near- and mid-term research is emphasized which is appropriate given the market need for improved electric drive systems to drive faster market penetration. Long-term research efforts are focused on permanent magnet materials and soft magnetic material modeling. This is appropriate given the support that is available for long term component research available in other agencies.

Reviewer 3:
The reviewer stated yes, and clearly observed more focus on mid- to long-term approaches, which should be the focus.

Reviewer 4:
The reviewer stated yes; the ED system cost and performance target are clearly called out for 2020 and 2025.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer enthusiastically stated yes.

Reviewer 2:
The reviewer agreed that important issues and challenges were identified; the challenges are clear and there is a good mix of projects to address them.

Reviewer 3:
The reviewer said yes, and added that there is an opportunity to tie challenges together. For example, this reviewer highlighted progression to greater than 600 volt (V) batteries coupled with standards development for direct-current (DC) fast charging at voltage levels greater than current Society of Automotive Engineers (SAE)

1772 and Chademo standards, which are presently limited. As another example, the reviewer inquired about what should be the maximum high-power charging 350+ KW power charge voltage.

Reviewer 4:
The reviewer noted that key challenges around cost, power, and power density were identified. Challenges pertaining to reliability, lifetime, and sustainable manufacturing were not explicitly identified.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer enthusiastically stated yes.

Reviewer 2:
The reviewer stated yes, there is a good plan and roadmap to address the issues and challenges.

Reviewer 3:
The reviewer noted that categories of technology solutions were identified for addressing challenges in reducing cost, improving power capability, and increasing power density. There was a clear link between the technology solutions and the issues and challenges.

Reviewer 4:
The reviewer noted that the $6/kW 2025 Electric Drive Technology (EDT) system target for a 100 kW EDT system and a 100,000-unit annual production volume is certainly a challenge. The reviewer recommended having a targeted bill of material with cost targets by component to address issues by specific component technology with basic research focus to address the specific challenge of that component.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer stated yes, the progress compared to the previous year has been clearly identified.

Reviewer 2:
The reviewer stated yes and noted that the 100kW traction inverter cost targets are benchmarked between 2017, 2020, and 2025.

Reviewer 3:
The reviewer noted that a chart presenting multi-year progress, achieved and forecast, for reducing cost was presented. The status of each technology focus area was presented. There was not a year-to-year comparison between 2016 (previous year) and 2017 (current year) results.

Reviewer 4:
The reviewer stated that progress was less clearly benchmarked against the previous year. The reviewer looked at the presentation file from 2016 to know what was reported in the previous year. The reviewer noted that an area of improvement would be to have a more specific slide to highlight areas from 2016 that are continuing and, more importantly, what was found to not be practical technology to continue as a focus area for 2017 and beyond.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer stated yes, there is a good mix of projects that clearly address the problems and barriers VTO is trying to solve.

Reviewer 2:
The reviewer stated yes, the projects are addressing the goal of reducing the cost of the electric drive system to $6/kw by 2025. There is a broad portfolio of projects in power electronics and electric machines addressing this challenge from a wide perspective.

Reviewer 3:
The reviewer stated yes, the projects in this technology area are addressing the broad problems and barriers that VTO is trying to solve and observed that certainly the biggest challenge of cost should continue to guide the technology area.

Reviewer 4:
The reviewer stated yes, the projects in this technology area are addressing the broad problems and barriers that VTO is trying to solve. The reviewer noted that key technologies such as silicon carbide (SiC) semiconductor efficiency improvements, non-rare-earth materials for motors, and film capacitors for traction inverters are listed to break through.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer stated yes, the program area is focused on the right technology areas. It is well-managed and shows a path to addressing VTO's needs

Reviewer 2:
The reviewer stated yes, the program area appears to be focused, well-managed, and effective in addressing VTO's needs.

Reviewer 3:
The reviewer stated yes, the program is clearly focused on the VTO's needs. The electric drive system is a key component of the VTO's goal of increasing energy efficiency in the automotive industry by funding the development of technology that will accelerate the market penetration of electric vehicles EVs). The program appears to be well-managed in that an appropriate allocation of resources has been made between power electronics and electric machines, and that the performance targets for each technology have been clearly defined. The program appears to be effective in that the majority of projects appear to be making significant progress towards meeting their targets.

Reviewer 4:
The reviewer stated yes, the program area appears to be focused, well-managed, and effective in addressing VTO's needs. An improvement could be a list of projects and funding level as an appendix to show how the fiscal year (FY) budget is being spent to address VTO needs. So what was spent on what projects in 2016 versus the reduction in 2017 to give us an idea what program areas are being emphasized.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer noted that the key strength is the diversification and broad range of technology areas covered, all of which are critical to meeting the performance targets and VTO's needs. The reviewer stated that there are no key weaknesses but more verification of the technologies developed in an actual system would add more value.

Reviewer 2:
The reviewer commented that a key strength of the projects in this focus area is the support of development of advanced functional materials (semiconductors, magnetics, capacitors, insulators, and conductors) with

properties optimized for high-power density and high-efficiency electrical machines. The development of these materials in concert with the development of power electronic and machine systems promotes fertile cross-collaboration between research and engineering communities that otherwise rarely interact. This accelerates the development of materials technologies that meet system level needs, and expands the design space of machines that can quickly take advantage of unique properties of new materials. The development of wide bandgap (WBG) power modules stands out as an area where the materials and systems teams have effectively collaborated.

The reviewer noted that a weakness of this program area is that the path to market of many of the new technologies are not always completely clear. Deeper involvement by material and component manufacturers, both domestic and foreign, would accelerate the commercialization of these new technologies to the scale needed to supply the automotive and mobility industries. The development of polymer multilayer capacitors is a potentially transformational technology that could fail to achieve market acceptance if the development of the production-scale equipment is not successful.

Reviewer 3:

The reviewer identified key strengths as increasing DC fast charge technology and WBG technologies. The reviewer identified a weakness as lack of cross connection to motor technology and proposed a WBG enabled motor or a WBG enabled DC fast charging topology.

Reviewer 4:

The reviewer stated that the overall system cost target is clear but the sub-module cost target needs further development.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer state yes, the projects are novel and show promise in terms of addressing the barriers. In some cases, the practical aspects need to be better taken into consideration to make sure that there is ultimately a good path for commercialization.

Reviewer 2:

The reviewer noted that there is a range of approaches being pursued with levels of novelty that vary with the risk being undertaken. Development of codes and standards are an example of a low-risk approach that will likely lead to modest, but entirely necessary, improvements in marketability of the power electronic and electric drive technologies. Truly innovative efforts, such as the computational modeling of soft magnetic materials, are addressing foundational problems in the physics of magnetic materials. Success is not guaranteed, and may depend on the status of high-performance computing technology. However, the reward for successfully innovating in this area could be a substantial improvement in the efficiency of systems that use soft magnetic materials.

Reviewer 3:

The reviewer stated yes, these projects represent novel and/or innovative ways to approach these barriers and cautioned that the approaches might be so novel that they may be difficult to manufacture in some instances.

Reviewer 4:

The reviewer stated yes, these projects represent novel and/or innovative ways to approach these barriers.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

The reviewer responded yes, the program area has engaged appropriate partners.

Reviewer 2:
The reviewer responded yes, the program has engaged appropriate partners in industry, academia, and national laboratories. More involvement by foreign and domestic component and material manufacturers may accelerate the market penetration of these technologies. More coordination with National Aeronautics and Space Administration and U.S. Department of Defense laboratories would promote allocation of resources that are not being addressed in aerospace and naval electrification programs.

Reviewer 3:
The reviewer responded yes, key partners are represented. In some cases, key technology does reside outside the United States and there might be some need to explore when and at what level those key technical suppliers could be effectively engaged to bring their technology to the United States—like was done with Hitachi motors in the Kentucky plant, and Danfoss in New York, etc.

Reviewer 4:
The reviewer commented that, in general, the answer is yes, the program area has engaged appropriate partners, but more collaboration with industry and academia is needed. The more effective collaboration seems to be among the national laboratories.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer stated yes, the program area is effectively collaborating with its partners.

Reviewer 2:
The reviewer thought the program was collaborating with partners effectively and noted that the key is manufacturing technology to commercialize the technology.

Reviewer 3:
The reviewer stated yes, the program area is collaborating with partners effectively.

Reviewer 4:
The reviewer noted that better collaboration with industry and academia is needed.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer could not identify any gaps in the technology portfolio.

Reviewer 2:
The reviewer noted that the portfolio seems comprehensive and complete. One area that might require more attention is advanced manufacturing especially additive manufacturing for electric machines.

Reviewer 3:
The reviewer commented that methods for doubling component life (300,000 miles) for new mobility services could be a new addition to the portfolio.

Reviewer 4:
The reviewer indicated that it looked like the film capacitor has a larger gap in the portfolio.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer noted that advanced manufacturing, especially additive manufacturing in electrical machines, could be more adequately addressed as well as more integrated systems and fully integrating the power electronics and electric machines.

Reviewer 2:
The reviewer commented that reliability, lifting, and sustainable manufacturing are topics that would benefit from increased attention.

Reviewer 3:
The reviewer stated that perhaps the need for power system and drive system safety architecture for autonomous vehicles could be more adequately addressed; in particular, the reviewer pointed out what kind of potential redundancy, safety and reliability is needed.

Reviewer 4:
The reviewer opined that thermal material could be more adequately addressed.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer stated that advanced manufacturing, especially additive manufacturing in electrical machines and more integrated systems and fully integrating the power electronics and electric machines, should be considered for additional funding.

Reviewer 2:
The reviewer commented that system prognostics and non-destructive evaluation and testing technology are areas that would help promote the market penetration of cost-competitive electric vehicles should be considered for additional funding.

Reviewer 3:
The reviewer did not know of any areas that should receive additional funding.

Reviewer 4:
The reviewer stated that a higher voltage system (e.g., 800V) should receive additional funding.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer stated that focusing more on advanced materials, advanced manufacturing and more integrated systems is a new way to approach barriers.

Reviewer 2:
The reviewer recommended the goal of avoiding rare-earths in motor technology given the current market conditions for commodities and specialty metals. While future supply shocks may always be a possibility, this reviewer indicated that there may be benefits in shifting focus away from reducing rare-earth content back towards increased performance.

Reviewer 3:
The reviewer had no suggestions.

Reviewer 4:
The reviewer had no suggestions.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer recommended that the program continue the laboratory focus on materials and commercial original equipment manufacturer (OEM), and suppliers for component developments.

Reviewer 2:
The reviewer had no further suggestions.

Reviewer 3:
The reviewer had no other suggestions to make.

Reviewer 4:
The reviewer had no suggestions.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 2-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
edt015	Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors	Iver Anderson (Ames Laboratory)	2-12	3.60	3.60	3.50	3.30	**3.55**
edt061	Cost-Effective Fabrication of High-Temperature Ceramic Capacitors for Power Inverters	Balu Balachandran (ANL)	2-16	3.50	3.50	3.67	3.50	**3.52**
edt067	High-Efficiency High-Density GaN-Based 6.6kW Bidirectional On-Board Charger for PEVs	Charles Zhu (Delta Products Corporation)	2-18	3.50	3.25	3.25	3.38	**3.33**
edt074	Non-Rare Earth Electric Motors	Tim Burress (ORNL)	2-21	3.29	3.14	3.00	3.00	**3.14**
edt075	Electric Motor Thermal Management	Kevin Bennion (NREL)	2-27	3.08	3.25	3.25	3.00	**3.18**
edt076	Electric Drive Inverters	Madhu Chinthavali (ORNL)	2-32	3.00	2.75	3.00	2.75	**2.84**
edt077	Wireless Power Transfer Integrated Chargers	Veda Galigekere (ORNL)	2-34	3.00	2.88	2.75	3.00	**2.91**
edt078	Power Electronics Thermal Management	Gilbert Moreno (NREL)	2-37	2.67	2.83	3.50	2.67	**2.85**
edt079	Materials for Advanced Packaging	Andy Weresczack (ORNL)	2-40	3.13	3.00	3.25	3.13	**3.08**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
edt080	Performance and Reliability of Bonded Interfaces for High-Temperature Packaging	Paul Paret (NREL)	2-43	3.25	3.00	3.25	3.25	**3.13**
edt081	Multilayered Film Capacitors for Advanced Power Electronics and Electric Motors for Electric Traction Drives	Deepak Langhe (Polymer Plus)	2-45	3.50	3.33	3.33	3.33	**3.38**
edt082	Highly Integrated Wide Bandgap Power Module for Next Generation Plug-In Vehicles	Brian Peaslee (General Motors)	2-47	3.25	3.13	3.00	3.38	**3.17**
edt083	650V SiC Integrated Power Module for Automotive Inverters	Monty Hayes (Delphi Automotive Systems, LLC)	2-51	3.00	2.88	3.00	2.88	**2.92**
edt087	Electrical Performance, Reliability Analysis, and Characterization	Tim Burress (ORNL)	2-54	3.30	3.20	3.20	3.20	**3.23**
Overall Average				**3.23**	**3.15**	**3.20**	**3.11**	**3.17**

Presentation Number: edt015
Presentation Title: Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors
Principal Investigator: Iver Anderson (Ames Laboratory)

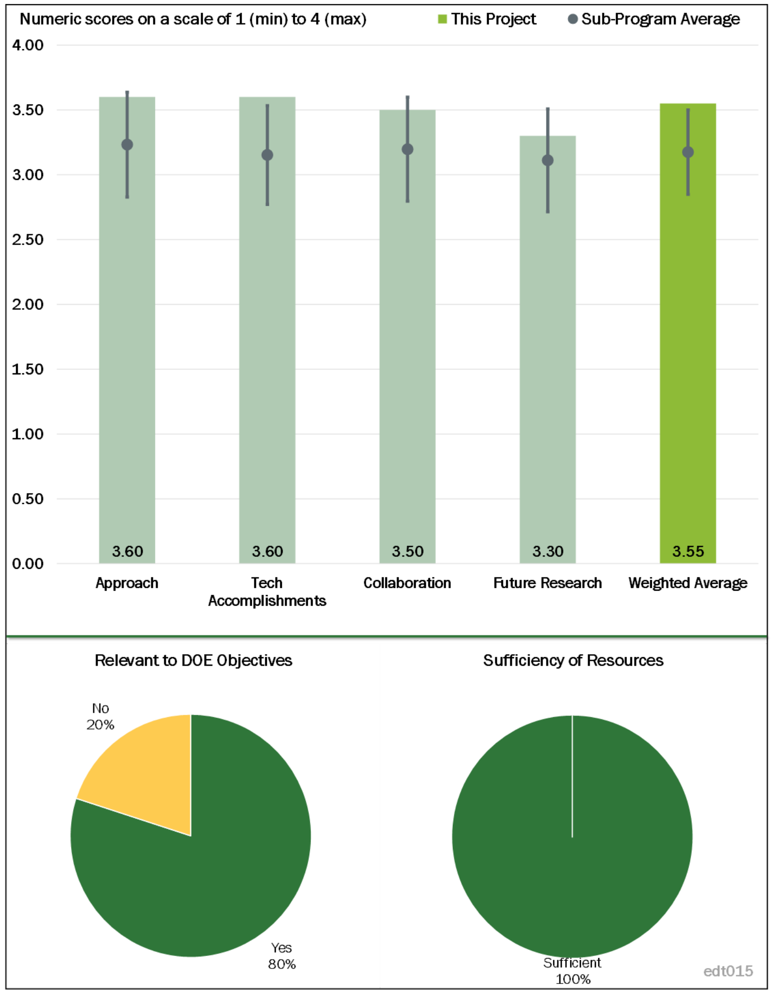

Figure 2-1 - Presentation Number: edt015 Presentation Title: Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors Principal Investigator: Iver Anderson (Ames Laboratory)

Presenter

Iver Anderson, Ames Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked the approach for this project is to develop comprehensive models for the magnetic behavior of materials, which drive the specific processing steps in the fabrication process. This is a great approach, as it leads to a greater understanding about which steps lead to different characteristics. An example was given in the presentation about how the modelling approach saved time and effort when investigating the effects of adding nickel.

Reviewer 2:

The reviewer said that the project approach dives into the physics and material properties of the targeted and new magnetic materials. The approach is very systematic, and feasible.

Reviewer 3:

The reviewer remarked that the investigator has clearly laid out near-term and long-term non-rare-earth (RE) magnet development work with how a super aluminum-nickel-cobalt-(AlNiCo) magnet will be realized.

Reviewer 4:

The reviewer observed a very systematic approach.

Reviewer 5:

The approach is quite nice and good performance has been achieved. The reviewer would like to see an approach slide that discusses various aspects of the problem and challenges of the non-RE magnets.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer remarked the project is making quantifiable progress across the spectrum.

Reviewer 2:
The reviewer remarked that the project is making great strides to understand at a material level what is happening with the magnetic materials. The formation process, and certain processes that cause variation, will help manufacturers make higher quality magnets. The project completed bulk magnets in March, but did not present magnetic properties yet. This reviewer noted that some sort of physical testing is needed, for a go/no go decision, before moving on to the next iteration.

Reviewer 3:
The reviewer believed the authors are making good progress towards the DOE goal. One thing the reviewer would like to see is the cost target for these magnets and whether they can be achieved in the near-term.

Reviewer 4:
The reviewer observed the team varied the magnet composition in order to determine the tradeoffs among saturation, remanence, coercivity, and energy product, leading to optimization of the magnet. The magnet's coercivity was 8% higher than the previous year, though the other major parameters decreased. However, the team has a plan in place to further optimize the magnet.

Reviewer 5:
The reviewer said apart from conducting basic research related to non-RE magnets for electric motors, the DOE VTO should encourage the investigator to collaborate either with industry or a university, and the project must build an electric machine that could be driven by inverter. This will allow the investigator to see how super-AlNiCo performs in an inverter-fed application, including any abnormal operating conditions of an inverter, such as an unsymmetrical fault in the inverter.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that this project has a very good team. It covers research laboratories, magnet manufacturers, motor manufacturers and vehicle OEMs.

Reviewer 2:
The reviewer noted that the team is collaborating with several academic and industrial partners to develop technical targets for the program.

Reviewer 3:
The reviewer remarked that university, industry, and DOE-laboratory collaboration exists in this project.

Reviewer 4:
The reviewer commended the amount of engagement on this project, but a way must be found to have regular discussion with OEMs on their magnet needs/types.

Reviewer 5:
The reviewer suggested that the group start making progress towards building a prototype by involving OEM Tier 1 suppliers.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, , mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the planning seems logical as a next step.

Reviewer 2:
The reviewer commented the project has a good plan for future research, where the theoretical models will be expanded and improved and the magnet fabrication process will be further optimized.

Reviewer 3:
According to the reviewer, the project has good overall goals listed, but is lacking milestones to gauge progress. The project had relevant risks listed, but there were not any alternative development pathways presented for mitigating risk.

Reviewer 4:
The reviewer remarked it would be desirable if test samples are used for electric motor fabrication.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that the magnets being developed in this project are an enabling technology, supporting the manufacture of lower cost electric motors. Electric motors have been proven to reduce petroleum use in hybridized vehicles.

Reviewer 2:
The reviewer commented the project supports DOE objectives by developing a low-cost motor for electrified vehicles.

Reviewer 3:
The reviewer said that this project develops new magnet materials that can replace RE magnets, thus eliminating or reducing exposure to the highly volatile RE magnet market.

Reviewer 4:
This reviewer did not hear the investigator talking about how his research will impact DOE’s petroleum displacement objective. The reviewer said if using super-AlNiCo allows to shrink the size of an electric motor while lowering its weight yet keeping high-efficiency operation intact over the temperature, it can be justified that the proposed research would meet DOE’s objective for petroleum replacement.

Reviewer 5:
This reviewer’s only concern is that market dynamics change quicker than the research direction can to answer a specific question. Understanding fundamentals or basic science seems to be the best way for a project to stay relevant if it is followed up by educating industry with findings.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented the resources are sufficient and a good team of national laboratories is formed to tackle the challenges.

Reviewer 2:
The reviewer said the resources appear to be appropriate for the project.

Reviewer 3:
The reviewer said the investigator did not mention that resources were lacking.

Reviewer 4:
The reviewer said that the project research is progressing well with the resources. It appears the project is on track, but the reviewer pointed out there is a lack of milestones to compare against.

Presentation Number: edt061
Presentation Title: Cost-Effective Fabrication of High-Temperature Ceramic Capacitors for Power Inverters
Principal Investigator: Balu Balachandran (Argonne National Laboratory)

Presenter

Balu Balachandran, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the planned and executed testing under real-application conditions is well thought out.

Reviewer 2:

The reviewer said that this seems to be a good approach to produce low-cost, high-temperature capacitors. The higher temperature rating of these capacitors will allow size reduction of the inverter system.

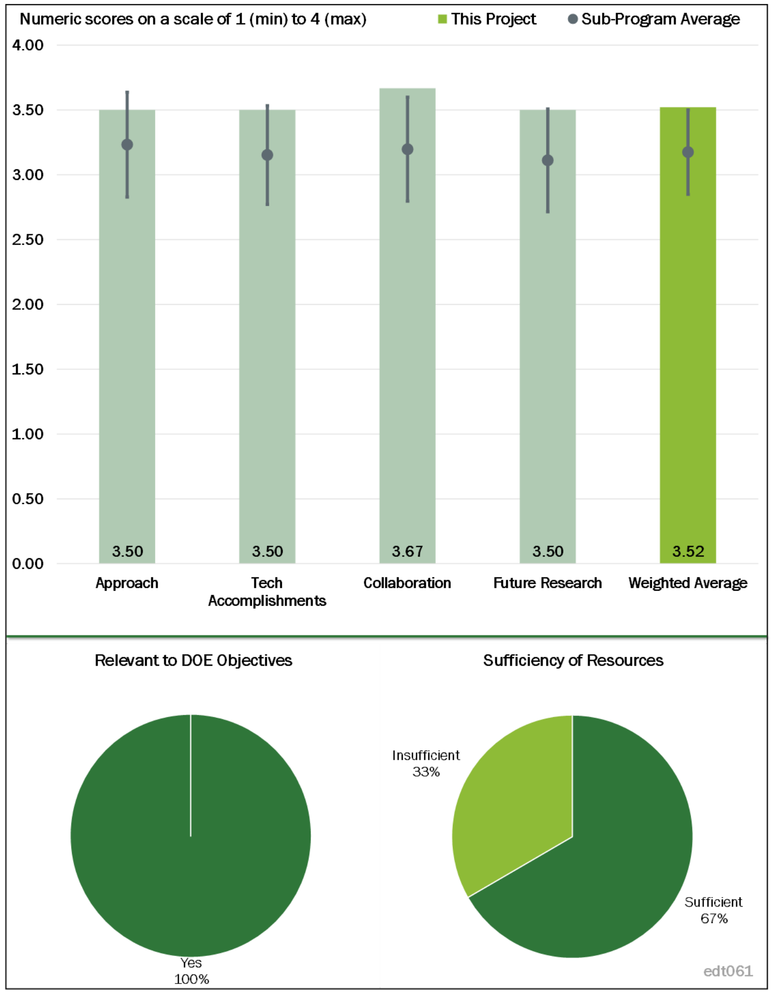

Figure 2-2 - Presentation Number: edt061 Presentation Title: Cost-Effective Fabrication of High-Temperature Ceramic Capacitors for Power Inverters Principal Investigator: Balu Balachandran (Argonne National Laboratory)

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said that the capacitors appear to perform well and the team is making good progress on scaling up the system for larger components.

Reviewer 2:

The reviewer commented that accomplishments have been substantial, but this reviewer would have liked to see a faster pace of work than it has been over the years.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the team partnered with Delphi to determine technical specifications, Sigma Technologies for developing a large-scale fabrication process, and Penn State University for characterization and testing. The reviewer found that this seems to be a good combination for the work.

Reviewer 2:
This reviewer would like to see direct OEM involvement.

Reviewer 3:
The reviewer noted a great diversity of experience, integration, and contribution in the value chain.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

No comments were received in response to this question.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that low-cost, high-temperature capacitors are critical to meeting the size and cost targets of inverter systems.

Reviewer 2:
The reviewer said that the project definitely addresses a key element of what is needed as industry moves to WBG-based power electronics.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed the funding level slowed this work.

Reviewer 2:
The reviewer said that the resources for this project appear to be sufficient.

Presentation Number: edt067
Presentation Title: High-Efficiency High-Density GaN-Based 6.6kW Bidirectional On-Board Charger for PEVs
Principal Investigator: Charles Zhu (Delta Products Corporation)

Presenter

Charles Zhu, Delta Products Corporation

Reviewer Sample Size

A total of four reviewers evaluated this project

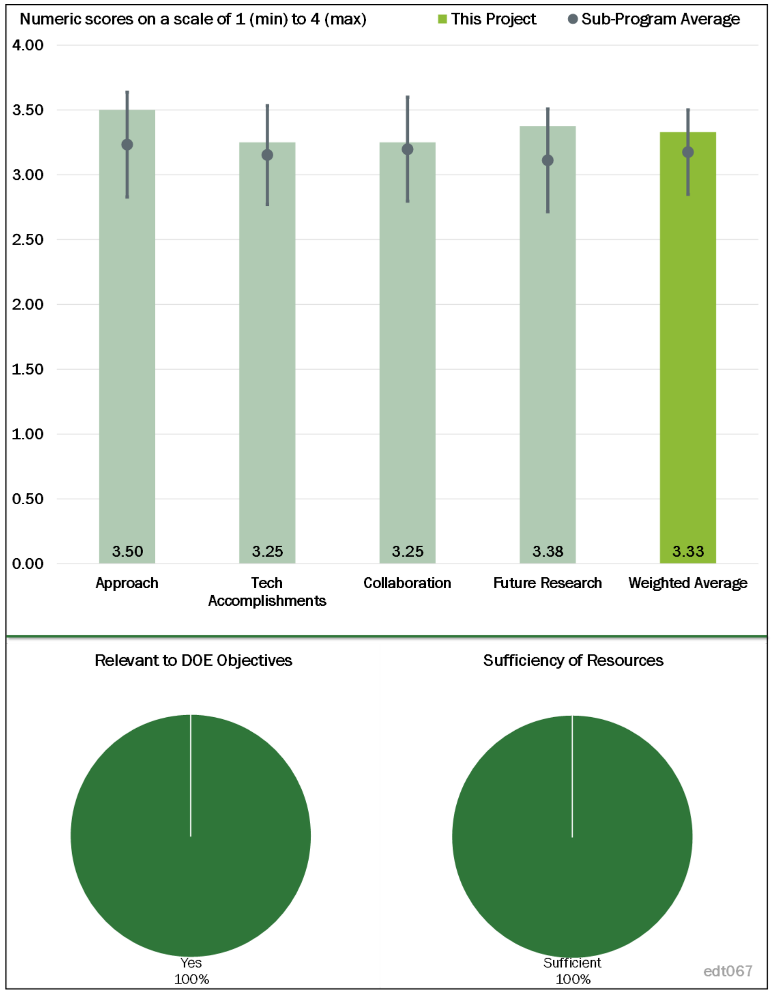

Figure 2-3 - Presentation Number: edt067 Presentation Title: High-Efficiency High-Density GaN-Based 6.6kW Bidirectional On-Board Charger for PEVs Principal Investigator: Charles Zhu (Delta Products Corporation)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach is technically sound, and has produced promising results.

Reviewer 2:

The reviewer commented that the investigator has tested three generations of gallium nitride (GaN) metal-oxide-semiconductor field-effect transistor (MOSFETs) while developing a high-efficiency on-board charger for plug-in electric vehicles (PEVs) and then he decided the best GaN MOSFET that works in his applications rather than selection based on lowest Rds(on). The investigator approach that a bi-directional on-board charger could allow PEVs to work as emergency power source, particularly in an area affected by natural disaster, could be very appealing to early adopters of electric cars.

Reviewer 3:

The reviewer commented that a basic approach is laid out to address the objectives. Other than building A and B samples with GaN, it is unclear to this reviewer how or what will accomplish Delta's end goals.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer commented that progress has been very good, and demonstration testing has gone extremely well.

Reviewer 2:
The reviewer detailed that a prototype charger was fabricated and tested with a 30° Celsius (C) coolant to extrapolate data for higher temperature coolant. Efficiency was measured and found to be 95% at 50% output, which could be the case for most of the time for the proposed on-board charger while handling power flow in either redirection.

Reviewer 3:
The reviewer said that progress on hardware was excellent, and this reviewer would like to see more data.

Reviewer 4:
The reviewer observed good progress and learnings, overall. The reviewer had some concern that B-samples are falling well short of ambient design intent specifications and that no attempt has been made at conducting an electromagnetic compatibility (EMC) survey, knowing that EMC is a concern when pushing higher switch speeds with WBG semiconductors, and that while the semi's temperatures are good, other active and passive components in a WBG power conversion system may prove to be a challenge.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that working directly with the device manufacturer and an OEM is exactly the correct path for this project.

Reviewer 2:
The reviewer observed a solid team with wide participation.

Reviewer 3:
The reviewer noted that university/industry collaboration exists in the project. The converter topology proposed by the Virginia Tech University Center for Power Electronics Systems is completely different than converter topology developed by Delta, therefore, it is difficult to assess how effective collaborative activity could be for this project.

Reviewer 4:
The reviewer observed good collaboration with industry and academia. The reviewer would have liked to have seen the National Renewable Energy Laboratory (NREL) contributing to thermal work, and/or Oak Ridge National Laboratory (ORNL) contributing to power conversion, as a team member to round out the team's capabilities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that size reduction and improved thermal performance are critical to production application. Delta has a solid plan for this in future testing/development.

Reviewer 2:
The reviewer remarked that the commercialization plan is stated in the project report, and this should help meet DOE's "Technology to Market" goal. Also, the reviewer pointed out that the investigator has stated how he plans to improve developed technology, which should support his objectives towards commercialization plans for developed technology despite the excessively high price of GaN MOSFETs.

Reviewer 3:
The reviewer said these are good, natural, next steps in development, but not necessarily research.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that lower cost, high-performance and smaller volume chargers that can operate at higher voltages are critical to mass adoption to electric drive technologies (EDTs).

Reviewer 2:
The reviewer commented that exploring this application of WBG along with new features for the consumers are relevant to the program.

Reviewer 3:
The reviewer said that demonstration by testing high efficiency should allow energy savings; however, the project report does not quantify the petroleum displacement potential due to introduction and mass adoption of the GaN MOSFET-based on-board charger for PEVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that Delta has adequate resources for this project. On vehicle testing, it will be critical to finalize this project.

Reviewer 2:
The reviewer said the investigator did not mention a lack of resources.

Presentation Number: edt074
Presentation Title: Non-Rare Earth Electric Motors
Principal Investigator: Tim Burress (Oak Ridge National Laboratory)

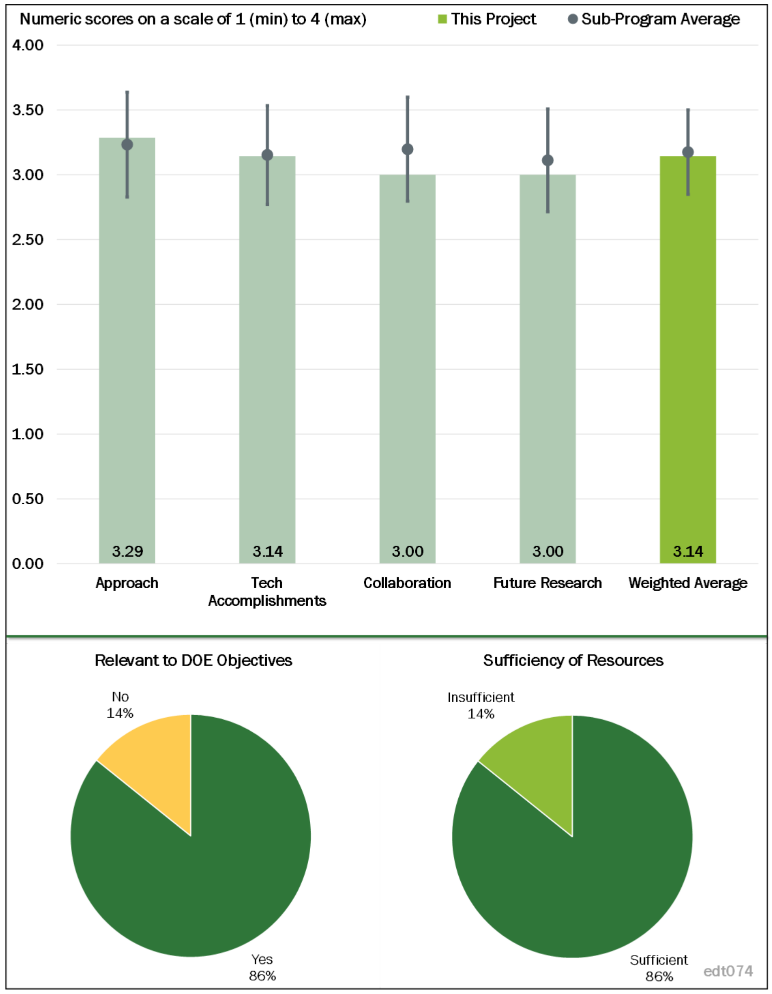

Figure 2-4 - Presentation Number: edt074 Presentation Title: Non-Rare Earth Electric Motors Principal Investigator: Tim Burress (Oak Ridge National Laboratory)

Presenter

Tim Burress, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the project approach of working on modeling, materials, and prototype design/build for validation is a good approach. This project focused on a commercial motor footprint (Prius motor) as a form factor. The reviewer said it is feasible that the improved motor could be integrated into a vehicle such as the Prius for comparative testing in a future program.

Reviewer 2:

The reviewer said that the technical challenges are addressed through modeling and fits well with fundamental work on non-RE magnets in Ames.

Reviewer 3:

The reviewer summarized that the approach is a broad-based approach toward addressing both the system and material level issues facing the development of non-RE containing motors. A robust system design effort has led to the demonstration of a high-power, non-RE containing motor. This prototype development effort was supported by component modeling and characterization efforts that included modeling the loss mechanisms in soft magnetic materials, investigating high-silicon (Si) content steel manufacturing, and investigating high-conductivity carbon nanotube (CNT)/copper (Cu) matrix composites.

The reviewer noted that there appears to be an effective allocation of resources among the various development tasks. The machine design and component characterization tasks are feasible and are integrated with other efforts that provide relevant data, such as thermal conductivity of components such as windings. According to the reviewer, the CNT/Cu conductor development, high-Si steel development, and soft magnetic material modeling are longer-term, higher risk efforts that will face challenges but are potentially transformational.

Reviewer 4:

The reviewer said this is a very good approach to developing new motor technologies that do not depend on RE magnet materials. New core and winding materials are being developed to improve power density and efficiency. Additionally, advanced modelling methods are being developed that will aid the design process.

Reviewer 5:

The reviewer commented that the project covers a broad range of topics, and several of them can have a very significant impact on motor technologies moving forward. The reviewer suggested picking the one or at most two most-promising technologies and focus on further developing them and scaling them up to the point that full-scale motors can be built. The reviewer's opinion is that CNT/Cu conductors should be a focus area.

Reviewer 6:

The reviewer commented that an advanced modeling tool will allow investigators to get a motor model well before a physical machine is built. This will help mitigate any risks, such as needs for unnecessary revisions. If the developed motor model and its parameters are used for some advanced simulation tools (e.g., hardware-in-the-loop), the reviewer recommended simulation to assess how the motor could perform when driven by the inverter.

Reviewer 7:

The reviewer said that the fundamental approach of performing fundamental research to improve motor modeling accuracy first is good. The reviewer pointed out that thermal transfer in windings is good work; however, as seen from Toyota benchmarking by ORNL, and by Bosch, Denso, and General Motors' (GM) applications, bar windings are becoming the leading technique for more effective heat transfer. There is now a baseline to compare improved heat transfer with bar versus fly winding.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer commented that it seems like the investigators are carrying out basic research, which looks great. This reviewer suggested that investigators should explore issues related to the application of the proposed machine. One such example is looking into demagnetization that could occur if the inverter-fed electric machine system experiences unsymmetrical faults in the inverter hardware, which could result in significant direct current (DC) current flow through stator windings.

Reviewer 2:

The reviewer commented that the modeling efforts are building on previous work to increase accuracy and the computational domain. The project investigated thermal characteristics of motor windings, along with an ultra-conductive Cu technology that incorporates CNT into a Cu matrix. The reviewer observed that the project developed new processing methods for low-loss ferrosilicon (FeSi) core materials and completed a motor design.

Reviewer 3:

The project has made noteworthy progress in designing and demonstrating a RE-free motor that exceeds the power and power density targets of the DOE's 2022 EV roadmap. It is not clear if the motor prototypes also meet the efficiency targets over the entire range of speed and power. The reviewer commented that reliability was not addressed. The series/parallel synchronous reluctance (SynchRel) concept is intriguing and opens up regions of performance for completely magnet-free SynchRel machine designs that may not have been addressed before. However, according to the reviewer, the impact of the series/parallel scheme on the complexity and cost of the power electronics and the motor controller was not discussed.

The other technology efforts are longer-term R&D efforts that are critical to long-term competitiveness, but their link to meeting the 2022 targets are not as well defined. The reviewer commented that it is intuitively apparent that an improved ability to model the magnetization processes in soft magnetic materials, based on micromagnetic approaches that are supported by atomistic simulations, should lead to improved motor designs. However, it may not be possible to quantify the degree of expected improvement at this time. The reviewer said that without this information, it is then also not possible to compare the benefit of the simulation approach to the cost of the computational methods needed to realize it. Future work in this space should focus on building transfer functions that connect system level performance metrics to design and microstructure parameters that are used in the computational framework.

Reviewer 4:
The reviewer said that proving the feasibility of a reconfigurable-winding SynchRel machine (six switches) needs technical assessments from power switch packaging, thermal, and motor control parameter changes "on-the-fly"—then compare this to a two-speed gearbox.

Reviewer 5:
The reviewer said that the progress so far is okay but difficult to judge due to lack of quantifiable targets. The reviewer remarked that the authors need to state the targets clearly.

Reviewer 6:
The reviewer pointed out that it would have been helpful if the actual DOE goals were listed side by side with the program metrics, but in the presentation and oral presentation, it was validated that the cost and volume targets were being met. The project is on track with the quarterly milestones. The reviewer said that manufacturing and processing new materials are being worked through as a potential further performance improvement.

Reviewer 7:
The reviewer detailed that a lot of good work has been done but in some cases the outcome might not be very clear, and gave as an example the case of advanced materials modeling at the grain level.

According to this reviewer, it was mentioned that a ferrite motor can accomplish significantly more power within the same volume compared to an interior permanent magnet motor. The reviewer asked how this was accomplished, and asked if a thorough demagnetization analysis/testing especially at very low temperatures was performed.

The concept of a synchronous reluctance machine with reconfigurable windings has been presented. The reviewer noted that the concept of reconfigurable windings has been proposed in literature a long time ago, especially for induction machines. It was never widely adopted due to additional cost and reliability concerns due to the additional circuitry needed. The reviewer said that some comments/discussions about this point should be included.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted strong collaboration exists among ORNL; NREL; University of Wisconsin, Madison; and BorgWarner. These collaborative activities will help investigators solve application related issues.

Reviewer 2:
The reviewer noted that collaborations with Wisconsin, NREL, and Ames appear to be well coordinated and are adding value to the project.

Reviewer 3:
The reviewer commented that it seems there is good collaboration between the different groups within ORNL as well as between ORNL and other national laboratories. The level of collaboration with industrial partners or universities was not very clear.

Reviewer 4:
The reviewer commented that the project has strong collaboration with academia and other labs. The team is coordinating with other projects such as Development of Radically Enhanced AlNiCo Magnets (DREaM) to keep alternative motor design options open. The reviewer remarked that it would have been a stronger collaboration if there was a motor manufacturer as part of the team.

Reviewer 5:
The reviewer said that the team partnered with the University of Wisconsin to aid the motor design and finite element analysis studies. NREL will provide feedback on motor cooling techniques and the team is involved with the DREaM project at Ames. The reviewer would like to see an industry partner here to ensure that the technologies will have a commercialization path.

Reviewer 6:
The reviewer said that the authors need to coordinate with an OEM to understand the requirements of the new magnets and guide research accordingly.

Reviewer 7:
The reviewer said that there seems to be little evidence presented on which partners performed what work on the project. Contributions from the University of Wisconsin, NREL and Ames are noted, but it was not clear what work was performed. The reviewer did not see contributions from BorgWarner.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the team has a good plan for continuing development of their advanced materials, modeling methods, and motor prototypes.

Reviewer 2:
The reviewer commented that the investigator plans to build a prototype.

Reviewer 3:
The reviewer said the goal of building and testing a full scale motor would be very valuable. The key challenge is which areas to focus on and which technologies/learnings would go into this prototype. The reviewer commented this was not very clear.

Reviewer 4:
The reviewer said that the proposed future research is to move to an optimized design based on the phase on results (and experimental findings). There are a few alternative options being followed (and developed) to help mitigate risk, and potentially advance motor designs. The reviewer noted that the project had a couple material-related challenges listed, which were good to track. The project missed a couple of major challenges (torque ripple and acoustic noise) that would need mitigation to enable commercial (and end consumer) acceptance of the SynchRel motor being prototyped.

Reviewer 5:
The proposed future research has parallel tasks centered on numerical and experimental studies of magnetic materials, conductor materials, and advanced electric motors. The go/no-go decision point of having a design projected to meet DOE’s 2020 motor targets is appropriate. The reviewer said the team may wish to clarify if these are year 2020 or year 2022 motor targets.

Reviewer 6:
The reviewer said that in addition to using results from evaluation and materials research to design, build, and test the prototype, the feasibility of using CNT and the high-Si lamination in the motor design needs to be addressed.

Reviewer 7:
The reviewer commented that the authors need to state the targets clearly, which are currently missing and therefore not able to judge any risks that can be anticipated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that it does in reducing dependence on RE magnets.

Reviewer 2:
The reviewer remarked that low-cost non-RE motor solutions are relevant.

Reviewer 3:
The reviewer commented that this project focuses on the important strategic area of reducing RE magnetic materials. This can have a significant impact on sustainability and the cost of traction motors moving forward.

Reviewer 4:
The reviewer pointed out that making a better electric motor would help accelerate hybridization of vehicles, which has been proven to reduce the amount of petroleum required. The new materials being investigated and how to process them for manufacturing has the potential to be a technology leap moment.

Reviewer 5:
The reviewer detailed that the fundamental understanding of magnetic materials imparted by the advanced modeling task may accelerate the introduction of higher performance magnetic materials enabling increased motor efficiency. The development of a non-RE containing motor will increase the sustainability of the supply chain that supports electric vehicle manufacturing. These effects would have the effects of increasing market penetration of higher efficiency EVs, reducing the demand for petroleum in the transportation sector.

Reviewer 6:
The reviewer said this project seeks to develop motor technologies that avoid the market risk associated with RE magnetic materials while maintaining high power density and efficiency.

Reviewer 7:
The reviewer commented that this was not discussed in the project report and during oral presentation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that based on the scope, it seems that allocated funding should be sufficient.

Reviewer 2:
The reviewer commented that the team is progressing in a timely manner.

Reviewer 3:
The reviewer said that the project budget seems appropriate for the level of effort that is in the project scope.

Reviewer 4:
The reviewer found that resources for this project appear to be sufficient.

Reviewer 5:
The reviewer said that the investigator did not mention that resources are lacking.

Reviewer 6:
The reviewer commented that at some point the labs need to engage an OEM and work toward a prototype magnet. This needs to be addressed while planning research.

Reviewer 7:
The reviewer said that it seems the many technical challenges to fabricating and processing FeSi motor laminations and ultra-conductive Cu will require more resources.

Presentation Number: edt075
Presentation Title: Electric Motor Thermal Management
Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

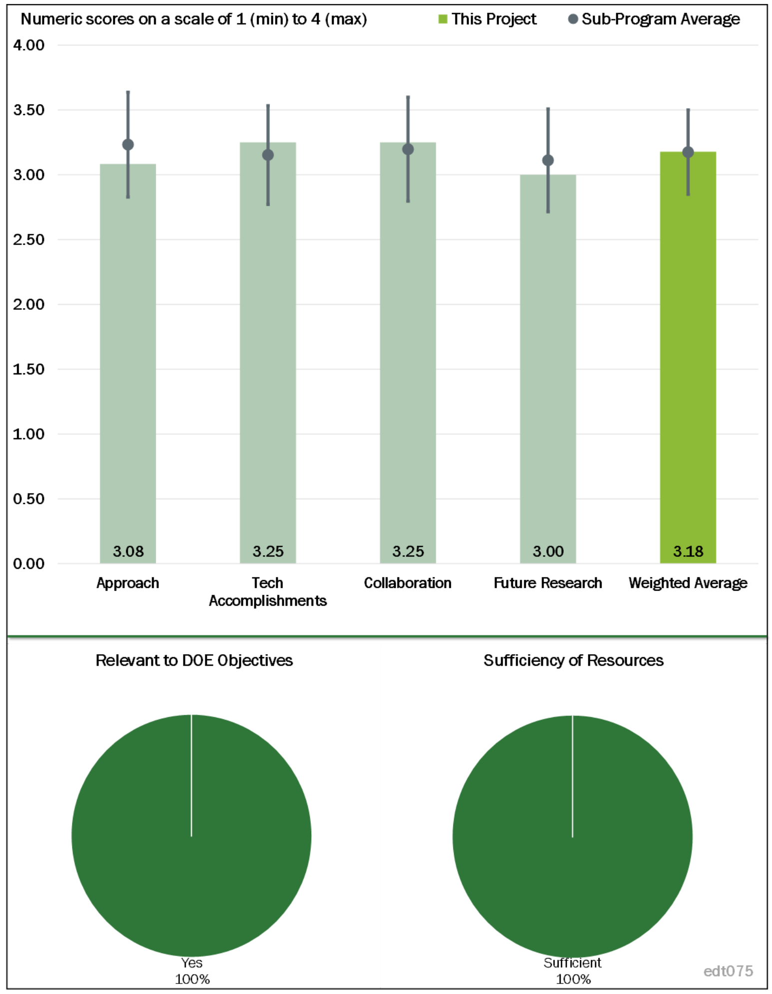

Figure 2-5 - Presentation Number: edt075 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Presenter

Kevin Bennion, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer detailed that the project attempts to experimentally quantify various aspects of thermal management for electric motors. It will become more valuable once these results feed into an electric motor design process and the motor thermal performance is experimentally verified.

Reviewer 2:

The reviewer said that the project has completed a well-designed down-selection method choosing the most appropriate thermal management technologies, and identified the most important material property data that are needed to enable those technologies. Experimental data has been used to validate thermal models using multiple materials. The project is well integrated with motor design efforts at ORNL. The reviewer noted that the interaction with Ames is generating needed data on both the thermal and mechanical properties of AlNiCo permanent magnets.

Reviewer 3:

The reviewer said that this work focuses on performing thermal measurements on motors and developing detailed thermal models. The project will characterize materials and investigate different cooling methods.

Reviewer 4:

The project is focused on motor cooling and is well integrated with other DOE projects. The reviewer prefers providing a strong motivation for the study compared to a traditional approach and the gains in terms of pumping power or performance.

Reviewer 5:
The reviewer said that active cooling of the electric machine will allow size reduction and will improve peak load capability. However, cost and complexity due to active cooling system should be justifiable for a given application.

Reviewer 6:
The project is addressing barriers as they come along, and that they are not laid out. The project is feasible, and supporting others, but less structured then a stand-alone program.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that the team has made good progress on measuring the thermal properties of direct impingement and passive cooling methods. The team has also performed transverse rupture strength and thermal conductivity characterization of the Ames magnet material, along with two AlNiCo comparables.

Reviewer 2:
The reviewer said that the established test setups as well as the experimental results are very useful. Once they feed into an actual motor design process and the motor thermal performance is verified, this work will become even more valuable. The reviewer also commented that the project needs to focus more on quantifying the impact of different insulation materials on the motor's thermal performance, and the long-term/life impact of spray cooling on the insulation system needs to be quantified.

Reviewer 3:
The reviewer found that the project is enabling other projects such as non-RE and DREaM to advance. Thermal management is one of the large barriers to increasing power density in electric motor and power electronics, which enable hybridization and meeting DOE's goals.

Reviewer 4:
The reviewer said that the project has made excellent progress in selecting appropriate thermal technologies, constructing thermal models, and collecting the experimental data needed to validate those models. The availability of the models and data will accelerate the development of energy-efficient EV motors.

Reviewer 5:
The reviewer commented that based on the presentation, the project seems to be on track.

Reviewer 6:
The reviewer commented that basic research work completed including characterization and testing at ORNL and Ames Laboratory.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed good collaboration with other national laboratories as well as industrial partners.

Reviewer 2:
The reviewer said the project is well-coordinated with the motor design effort at ORNL and the AlNiCo development at Ames. The project is sharing appropriate models and data with industry participants.

Reviewer 3:
The reviewer said that collaboration and coordination seems adequate for the project.

Reviewer 4:
The reviewer commented that the main effort described is supporting other projects and institutions. After the modeling is completed, there may be more opportunities for collaboration with academia and motor manufacturers.

Reviewer 5:
The reviewer pointed out that the investigator proactively seeks inputs from the motor industry, which will be extremely valuable for technology transfer from NREL to U.S. industries.

Reviewer 6:
The reviewer said that thermal measurements and models support motor research at ORNL, and the material characterization work supports magnet research at Ames.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the project is focused on extending the model development to system components that more closely represent production designs. This work should be prioritized to accelerate introduction of advanced electric motor designs. The work on new materials is generating valuable data useful for the development of RE-free permanent magnets.

Reviewer 2:
The reviewer commented that the team has a clear plan for future research.

Reviewer 3:
The reviewer said that motor technology that exploits the benefits of WBG devices is needed and the investigator plans to explore insulation systems needed to sustain higher dv/dt and over-voltage caused by fast-switching of a SiC inverter.

Reviewer 4:
The reviewer said that in general, the proposed work is good. The reviewer referenced previous suggestions to build and test a motor prototype to verify the results; investigate impact of different insulation systems; and investigate the long-term/life impact of spray cooling on an insulation system.

Reviewer 5:
The reviewer said that the project seems to be doing good work supporting other projects, but does not appear to be a stand-alone effort. The project described supporting a non-RE project, and Ames-led magnet development. The project goes until 2019, but milestones or goals past September 2017 are not listed. The reviewer pointed out that barriers, risks, and alternative pathways were not listed.

Reviewer 6:
The reviewer said that the planning of the future work was to test non-RE magnets but the challenges associated with the new magnets was not clearly presented. The work seems a repeat of the past without demonstrating any novelty.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that determining the optimal cooling methods for motor windings should lead to higher power density and/or a longer lifetime of the motors. The characterization work supports development of new magnetic materials, which will reduce exposure to the volatile RE magnet market.

Reviewer 2:
The reviewer said that thermal management is a key technology area that enables meeting performance metrics of traction motors and hence meeting the overall electric drivetrain performance targets.

Reviewer 3:
The reviewer commented that this project is a supporting effort for other projects, enabling them to increase petroleum displacement. Thermal management is one of the larger challenges to shrinking down the physical footprint of power electronics and motors, and this work could help enable those more power dense packages.

Reviewer 4:
The reviewer remarked that this project is providing thermal models and data that may accelerate the introduction of energy efficient electric motors. This may increase the market penetration of EVs, leading to the reduction of petroleum consumed in the transportation sector.

Reviewer 5:
The reviewer detailed that active cooling of an inverter-fed electric motor will shrink the size and reduce the weight of an electric machine, which could make electric drivetrains lighter. Light-weight vehicles are going to consume less fuel. However, according to the reviewer the investigator did not quantify petroleum displacement data. The reviewer encouraged the investigator to quantify by using a baseline example of how the active cooling proposed will reduce the size and weight of an electric motor, thereby resulting in fuel savings.

Reviewer 6:
The reviewer said the project supports potential use of non-RE magnets, and this project does not support petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that project resources seem sufficient for the scope of work.

Reviewer 2:
The reviewer said that based on the scope, the funding level seems sufficient.

Reviewer 3:
The reviewer pointed out that the project did not define milestones very far out (only until September 2017). As these are in progress, there appears to be sufficient resources.

Reviewer 4:
The reviewer found that resources for this project appear to be sufficient.

Reviewer 5:
The reviewer commented that the investigator did not mention that resources are lacking.

Reviewer 6:

The reviewer said that resources are more than sufficient for the project.

Presentation Number: edt076
Presentation Title: Electric Drive Inverters
Principal Investigator: Madhu Chinthavali (Oak Ridge National Laboratory)

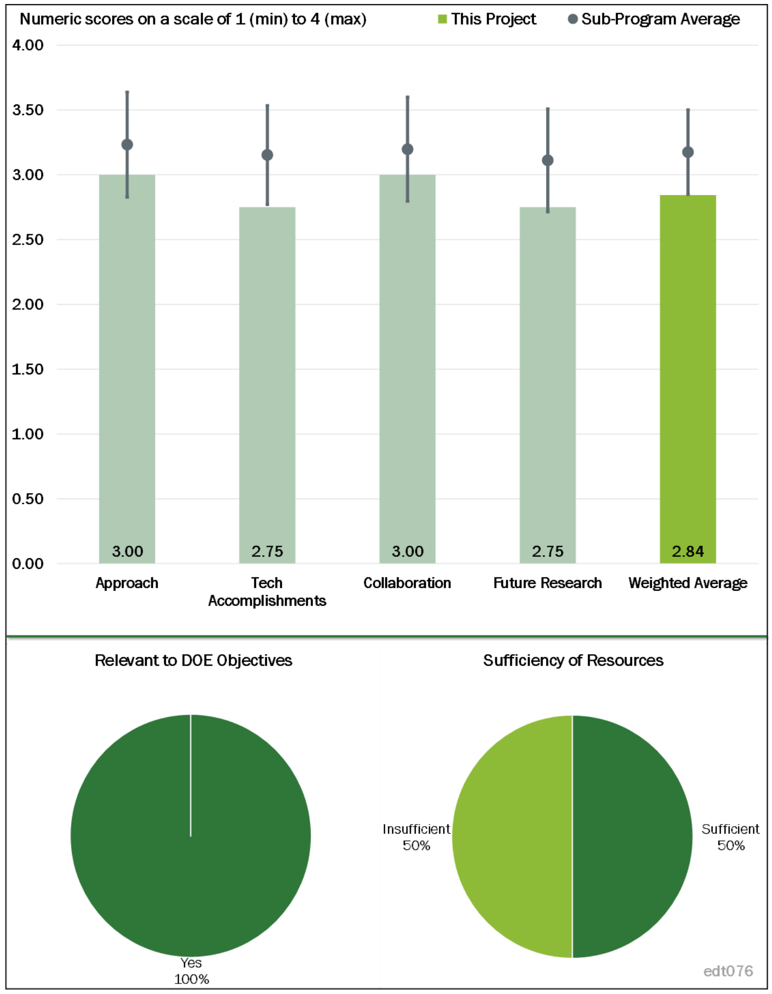

Figure 2-6 - Presentation Number: edt076 Presentation Title: Electric Drive Inverters Principal Investigator: Madhu Chinthavali (Oak Ridge National Laboratory)

Presenter

Madhu Chinthavali, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project should not need to develop a short circuit test circuit for capability evaluation. A standard test circuit from previous work should be sufficient. The reviewer agreed that a low-parasitic package at high di/dt operation is needed, and pointed out that a traction inverter topology that includes a series-integrated buck/boost converter cannot be assumed in most cases. The reviewer noted that this approach adds series conversion losses for the benefit of integrating a wired charger, which adds powered time to inverter standby mode and adds potential failure modes while on plug.

Reviewer 2:

The reviewer noted that there are three tasks planned, Tasks 2, 3 and 4. The reviewer said that the scope might be too big; there is a risk to do all three. The reviewer suggested focusing on one task and doing it more thoroughly.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said that progress is satisfactory towards the overall concept selected.

Reviewer 2:

The reviewer said that this is the first year of the program, and so far it is on a good track.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed a good team.

Reviewer 2:
The reviewer was unclear what collaboration was performed by SBE, ROHM, Cree, and REMTEC, other than providing parts.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the gate drive techniques to improve the light load efficiency is of marginal benefit, given the remarkably low E_on and E_off of SiC MOSFETs. Operation without anti-parallel SiC Schottky barrier diodes (SBD) has been previously proven to be viable.

Reviewer 2:
The reviewer said that high power efficiency needs to be considered as well.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that certainly improving efficiency supports this goal.

Reviewer 2:
The reviewer noted novel circuit technology with advanced packaging to reduce cost, improve efficiency and reliability, and increase power density of traction drive system for EVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that team composition seems adequate with funding level.

Reviewer 2:
The reviewer said that three hardware (Task 2, 3, and 4) evaluations is too much, and the reviewer suggested focusing on only one.

Presentation Number: edt077
Presentation Title: Wireless Power Transfer Integrated Chargers
Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

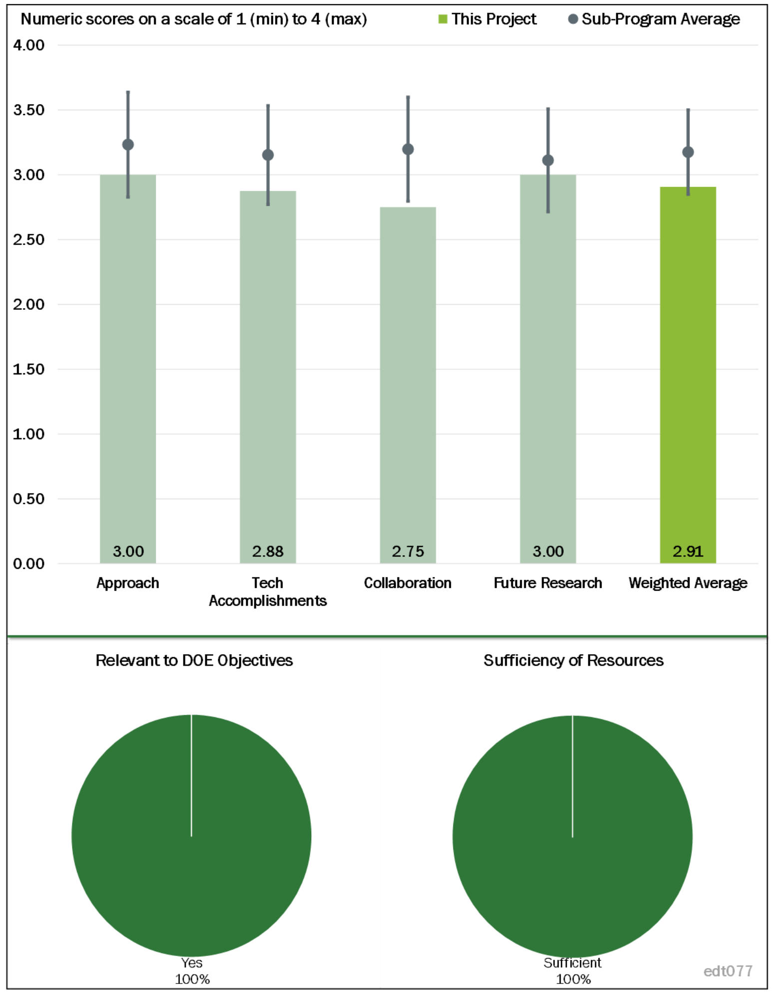

Figure 2-7 - Presentation Number: edt077 Presentation Title: Wireless Power Transfer Integrated Chargers Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Presenter

Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed a sound approach, and that alternatives were considered and evaluated.

Reviewer 2:

The reviewer commented that to save the voltage regulator stage by sharing the boost converter in the traction inverter electronics is a cost-saving approach.

Reviewer 3:

The reviewer said that the lifetime for the integrated DC-DC converter due to increased use of the boost converter is listed as one of the two technical barriers. The reviewer was not clear why the increased use of the boost converter is a technical barrier. The reviewer remarked that the project is well-designed; however, it is not clear that how this project is integrated with other efforts. Several ORNL researchers as well as NREL were mentioned as collaborators but their roles were not clear in this project.

Reviewer 4:

The reviewer said that the project identified a few challenges in designing and optimizing a wireless charging system, and integrating it into a larger DC/DC converter. The project is feasible, but should look at past DOE power electronic projects to try and learn from them. The reviewer noted that the team has NREL assisting with thermal management. The thermal management challenge during wireless charging was highlighted by this reviewer, who also asked if there is any power load required during charging (wireless transfer electronics, DC/DC electronics, battery, etc.). The reviewer said that estimated efficiencies (translates to heat load) should be considered early in the design/evaluation/simulation process.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that technical progress is good to this point, and that direction and progress is in line with DOE goals.

Reviewer 2:
The reviewer said that some progress has been achieved. Several topologies have been studied but as indicated by the presenter, the final topology has not been selected. The project proposed secondary side power regulation. The reviewer noted that only a system-level design was performed in FY 2017, and that hardware design and validation will be performed in FY 2018.

Reviewer 3:
The reviewer said that the project did not list the performance indicators it was trying to meet, other than design a smaller wireless charger. An initial simulation verified the wireless circuit design. The reviewer said that the overall goal of the project, to reduce the size of the charging interface, is one that would help DOE get to its goal of more hybridization.

Reviewer 4:
The reviewer remarked that this is a newly started program, and so far, the progress is okay.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that collaborating with NREL is the right path for the thermal work, and that there are many skilled and capable resources at NREL in this area.

Reviewer 2:
The reviewer noted that NREL has good capability for thermal performance development, and it is a good collaboration between the national laboratories.

Reviewer 3:
The reviewer noted that NREL is mentioned as a partner in thermal management, but there is no mention of any specific goals and coordination. The reviewer pointed out that several ORNL staff members are mentioned but their roles are not mentioned.

Reviewer 4:
The reviewer said that the project is utilizing NREL to help with power management, but it lacks coordination with other institutions and vehicle OEMs. The reviewer noted that one audience member pointed out that lessons learned from DOE power electronics projects from last year's AMR do not appear to be incorporated into this project. The reviewer said it would help if the project went back and looked at recent past projects, and tried to collaborate with industry and other organizations in DOE to reduce the project learning curve.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed a good plan moving forward, and the project team obviously understands the elements yet to be engineered.

Reviewer 2:
The reviewer said that the plan for hardware implementation is not clear, and that specifications for hardware performance such as efficiency, power density, etc. are not given. The reviewer said that the size of the ferrite coil is given as the limiting factor in hardware implementation but a risk mitigation strategy is not proposed.

Reviewer 3:
The reviewer said that the proposed future work is logical, but only listed at a high level. At a high level the project has good goals, but goals need to be broken down to trackable milestones and targets. The reviewer said that the project is lacking decision points beyond a simulation study of an 11 kW charger design in September 2017. The reviewer said that the few barriers that were listed were very high-level. The reviewer said that the project did not list specific barriers, or list alternative pathways to mitigate risk.

Reviewer 4:
The reviewer said that because the boost converter is shared by an existing power inverter module, the focus should be on the 11 kW wireless charger side.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer affirmed yes, the project does support the overall objectives. EV charging infrastructure and technology is critical to the adoption of non-internal combustion engine vehicles.

Reviewer 2:
The reviewer said that wireless charging is one of the key components to widespread EV deployment.

Reviewer 3:
The reviewer said that vehicle charging is a key part of pure electric and plug in vehicles. Having a safe, easy method to charge the vehicle, while having a low cost, is critical to adoption. The reviewer said this project helps with the wireless charging and low-cost pieces, which will help DOE meet its objective.

Reviewer 4:
The reviewer said it saves the cost and weight for wireless charger by sharing with a traction inverter boost converter.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the project appears to be running on track, and the resources appear to be sufficient.

Reviewer 2:
The reviewer said this project seems to have sufficient funds based on FY 2017 funding of $650,000.

Reviewer 3:
The reviewer said that seemingly ORNL has staffed the project adequately and is making solid progress. The team seems to be on track and is managing the project accordingly.

Reviewer 4:
The reviewer said that the resources seem sufficient.

Presentation Number: edt078
Presentation Title: Power Electronics Thermal Management
Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

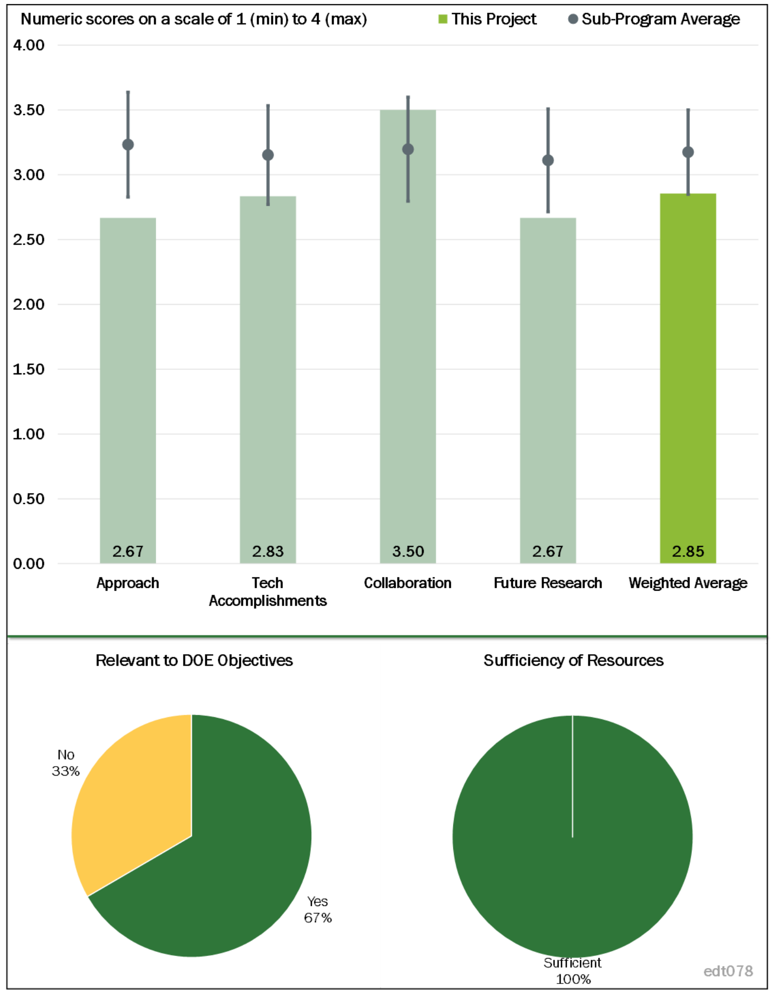

Figure 2-8 - Presentation Number: edt078 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Presenter
Gilbert Moreno, National Renewable Energy Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the technical barriers are generic to all power electronic cooling systems. The project is well-designed with several alternative thermal management schemes. There are three collaborative groups and their tasks are well defined.

Reviewer 2:
The reviewer said that NREL is evaluating multiple strategies for cooling power electronics. By studying inverters currently in production, the project team is able to evaluate the pros and cons of each system. The reviewer observed a solid approach.

Reviewer 3:
Regarding the approach, the reviewer asked what led to the decision to use the 2012 Nissan LEAF inverter as the benchmark for automotive power electronics thermal management. The reviewer noted that many other automotive inverters as benchmarked by ORNL should have led to a higher level of thermal management strategies as the starting point for advancing thermal design.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that this work is directed towards capacitor cooling. Computed capacitor temperatures were given but they were not verified by experimental measurements. The reviewer noted that the project investigated several capacitor cooling strategies for four different inverter configurations. A baseplate-cooled design was shown to reduce heat spreading on the module, which lowers capacitor and gate driver temperatures.

Reviewer 2:
The reviewer said that NREL seems to be moving in the correct direction, but could accelerate their efforts. The reviewer noted that the first stage of this project is primarily benchmarking.

Reviewer 3:
The reviewer commented the project is not specifically advancing the present state-of-the art: capacitor heating by power module, thermal interface material (TIM) degradation, capacitor active thermal management, eliminating the TIM layer, bus bar cooling, etc. are all known industry solutions.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that excellent collaboration has been established with John Deere, Kyocera, and ORNL.

Reviewer 2:
The reviewer said that collaboration is sufficient.

Reviewer 3:
The reviewer noted good collaboration with industry and national laboratory partners. While it may be slightly out of scope, the reviewer would like to see power module providers included in the study.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that many alternate cooling strategies were considered based on sound engineering judgement, and that risk mitigation will be implemented.

Reviewer 2:
The reviewer said that proposed future strategies need to be detailed to include power module/device manufacturers in order for this work to have longer term value.

Reviewer 3:
The reviewer pointed out that it is very difficult to develop thermal management concepts that are applicable to a wide range of inverter designs.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that thermal management is the key to efficient EV power electronic systems.

Reviewer 2:
The reviewer said this work is an enabling technology for electric drive components required for EVs/plug-in hybrid electric vehicles (PHEVs)/hybrid electric vehicles (HEVs)/and fuel cell EVs.

Reviewer 3:
The reviewer said that relative contributions to petroleum displacement appear to be minimal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources seem to be sufficient.

Reviewer 2:
The reviewer commented that resources are sufficient.

Reviewer 3:
The reviewer pointed out that the DOE cost share budget is $493,000 for FY 2017.

Presentation Number: edt079
Presentation Title: Materials for Advanced Packaging
Principal Investigator: Andy Wereszczack (Oak Ridge National Laboratory)

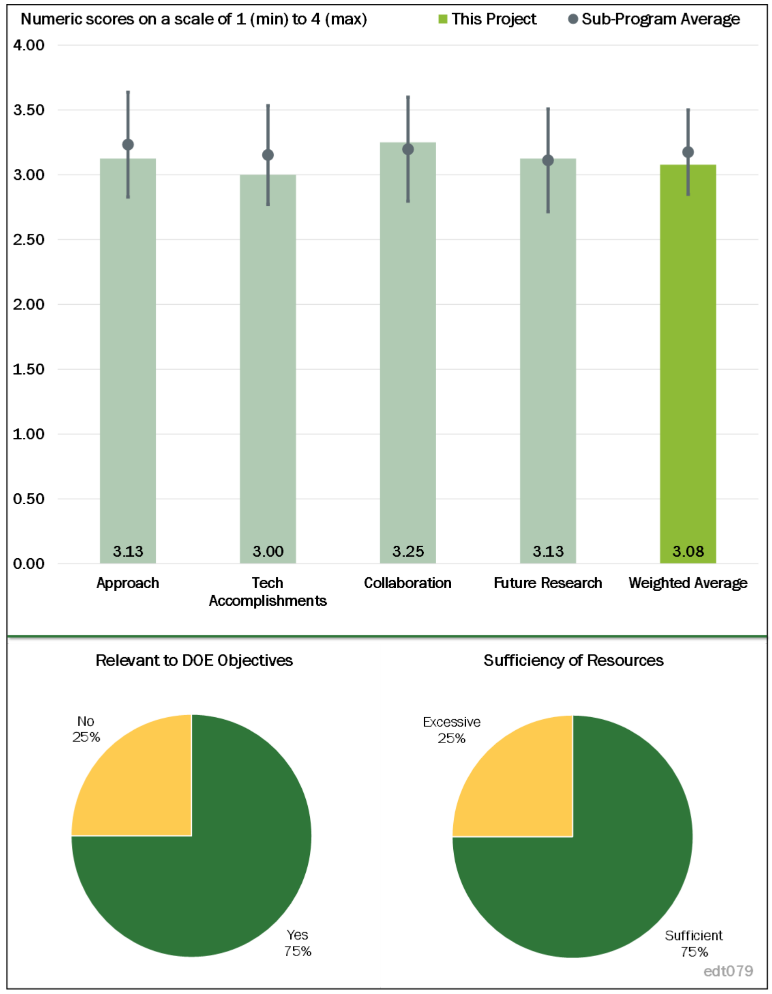

Figure 2-9 – Presentation Number: edt079 Presentation Title: Materials for Advanced Packaging Principal Investigator: Andy Wereszczack (Oak Ridge National Laboratory)

Presenter

Andy Wereszczack, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the project proposed sintered-silver (Ag) interconnect technology with at least a 15-year lifetime. The project uses commercially available Ag pastes and this work is to develop the sintering technique to produce interconnects. The reviewer said that no integration to other efforts is shown, although many partners are mentioned.

Reviewer 2:

The reviewer said that the approach is sound and addresses the technical barriers. The project seems well designed and thoroughly outlined.

Reviewer 3:

The reviewer commented it is a well-designed project focused on a high-temperature bonding technology.

Reviewer 4:

The reviewer said the project advances the processing and mechanical reliability of sintered-Ag for power electronic devices.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said that the technical accomplishments to date are good and seemingly on track.

Reviewer 2:
The reviewer noted that reduced cost reflow oven processing technology is used for sintered-Ag interconnects to reduce cost. The reviewer said the project developed open contact drying with heat applying from the bottom without pressure of printed sinterable Ag paste. The reviewer detailed that the project developed new test methods for tension/shear using cantilever loading with deep beam theory for correction and apparent fracture toughness measurement using a three-point bending method.

Reviewer 3:
The reviewer said fabricate sufficient numbers of shear test specimens to judge potential of new contact-drying method for printed Ag paste.

Reviewer 4:
The reviewer commented that the project needs to pick up the pace to demonstrate the shear strength of the Ag joints. The shear strength data were not presented.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent collaboration with universities, national laboratories, and industry. According to the reviewer, this is exactly the type of collaboration that will enable this project to succeed.

Reviewer 2:
The reviewer said that collaboration partners are adequate to execute the project.

Reviewer 3:
The reviewer noted that 10 partners are involved in this program.

Reviewer 4:
The reviewer said that there are nine collaborators listed, and some of their roles are not very clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that proposed future work is right on track to properly evaluate the feasibility and reliability of this technology.

Reviewer 2:
The reviewer said that future work is well planned for the remainder of FY 2017 and the proposed work for FY 2018 is good. However, there is no alternate development pathway to mitigate risk. The reviewer said that long-term Ag electromigration under large current conduction should be considered.

Reviewer 3:
The reviewer said that the project is identifying the most practical, reliable, and economical Ag (or other metal) plating choice for use with sintered-Ag interconnects.

Reviewer 4:
The reviewer remarked that the future work may be well planned but the reviewer did not see a clear direction from the presentation.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said yes, this technology will enable high-reliability, low-cost electronics for electric drive applications.

Reviewer 2:

The reviewer said yes, and detailed that the project is focused on high-temperature bonding for WBG devices that will be used in future EVs

Reviewer 3:

The reviewer said to develop advanced sintered-Ag-interconnect technology to enable a 200°C-capable, low-cost, and reliable electronic package with at least a 15 year life.

Reviewer 4:

The reviewer said yes, only if the reduced cost sintered processed Ag interconnects can replace the commonly used Cu interconnects. However, the cost of Ag interconnect may be higher than that of the Cu metal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that project resources seem sufficient to achieve the goals of the project. Collaborative agreements with partners will help ORNL move forward with good outside support.

Reviewer 2:

The reviewer pointed out that the FY 2017 funding of $171,000 for this project seems sufficient.

Reviewer 3:

The reviewer found that the resources seem adequate for the project.

Reviewer 4:

The reviewer pointed out that there are 10 partners involved in the project.

Presentation Number: edt080
Presentation Title: Performance and Reliability of Bonded Interfaces for High-Temperature Packaging
Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

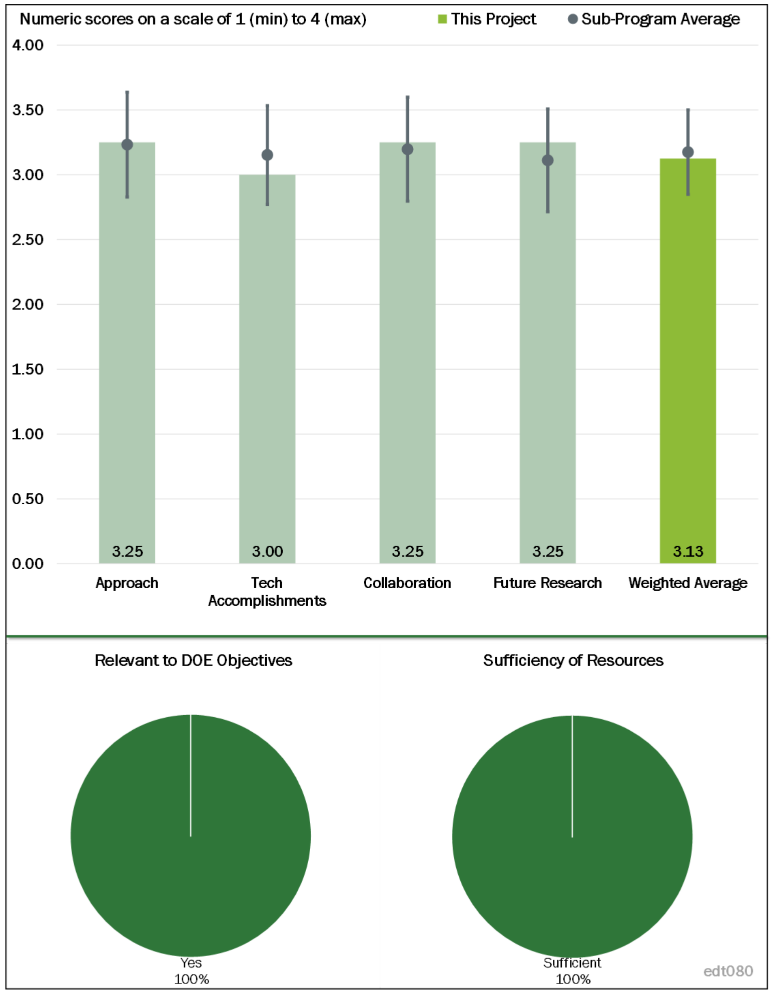

Figure 2-10 - Presentation Number: edt080 Presentation Title: Performance and Reliability of Bonded Interfaces for High-Temperature Packaging Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Presenter
Paul Paret, National Renewable Energy Laboratory

Reviewer Sample Size
A total of two reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the approach is sound with multiple avenues to examine the technology.

Reviewer 2:
The reviewer said that the sintered-Ag joint may reduce cost, improve reliability and the lifetime of the 200°C power electronic module.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that accomplishments have been solid, the project seems to be on track and has exhibited good results.

Reviewer 2:
The reviewer commented that mechanical characterization, thermal cycling and finite element method to capture fatigue behavior of sintered-Ag joints were studied. The project performed a shear test using double lap samples in an Instron tester. The project performed tests at Virginia Tech University and NREL, and Cu invar test coupons were used for temperature cycling tests. The project applied an Anand viscoplastic and other material models to sintered-Ag layer to yield J integral/cycle and strain energy density.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed an excellent collaborative arrangement, and technically capable partners.

Reviewer 2:
The reviewer said that concrete collaborations are demonstrated at both NREL and Virginia Tech University.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the planned work is in alignment with the goals of the project and should yield acceptable results.

Reviewer 2:
The reviewer said that additional simulations and experiments, more double lap, complete thermal cycling, and validation of crack propagation models are planned. The reviewer said that the mechanical and reliability aspects of the porosity of the sintered-Ag joints should be investigated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that this study will provide insight and technical results that will enable reliable WBG power modules, which are required for future electric drive inverters.

Reviewer 2:
The reviewer pointed out that sintered-Ag joints can potentially replace the conventional solder joints for power modules operating at 200°C.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that it seems that the team is adequately staffed, and has solid partnership arrangements to complete the project.

Reviewer 2:
The reviewer said that the DOE cost-share of funding is $492,000 for FY 2017.

Presentation Number: edt081
Presentation Title: Multilayered Film Capacitors for Advanced Power Electronics and Electric Motors for Electric Traction Drives
Principal Investigator: Deepak Langhe (Polymer Plus)

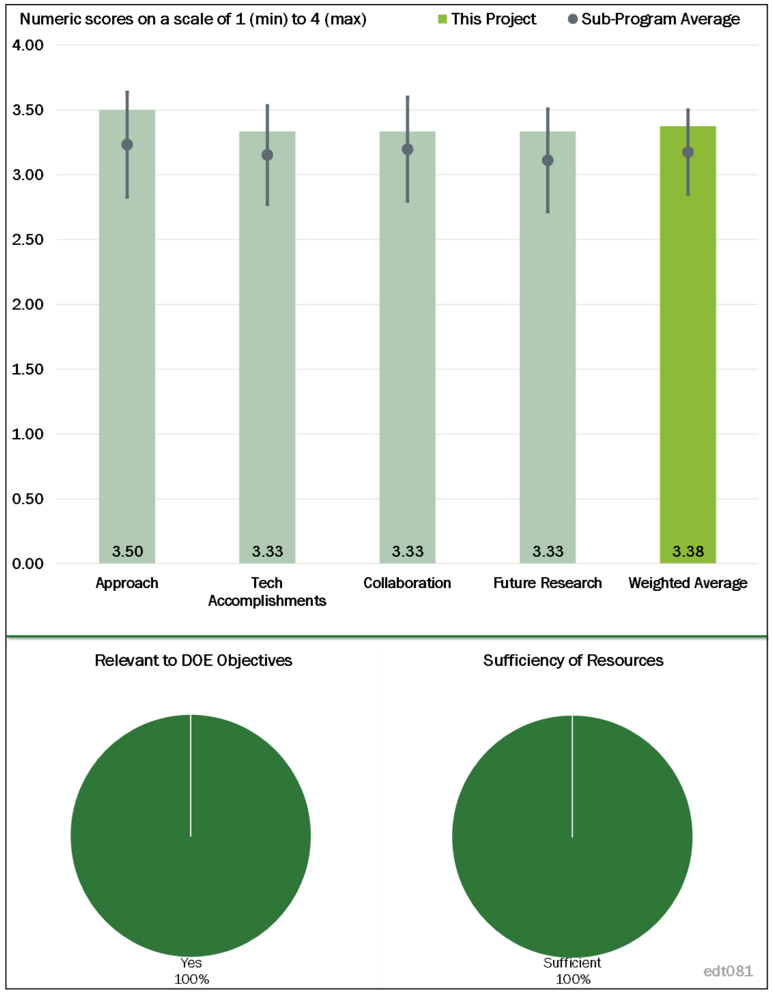

Figure 2-11 – Presentation Number: edt081 Presentation Title: Multilayered Film Capacitors for Advanced Power Electronics and Electric Motors for Electric Traction Drives Principal Investigator: Deepak Langhe (Polymer Plus)

Presenter
Deepak Langhe, Polymer Plus

Reviewer Sample Size
A total of three reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the project has well-defined technical targets and an interesting process for producing multilayered films. The process should allow for reduced capacitor volume while increasing the operating temperature compared to bi-oriented polypropylene (BOPP) capacitors.

Reviewer 2:
The reviewer said that this approach is outstanding because it is trying to take known materials and capture the best attributes of both.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer commented that the project is making real progress with some technical difficulties that the reviewer is confident the team will overcome.

Reviewer 2:
The reviewer detailed that the team was able to produce films down to approximately 4 micrometer (µm), but the film wrinkled significantly during the winding process. The 8µm film produced the best end results and was thus chosen for further study. The team performed thermal modeling to compare the performance of this capacitor to BOPP capacitors. The reviewer noted that several prototypes were built and tested and the team is investigating methods of reducing power loss.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer detailed that the industry partner SBE designs, fabricates, and tests the capacitor prototypes using the films developed by PolymerPlus. ORNL leads the thermal and cost modeling, and Case Western Reserve University investigates the material structure properties and develops new materials.

Reviewer 2:

The reviewer would like to see participation from OEMs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the team plans to improve the film quality so that thin films can be processed without wrinkles, and that several more prototypes and testing rounds are planned.

Reviewer 2:

The reviewer would like to see OEMs engaged or a Tier 1 supplier involved in testing of parts or contributing to the test plan.

Reviewer 3:

The reviewer acknowledged that some good progress has been shown to date, but the reviewer expressed concern that scaling these achievements up while scaling down the film thickness will prove to be a tremendous challenge, and it appears that these challenges are outside the scope of this particular project. Therefore, it is difficult for this reviewer to see the path to DOE program target goals. The reviewer asked if there are proposed alternate paths to address these.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said reducing the capacitor size and allowing the inverter to operate at higher temperatures, and that both contribute to the size reduction of the overall inverter system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources appear to be sufficient for this project.

Presentation Number: edt082
Presentation Title: Highly Integrated Wide Bandgap Power Module for Next Generation Plug-In Vehicles
Principal Investigator: Brian Peaslee (General Motors)

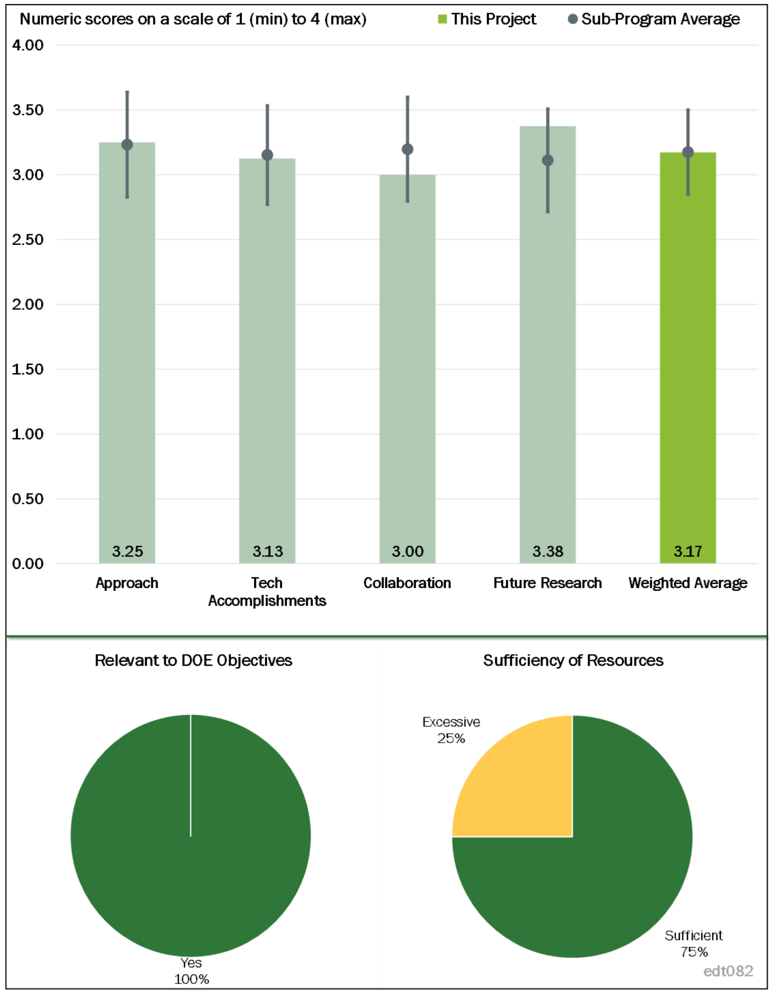

Figure 2-12 – Presentation Number: edt082 Presentation Title: Highly Integrated Wide Bandgap Power Module for Next Generation Plug-In Vehicles Principal Investigator: Brian Peaslee (General Motors)

Presenter
Brian Peaslee, General Motors

Reviewer Sample Size
A total of four reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the project appears to be demonstrating and focusing on the key benefits or issues with SiC MOSFET devices, including size reduction, power electronics efficiency, motor efficiency, thermal performance, and efforts to reduce inductance. The DC voltage of 600V is listed, but it seems the potential of SiC would enable higher voltages. The reviewer said that information regarding the tradeoffs of DC voltage and why 600V was selected would be interesting.

Reviewer 2:
The reviewer detailed that the project is to enable an inverter to meet or exceed DOE's 2020 target with a power density of 13.4kW/L, a specific power of 14.1kW/kg and $3.3/kW at efficiency of greater than 94% at 10-100% speed at 20% rated torque. The proposed solution is to integrate gate drivers inside WBG power modules to address the barriers of cost, reliability performance, mass and volume. The reviewer said that the goal is to increase the bus voltage to 600VDC. The reviewer said that the presenter should make clear how this increased bus voltage can address the technical barriers because WBG (assuming SiC devices) are already mostly rated at 1,200V even though 900V devices are commercially available. The reviewer asked if there is a large price differential among the 900V and 1,200V devices.

The reviewer noted that GM is the lead with Virginia Tech University, Monolith Semiconductor, and ORNL as the sub-recipients. Cree Wolfspeed is the key supplier and PowerAmerica is the collaborator.

Reviewer 3:
The reviewer said that test results, perhaps in the next phase, can help verify the effectiveness of the SiC MOSFET and the suggested advantages over insulated gate bipolar transistors (IGBT) power modules.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that the progress made thus far seems to line up with the intended plan.

Reviewer 2:
The reviewer noted that a two-layer sintering process patent was filed. No SBD was used as extra loss is low and furthermore, the SBD does not have a significant role in reducing switching losses for third-generation SiC MOSFETs. The reviewer said that power module thermal performance has margin without SBD. The reviewer said reduce overall parasitic inductance to below 5 nanohenries, and that signal path inductance is found to be important. Package inductance and thermal performance have been modeled and are below target. Employing a high-voltage motor, such as 600V, compatible with WBG could reduce cycle average losses. The reviewer noted that efficiency is not known, and there have been many investigations for third-generation SiC MOSFETs without SBD by device manufacturers.

Reviewer 3:
The reviewer commented that based on the presented information, the project appears to have made excellent progress in developing preliminary analysis, device selection, and initial design evaluation. It will be interesting to learn more about the design and challenges encountered as the project progresses. The reviewer commented that the loss reductions highlighted appear to be significant but no relative numbers are provided for comparison. This is also true for other graphs in the presentation. The reviewer asked how significant the loss reduction is in terms of energy savings in the vehicle in fuel use or range. It would be interesting to highlight the expected benefits and how this impacts the cost comparison with Si devices. The reviewer asked what the expected system cost benefits for SiC are.

Reviewer 4:
The reviewer noted good progress overall but it appears that the delay in selecting a SiC die caused by issues with Wolfspeed had slowed progress quite a bit. The reviewer hopes that now this is behind the team, it can get on with building and testing to verify what appears to have been some substantial and good modeling/simulation work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out that GM is the lead investigator, and Virginia Tech University, ORNL, and Monolith Semiconductor are the sub-recipients, while Wolfspeed is the supplier. PowerAmerica is the collaborator.

Reviewer 2:
The reviewer said that the project appears to involve good collaborations with other partners. The slides specifically highlight work performed by Virginia Tech University. The reviewer said it would be helpful to identify the roles of other partners such as ORNL, and it was not clear how PowerAmerica is collaborating on the project.

Reviewer 3:
The reviewer said the details of the collaboration are not quite clear from the materials on the presentation file.

Reviewer 4:
The reviewer noted good collaboration with Virginia Tech University and device suppliers or potential device suppliers. The reviewer said it was not clear what the collaboration and contribution is of ORNL is and the reviewer is unsure that they can contribute.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the highlighted future research appears to be aligned with the project goals. The reviewer noted that the challenge of higher temperature encapsulates and capacitors were listed, but there does not appear to be future work listed in these areas.

Reviewer 2:
The reviewer said that the current steps as presented for the future plan are sound and reasonable. However, a backup plan in case of failure of the suggested approach is not outlined. Also, it was unclear to this reviewer what the go/no-go criteria are as the future plan is based on a go/no-go review.

Reviewer 3:
The reviewer observed logical, orderly next steps. The reviewer agreed that the high-bandwidth current sense (using Rogowski coils), desaturation protection, and common-mode transient immunity that the principal investigator pointed out as "Challenges & Potential Barriers" are indeed potential problems. The reviewer would like to see the work associated with investigating/addressing these more prominently featured in the project and task lists

Reviewer 4:
The reviewer noted that high-bandwidth, low-cost current sensing, high-temperature encapsulate and capacitors are planned. Gate driver improvement will be implemented with three times more short circuit current protection than that of typical Si IGBT. The team plans a desaturation protection scheme and will investigate a high common-mode transient immunity.

The team will perform sintering trials and will build a half bridge configuration. The reviewer asked for the gate driver, what the criteria for this go/no-go gate review are. The reviewer cited a lack of detailed design, coupon construction and confirmation tests.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked yes, it supports the overall DOE objectives from the work done to date and the future plan when compared against the primary objectives.

Reviewer 2:
The reviewer said that highly integrated WBG power modules are essential for next-generation EVs to meet DOE objectives of petroleum displacement.

Reviewer 3:
The reviewer said that the development of electric drive components such as this SiC power module directly contribute to energy savings within vehicle applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that even though the resources are not detailed in the presentation file, overall, from the Overview and Relevance slides, it seems that they are sufficient.

Reviewer 2:
The reviewer said that the project appears to have a significant budget to accomplish the project goals.

Reviewer 3:
The reviewer said that a total budget of $5.67 million seems excessive for this power module project.

Presentation Number: edt083
Presentation Title: 650V SiC Integrated Power Module for Automotive Inverters
Principal Investigator: Monty Hayes (Delphi Automotive Systems, LLC)

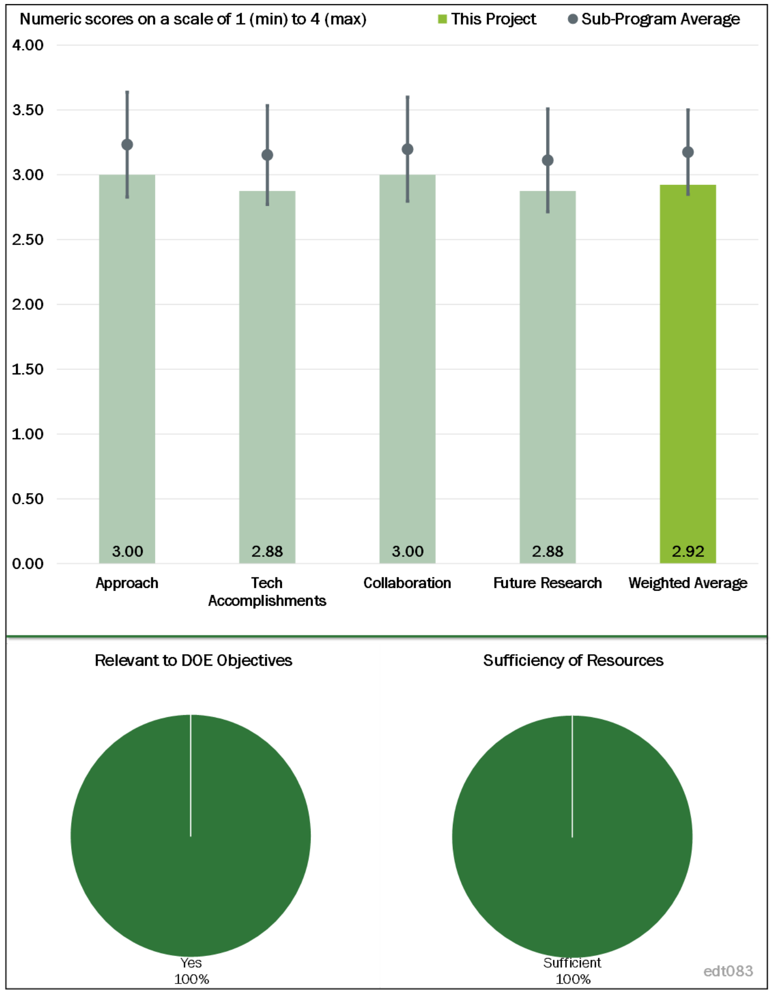

Figure 2-13 - Presentation Number: edt083 Presentation Title: 650V SiC Integrated Power Module for Automotive Inverters Principal Investigator: Monty Hayes (Delphi Automotive Systems, LLC)

Presenter
Monty Hayes, Delphi Automotive Systems, LLC

Reviewer Sample Size
A total of four reviewers evaluated this project

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the approach is sound, and it is in alignment with the goals of the project.

Reviewer 2:
The reviewer observed a target for bus voltages lower than 650V, and noted a 650V single switch device with double sided cooling and a half-bridge inverter. The reviewer asked if there is significant price differential among the 1,200V, 900V and 650V SiC devices.

Reviewer 3:
The reviewer said the major concern is the completion rate after about 1.5 years since the project started. Some of the objectives, such as the current rating of a single switch, have not been met in the design and fabrication. The reviewer noted that some of the remaining barriers are significant, especially with the amount of project time left. Among those are the cost-effectiveness and the final prototype fabrication, test and modification (if need be).

Reviewer 4:
The reviewer said that the project does not seem to have enough time for testing before starting a second iteration.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that the early results indicate that the project is on the right track.

Reviewer 2:

The reviewer noted a paralleling of five devices, 500 ampere root mean square (A_{rms}) single switch capability with thermistor on package, and Wolfspeed 650V G3 MOSFETs 75 amp at 25°C. The reviewer noted optimized gate resistance inside the package, and ability to control the di/dt and reduced oscillations. The reviewer said that static and dynamic characterization were performed, thermal characterization of heat sink assembly, and that the team investigated SiC inverter losses using a three-phase inductive load.

Reviewer 3:

The reviewer said that the progress made to date is significantly behind the projected percentage.

Reviewer 4:

The reviewer would like to have Delphi provide understanding of drivers in part yield.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the collaboration is clearly indicated.

Reviewer 2:

The reviewer said that the project has good collaboration and the appropriate partnerships to be successful.

Reviewer 3:

The reviewer noted that Wolfspeed, ORNL, and Volvo are the partners and their roles are listed. It is not clear what the roles of Volvo are.

Reviewer 4:

The reviewer observed no discussion about the extent to which each party is collaborating.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the proposed future work and project plan is in alignment with the objectives and goals of the project. Successful completion of this work should result in the team meeting the project goals.

Reviewer 2:

The reviewer said that future tasks are planned but more details are needed.

Reviewer 3:

The reviewer said that while the project needs some expedition, such plans or alternative development pathways are not outlined.

Reviewer 4:

The reviewer remarked that packaging the SiC device is an important step, but is just one of many elements needed to see incorporation of the technology. The reviewer is sure Delphi understands this comment and the need for more extensive work to move this technology into a vehicle.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that cost-effective WBG power modules are essential for EV deployment to meet the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer said yes, SiC inverters are the next step toward smaller, lighter, higher voltage traction inverters.

Reviewer 3:
The reviewer commented that as per the objectives of the project, the work done and the future work to be completed are relevant to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that a total budget of $2.16 million seems to be sufficient for the project.

Reviewer 2:
The reviewer said that the team is adequately staffed, and should be able to successfully complete the project.

Reviewer 3:
The reviewer said that even though the resources are not clearly mentioned in the presentation, it seems that they are sufficient.

Presentation Number: edt087
Presentation Title: Electrical Performance, Reliability Analysis, and Characterization
Principal Investigator: Tim Burress (Oak Ridge National Laboratory)

Presenter

Tim Burress, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project

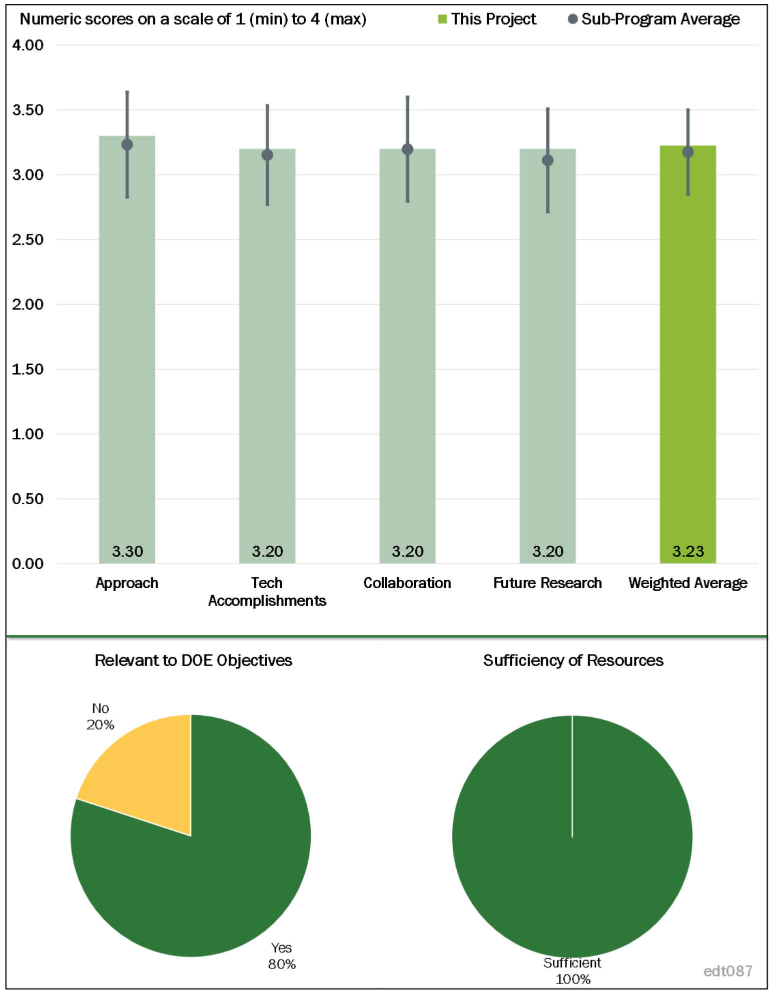

Figure 2-14 – Presentation Number: edt087 Presentation Title: Electrical Performance, Reliability Analysis, and Characterization Principal Investigator: Tim Burress (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the work is well organized and the approach is sound.

Reviewer 2:

The reviewer said that continuing to benchmark commercially available electric drivetrains is extremely valuable to the broader technical community, and that it also helps establish trends.

Reviewer 3:

The reviewer said this is a well-designed project that is gathering valuable data on the design and performance of production HEV systems and components.

Reviewer 4:

The reviewer said the core function of this project is to confirm power electronics and electric motor technology status and identify barriers and gaps to prioritize and identify R&D opportunities. This project helps with program planning and the establishment and verification of all of DOE’s 2020 targets.

Reviewer 5:

The reviewer said the project shows a comparison of several HEV architectures. The project does not provide any information on how this information will be used to identify gaps/challenges.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said this project is making excellent progress towards meeting all of its goals. It is well aligned with DOE goals pertaining to the development of advanced electric motor technology.

Reviewer 2:
The reviewer said great progress was made. Year after year more EDTs are benchmarked and compared to previous generations, which is extremely valuable. The reviewer said that great progress was made in terms of benchmarking the Prius 2017 EDT.

Reviewer 3:
The reviewer said obtain and publish detailed information on state-of-the-art technologies and their progression, and complete the 2017 Prius power control unit tear-down.

Reviewer 4:
The reviewer said that this project, in essence, is a benchmarking project. While there were technical challenges to overcome, they were directly related to controlling the motor/inverter. The demonstration of the system has some value to DOE, but the reviewer would state that it is of minimal value towards achieving DOE's goals.

Reviewer 5:
The reviewer said that the progress is okay but the goals were not clear.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that this project is effectively collaborating with Argonne National Laboratory (ANL) and NREL and receiving relevant system and component data from them.

Reviewer 2:
The reviewer said there is excellent collaboration between ORNL and their contributors, NREL and ANL.

Reviewer 3:
The reviewer noted that the project has three national laboratories involved.

Reviewer 4:
The reviewer commented that it seems the work is largely done within ORNL and there is some level of collaboration with other national laboratories.

Reviewer 5:
The reviewer commented that only ORNL was part of the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that finishing the benchmarking of the 2017 Prius as well as continuing to benchmark other new EDTs as they become available is an excellent direction.

Reviewer 2:
The reviewer said this project has a well-defined plan for future research. The reviewer said that if possible, the project should consider including component-level characterization of the main active components (magnets, conductors, IGBT's) to verify their performance.

Reviewer 3:
The reviewer said the future work was presented but the direction of the work was not clear.

Reviewer 4:
The reviewer said that with limited funding for EDTs, this work should be re-evaluated. The overall benefit to VTO and the OEMs is minimal. The reviewer would term it “nice to have” but not mission critical.

Reviewer 5:
The reviewer said select commercially available EV/HEV systems relevant to DOE’s VTO mission to help to determine DOE’s 2020 goal.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied yes, to the extent that it gives DOE more information on the systems currently being deployed versus the DOE targets in 2020 and 2025.

Reviewer 2:
The reviewer said that benchmarking commercially available EDTs and establishing trends is extremely valuable in terms of confirming and if needed modifying the technology roadmap to meet DOE targets.

Reviewer 3:
The reviewer said yes, this project is providing valuable performance data of production electric motor systems and components. These data will serve as a baseline that future advanced motor designs can be compared against. The reviewer remarked that the comparison will provide a means of assessing the competitiveness of those design, enabling manufacturers to make informed choices on market introduction of new products.

Reviewer 4:
The reviewer said that it was not quite clear on this aspect as the future direction was not presented.

Reviewer 5:
The reviewer said that the core function of this project is to confirm power electronics and electric motor technology status and identify barriers and gaps to prioritize and identify R&D opportunities.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed the resources are adequate.

Reviewer 2:
The reviewer said that based on the scope, the level of funding seems sufficient.

Reviewer 3:
The reviewer said that the resources of the project appear to be sufficient to meet the stated milestones.

Reviewer 4:
The reviewer believed the resource are adequate.

Reviewer 5:
The reviewer commented that this team has a good record of benchmarking the series of HEV/PHEV power inverters in the past. The reviewer said that so far the team has made good progress on the 2017 Prius tear-down.

Acronyms and Abbreviations

µm	Micrometer (micron)
^{0}C	Celsius (Centigrade)
Ag	Silver
AlNiCo	Aluminum-nickel-cobalt
AMR	Annual Merit Review
ANL	Argonne National Laboratory
A_{rms}	Ampere root mean square
BOPP	Bi-oriented polypropylene
CNT	Carbon nanotubes
Cu	Copper
DC	Direct current
DOE	U.S. Department of Energy
DREaM	Development of Radically Enhanced alnico Magnets
ED	Electric drive
EDT	Electric Drive Technologies
EMC	Electromagnetic compatibility
EV	Electric vehicle
FeSi	Ferrosilicon
FY	Fiscal year
GaN	Gallium nitride
GM	General Motors
HEV	Hybrid electric vehicle
IGBT	Insulated-gate bipolar transistors
kW	Kilowatt
MOSFET	Metal–oxide–semiconductor field-effect transistor
NASA	National Aeronautics and Space Administration
NREL	National Renewable Energy Laboratory

OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
R&D	Research and development
Rds(on)	Resistance from drain to source
RE	Rare earth
SAE	Society of Automotive Engineers
SBD	Schottky barrier diodes
Si	Silicon
SiC	Silicon carbide
SynchRel	Synchronous reluctance
TIM	Thermal interface material
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
V	Volt
VTO	Vehicle Technologies Office
WBG	Wide bandgap

3. Electrochemical Energy Storage

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress – at no cost to the Government.

The Battery and Electrification Technologies subprogram supports early-stage R&D to explore new battery chemistry and cell technology with the potential to reduce the cost of electric vehicle batteries by more than half to less than $100/kWh and increase the range to 300 miles while decreasing the charge time to less than 15 minutes. The activity supports the development of innovative materials and cell technologies capable of realizing significant cost reductions in three major R&D areas. Advanced Battery Materials R&D will focus on early-stage R&D of new lithium (Li)-ion cathode, anode, and electrolyte materials, which account for 50%-70% of plug-in electric vehicle battery cost of current technologies. Advanced Battery Cell R&D effort will focus on early-stage R&D of new battery cell technology that contain new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast charging. Electrification R&D focuses on early-stage research to understand the potential impacts of electric vehicle (EV) charging on the Nation's electric grid.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: es000
Presentation Title: Overview of the DOE VTO Advanced Battery R&D Program
Principal Investigator: David Howell (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer stated that the overall program was covered very well. The information provided allowed the audience to clearly see the advances made.

Reviewer 2:
The reviewer remarked that the project was definitely covered. The reviewer observed a clear picture of the multiple-level research approach. This reviewer noted some past success in helping science and engineering move to the point where U.S. firms can make profitable products, and highlighted a plan for the future that has risk, but is do-able.

Reviewer 3:
The reviewer commented that a clear and useful high-level understanding of the program area was given and overall strategy was covered.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer considered the balance to be very good with the understanding that the funding budget may be changed.

Reviewer 2:
The reviewer observed good balance, saying that this was, perhaps, the U.S. Department of Energy's (DOE) best-balanced portfolio in this respect. This reviewer further explained that a healthy research portfolio feeds a smaller advanced program and then the United States Advanced Battery Consortium (USABC), as the single vector, is used to bring the products to beta stage. In addition, the usual Small Business Innovation Research (SBIR) program provides support that is common to all offices.

Reviewer 3:
The reviewer commented that the balance is not inappropriate, but that shifting balance to a greater degree towards nearer-term R&D may provide a greater impact to U.S. industry.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer stated that the key issues and challenges were identified, and that both the technical and the associated cost issues were outlined.

Reviewer 2:
The reviewer said that the important issues and challenges were identified, both in the short-term (cost and energy density in the 350 Wh/kg region) and long-term (below $100/KWh). Additionally, this reviewer pointed out very high energy (lithium-sulfur [Li-S]), and of course, the new fast-charge focus.

Reviewer 3:
The reviewer said that cost and some of the major technical challenges were identified at a high level. Interaction with global industry is an important issue and an important challenge, but this reviewer remarked that it was not identified.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer commented that major areas for future work were identified related to addressing the cost challenge, and many of the major technical issues were identified.

Reviewer 2:
The reviewer stated that not only were plans covered in the talk, but also subcategorized by the various research areas in a battery. The plans seem quite appropriate as well, and described them as stretchy, but not silly.

Reviewer 3:
The reviewer noted that long- and short-term plans were highlighted that could address the issues and/or barriers, by using various technical solutions.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer commented that the progress was clearly benchmarked.

Reviewer 2:
The reviewer remarked that progress was laid out in general over the last several years to include progress over the last year, not just 2016-17 versus 2015-16.

Reviewer 3:
The reviewer stated that progress in terms of battery cost reduction and energy density increase was clearly described.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer said yes.

Reviewer 2:
The reviewer asserted that the projects are addressing the broad problems and barriers that VTO is trying to solve.

Reviewer 3:
The reviewer thought so, and added that the projects are moving toward more sustainable, less polluting ways to move people and goods from place to place. Clearly, the projects are attacking the specific battery goals as well.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer stated that the program area was extremely well managed. Work is broken down into programs by Technology Readiness Level (TRL) (roughly, not a slavish TRL 1 task, a TRL 2 task, etc.). Work is also broken down within a program into project groups by the components of the battery with appropriate work in each of several programs. This reviewer commented that there are now numerous examples of projects flowing through this matrix organization as they have success and of course those not succeeding are dropped and do not move up the ladder. The programs talk to each other both at the researcher and DOE management level and

also to other DOE programs on battery or transportation outside the VTO. The reviewer said the focus, management, and effectiveness of this program area is splendid.

Reviewer 2:
The reviewer affirmed that the program area appeared to be focused, well-managed, and effective.

Reviewer 3:
The reviewer noted that the program area appears to be well-managed and somewhat focused. Long term effectiveness for VTO and for the United States may be improved by greater diversity of research partners and greater collaboration with global industry.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer stated that the management is a strength, many of the highly talented, innovative and effective research groups are a strength, the advice form industry and other parts of government are also a strength. USABC stands out for industry support and being valued by American firms. The reviewer could not identify any weak projects from the talks.

Reviewer 2:
The reviewer stated that the projects related to potential near-to-mid-term implementation, which may have the ability to advance industry in the United States or globally (e.g., novel processing advances and high-voltage electrolytes), stand out most positively.

Reviewer 3:
The reviewer noted several key strengths of the projects, including involvement of the vast technical resources and collaboration of various national laboratories; the variety of technical approaches, appropriately funded to resolve technical issues, which increase the chances of the problem being overcome; and all aspects of the key battery system and the cell, which are being addressed. The reviewer indicated that a key weakness of the projects include some cost assumptions based on overcoming very difficult technical issues. Improvement in the nickel manganese cobalt oxide (NMC) cathode is a positive; nothing stands out for the weakness except maybe needing more work to resolve the silicon (Si) anode problems, and this is only because it appears to be near-term.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:
The reviewer stated yes, and acknowledged that some are highly risky but could change the world. Others are more likely to make progress but of a less grand step. The reviewer concluded that the balance is good.

Reviewer 2:
The reviewer asserted that most projects represent novel and/or innovative ways to approach the barriers. Meanwhile, continued this reviewer, a lesser number of projects will still usefully advance the general knowledge base even if the projects less specifically and directly approach the barriers.

Reviewer 3:
The reviewer noted that the question was not very clear. The reviewer believed that the projects' novel and innovative approaches to overcome the barriers are appropriate.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer said that the program area has very much engaged appropriate partners. Industry, government, and academia are all engaged.

Reviewer 2:
The reviewer stated that appropriate partners were engaged, although there are many researchers and battery companies outside the United States that could be added to the benefit of the work if that were permitted.

Reviewer 3:
The reviewer commented that there are a great number and variety of outstanding partners involved in projects. Increased balance towards industrial or research partners (versus national laboratories) may improve overall impact to industry. Greater partnership with global partners may also improve overall impact to industry.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer emphatically said yes.

Reviewer 2:
The reviewer remarked that the program was collaborating very effectively, both between projects and with industry, and with projects outside VTO.

Reviewer 3:
The reviewer commented that this program area has and continues to demonstrate effective collaboration with partners.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer observed no real gaps in the portfolio, presently. Fast-charge or Li plating were the only outstanding gaps and the program is filling that. This reviewer opined that this will be a powerful program if it gets the proper funding. Although the program may not need quite as much as was provided in the fiscal year (FY) 2017 budget, the reviewer noted that more is needed than the FY 2018 proposal.

Reviewer 2:
The reviewer stated that the technology area is generally well covered in the portfolio; however, there are some gaps. Areas such as battery cell hardware (cell can or cell pouch configuration and/or optimization, cell internal construction), as well as a coordinated effort in terms of battery abuse response improvement, may be among the gap areas.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer noted that the only topic not adequately addressed is fast-charge and/or Li plating, and that is coming soon. Thus, the reviewer clarified that it is more a matter of being ramped-up than unaddressed. The need was identified last year, a workshop was held, and the team is setting up to fund projects.

Reviewer 2:
The reviewer commented that a key topic that does not seem to be adequately addressed is external outreach to and collaboration with global industry.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer said that there were no other areas. The reviewer considered this program to be well positioned.

Reviewer 2:
The reviewer stated that improving the vehicle components that use the electrical energy, and identifying some ways to incorporate capture of the mechanical energy being generated (while the vehicle is moving) in the form of electrical energy, are areas that could be considered.

Reviewer 3:
The reviewer suggested study, analysis, reporting, and reflection on battery research and the battery industry outside of the United States.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer had no further recommendations. The reviewer considered the program to be well positioned. The reviewer approved of how the project currently spends money rather than on other work.

Reviewer 2:
The reviewer suggested putting greater focus and effort on battery manufacturing cost reduction and battery performance increase via battery manufacturing innovation.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer strongly said to keep the program funded.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 3-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es028	Materials Benchmarking Activities For CAMP Facility†	Wenquan Lu (ANL)	3-16	3.36	3.36	3.64	3.21	**3.38**
es030	Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities†	Andrew Jansen (ANL)	3-21	3.36	3.21	3.71	3.36	**3.33**
es049	Tailoring Integrated Layered- and Spinel Electrode Structures for High Capacity Lithium-Ion Cells	Michael Thackeray (ANL)	3-26	3.40	3.40	3.30	3.30	**3.38**
es052	Design of High-Performance, High-Energy Cathode Materials	Marca Doeff (LBNL)	3-31	3.00	3.00	3.50	3.25	**3.09**
es055	NMR and MRI Studies of SEI, Dendrites, and Electrode Structures	Clare Grey (U. of Cambridge)	3-37	3.70	3.50	3.70	3.30	**3.55**
es056	Development of High-Energy Cathode Materials	Jason Zhang (PNNL)	3-42	3.25	3.25	3.42	3.33	**3.28**
es059	Advanced *In Situ* Diagnostic Techniques for Battery Materials	Xiao-Qing Yang (BNL)	3-47	3.50	3.25	3.50	3.13	**3.33**
es085	Interfacial Processes in EES Systems Advanced Diagnostics	Robert Kostecki (LBNL)	3-51	3.50	3.63	3.13	3.25	**3.48**
es091	Predicting and Understanding Novel Electrode Materials From First-Principles	Kristin Persson (LBNL)	3-55	3.17	3.67	3.00	3.00	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es106	High-Capacity Multi-Lithium Oxide Cathodes and Oxygen Stability	Jagjit Nanda (ORNL)	3-58	3.17	3.00	3.17	2.92	**3.05**
es164	Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing†	Jianlin Li (ORNL)	3-63	3.33	3.25	3.17	3.25	**3.26**
es166	Post-Test Analysis of Lithium-Ion Battery Materials†	Ira Bloom (ANL)	3-63	3.25	3.25	3.50	2.67	**3.21**
es167	Process Development and Scale-Up of Advanced Active Battery Materials—Gradient Cathode Materials†	Greg Krumdick (ANL)	3-71	3.33	3.33	3.42	3.50	**3.36**
es168	Process Development and Scale-Up of Critical Battery Materials—Continuous Flow Produced Materials†	Greg Krumdick (ANL)	3-75	3.50	3.57	3.36	3.50	**3.52**
es183	*In Situ* Solvothermal Synthesis of Novel High-Capacity Cathodes	Feng Wang (BNL)	3-79	3.75	3.50	3.50	3.42	**3.55**
es201	Electrochemical Performance Testing†	Ira Bloom (ANL)	3-84	3.50	3.38	3.63	3.38	**3.44**
es202	INL Electrochemical Performance Testing†	Matt Shirk (INL)	3-88	3.75	3.75	4.00	3.63	**3.77**
es203	Battery Safety Testing†	Leigh Anna Steele (SNL)	3-91	3.75	3.50	3.88	3.50	**3.61**
es204	Battery Thermal Characterization†	Matthew Keyser (NREL)	3-94	3.88	3.75	4.00	3.75	**3.81**
es207	Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes†	David Wood (ORNL)	3-97	3.17	3.00	3.33	3.17	**3.10**
es220	Addressing Heterogeneity in Electrode Fabrication Processes	Dean Wheeler (Brigham Young U.)	3-101	3.70	3.40	3.50	3.30	**3.48**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es225	Design and Synthesis of Advanced High-Energy Cathode Materials	Guoying Chen (LBNL)	3-105	3.50	3.50	3.67	3.17	**3.48**
es226	Microscopy Investigation on the Fading Mechanism of Electrode Materials	Chongmin Wang (PNNL)	3-108	3.63	3.63	3.50	3.50	**3.59**
es231	High-Energy Density Lithium Battery	Stanley Whittingham (Binghamton U.-SUNY)	3-111	3.33	3.17	2.92	3.08	**3.17**
es232	High-Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions	Vincent Battaglia (LBNL)	3-116	2.88	2.88	3.75	2.88	**2.98**
es235	Characterization Studies of High-Capacity Composite Electrode Structures	Michael Thackeray (ANL)	3-119	3.20	3.30	3.10	3.20	**3.24**
es240	High-Energy Anode Material Development for Lithium-Ion Batteries†	Cary Hayner (Sinode Systems)	3-124	3.00	2.63	3.00	2.75	**2.78**
es241	Advanced High-Performance Batteries for Electric Vehicle (EV) Applications†	Ionel Stefan (Amprius)	3-128	3.50	3.38	3.38	3.25	**3.39**
es247	High-Energy Lithium Batteries for Electric Vehicles†	Herman Lopez (Envia Systems)	3-132	3.38	3.38	3.75	3.13	**3.39**
es252	Enabling High-Energy/Voltage Lithium-Ion Cells: Electrolytes and Additives†	Dennis Dees (ANL)	3-136	3.50	3.40	3.30	3.40	**3.41**
es253	Enabling High-Energy/Voltage Lithium-Ion Cells: Theory and Modeling†	Dennis Dees (ANL)	3-140	3.50	3.63	3.50	3.38	**3.55**
es254	Enabling High-Energy/Voltage Lithium-Ion Cells: Materials Characterization†	Dennis Dees (ANL)	3-143	3.40	3.30	3.40	3.30	**3.34**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es261	Next-Generation Anodes for Lithium-Ion Batteries: Overview†	Dennis Dees (ANL)	3-147	3.44	3.31	3.75	3.25	**3.39**
es262	Next-Generation Anodes for Lithium-Ion Batteries: Fundamental Studies of Si-C Model Systems†	Robert Kostecki (LBNL)	3-153	3.44	3.31	3.56	3.38	**3.38**
es263	Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing†	Stuart Hellring (PPG)	3-158	3.30	3.40	3.30	3.30	**3.35**
es264	Li-Ion Battery Anodes from Electrospun Nanoparticle/ Conducting Polymer Nanofibers†	Peter Pintauro (Vanderbilt U.)	3-161	2.90	3.30	3.20	3.00	**3.15**
es265	UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of Lithium-Ion Battery Electrodes†	John Arnold (Miltec UV International)	3-164	3.40	3.20	3.00	3.20	**3.23**
es266	Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing†	Ranjeet Rao (PARC)	3-168	3.25	3.25	3.50	3.13	**3.27**
es267	Commercially Scalable Process to Fabricate Porous Silicon†	Peter Aurora (Navitas Systems)	3-172	3.29	3.36	3.29	3.14	**3.30**
es268	Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials†	Aaron Feaver (Group14 Technologies)	3-175	2.93	2.93	3.21	2.86	**2.96**
es269	An Integrated Flame Spray Process for Low-Cost Production of Battery Materials†	Yangchuan Xing (U. of Missouri)	3-179	2.70	2.50	2.60	2.60	**2.58**
es271	New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage†	Peng Du (Silatronix)	3-184	3.17	3.00	3.25	3.00	**3.07**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es273	Composite Electrolyte to Stabilize Metallic Lithium Anodes	Nancy Dudney (ORNL)	3-188	3.75	3.50	3.75	3.63	**3.61**
es274	Nanoscale Interfacial Engineering for Stable Lithium Metal Anodes	Yi Cui (Stanford U.)	3-191	3.38	3.63	3.38	3.75	**3.55**
es275	Lithium Dendrite Prevention for Lithium-Ion Batteries	Wu Xu (PNNL)	3-194	3.50	3.25	3.50	3.38	**3.36**
es276	Mechanical Properties at the Protected Lithium Interface	Nancy Dudney (ORNL)	3-197	3.63	3.50	3.88	3.63	**3.59**
es277	Solid Electrolytes for Solid-State and Lithium-Sulfur Batteries	Jeff Sakamoto (U. of Michigan)	3-199	3.75	3.63	3.38	3.38	**3.59**
es278	Overcoming Interfacial Impedance in Solid State Batteries	Eric Wachsman (U. of Maryland)	3-201	3.50	3.33	3.33	3.50	**3.40**
es288	Construction of High-Energy Density Batteries†	Christopher Lang (Physical Sciences Inc.)	3-203	3.20	3.20	3.10	3.13	**3.18**
es289	Advanced Polyolefin Separators for Lithium-Ion Batteries Used in Vehicle Applications†	Weston Wood (Entek)	3-206	3.50	3.30	2.90	3.10	**3.28**
es290	Hybrid Electrolytes for PHEV Applications†	Surya Moganty (NOHMs Technologies)	3-209	3.13	3.13	3.13	2.88	**3.09**
es291	SAFT-USABC 12V Start-Stop Phase II†	Alla Ohliger (Saft)	3-213	3.25	3.38	2.88	3.00	**3.23**
es293	A Closed Loop Process for the End-of-Life Electric Vehicle Lithium-Ion Batteries†	Yan Wang (WPI)	3-217	3.30	3.20	3.30	3.10	**3.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es296	Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries	Chulheung Bae (Ford Motor Co.)	3-220	3.50	3.42	3.58	3.42	**3.46**
es298	Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries	Kandler Smith (NREL)	3-224	3.71	3.57	3.71	3.43	**3.61**
es299	Microstructure Characterization and Modeling for Improved Electrode Design	Kandler Smith (NREL)	3-229	3.50	3.50	3.71	3.57	**3.54**
es300	Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment	John Turner (ORNL)	3-233	3.42	3.33	3.50	3.42	**3.39**
es301	Experiments and Models for the Mechanical Behavior of Battery Materials	John Turner (ORNL)	3-237	3.58	3.58	3.42	3.42	**3.54**
es302	Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling	Venkat Srinivasan (ANL)	3-241	3.67	3.50	3.50	3.58	**3.55**
es303	Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3D Mesoscale Simulations	Scott Roberts (SNL)	3-245	3.58	3.58	3.67	3.50	**3.58**
es304	Extreme Fast Charge and Battery Cost Implications	Shabbir Ahmed (ANL)	3-249	3.90	3.80	3.80	3.50	**3.79**
es305	Extreme Fast-Charging—Battery Technology Gap Assessment	Ira Bloom (ANL)	3-253	3.50	3.30	3.50	3.17	**3.36**
es306	Thermal Implications for Extreme Fast Charge	Matthew Keyser (NREL)	3-256	3.60	3.60	3.50	3.67	**3.60**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es307	Discovery of High-Energy Lithium-Ion Battery Materials	Wei Tong (LBNL)	3-259	3.25	3.17	3.42	3.00	**3.20**
es309	Electrode Materials Design and Failure Prediction	Venkat Srinivasan (ANL)	3-264	3.67	3.50	3.00	3.17	**3.44**
es310	Advancing Solid-State Interfaces in Lithium-Ion Batteries	Nenad Markovic (ANL)	3-267	3.13	3.13	3.13	3.00	**3.11**
es311	Understanding and Mitigating Interfacial Reactivity between Electrode and Electrolyte	Larry Curtiss (ANL)	3-270	3.38	3.25	3.00	3.38	**3.27**
es312	Daikin Advanced Lithium-Ion Battery Technology – High-Voltage Electrolyte	Joe Sunstrom (Daikin America)	3-274	3.50	3.13	2.63	3.13	**3.16**
es313	Performance Effects of Electrode Processing for High-Energy Lithium-Ion Batteries†	David Wood (ORNL)	3-277	3.00	3.42	3.25	3.08	**3.25**
es315	Developing Flame Spray Production Level Process for Active Materials†	Greg Krumdick (ANL)	3-282	3.00	3.00	3.17	3.08	**3.03**
es331	Development of a High-Energy Density EV Cell†	Mohamed Alamgir (LG Chem Power)	3-286	3.17	3.17	3.00	3.17	**3.15**
es332	High Electrode Loading EV Cell†	William Woodford (24M Technologies)	3-289	3.50	3.13	2.75	2.75	**3.13**
es333	Silicon Electrolyte Interface Stabilization Focus Group†	Anthony Burrell (NREL)	3-293	3.71	3.21	3.64	3.50	**3.43**
es334	Insights from Mesoscale Characterization Guides Rational LIB Design	William Chueh (Stanford U.)	3-298	3.75	3.63	3.00	3.63	**3.58**
es335†	Next-Generation Anodes for Lithium-ion Batteries: Materials Advancements	Zhengcheng Zhang (ANL)	3-301	3.25	3.31	3.69	3.25	**3.34**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
es336	Extreme Fast Charging (XFC) Gap Assessment†	Christopher Michelbacher (INL)	3-306	3.80	3.50	3.90	3.75	**3.66**
Overall Average				**3.40**	**3.33**	**3.40**	**3.26**	**3.35**

† Denotes a poster presentation.

Presentation Number: es028
Presentation Title: Materials Benchmarking Activities For CAMP Facility
Principal Investigator: Wenquan Lu (Argonne National Laboratory)

Presenter

Wenquan Lu, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

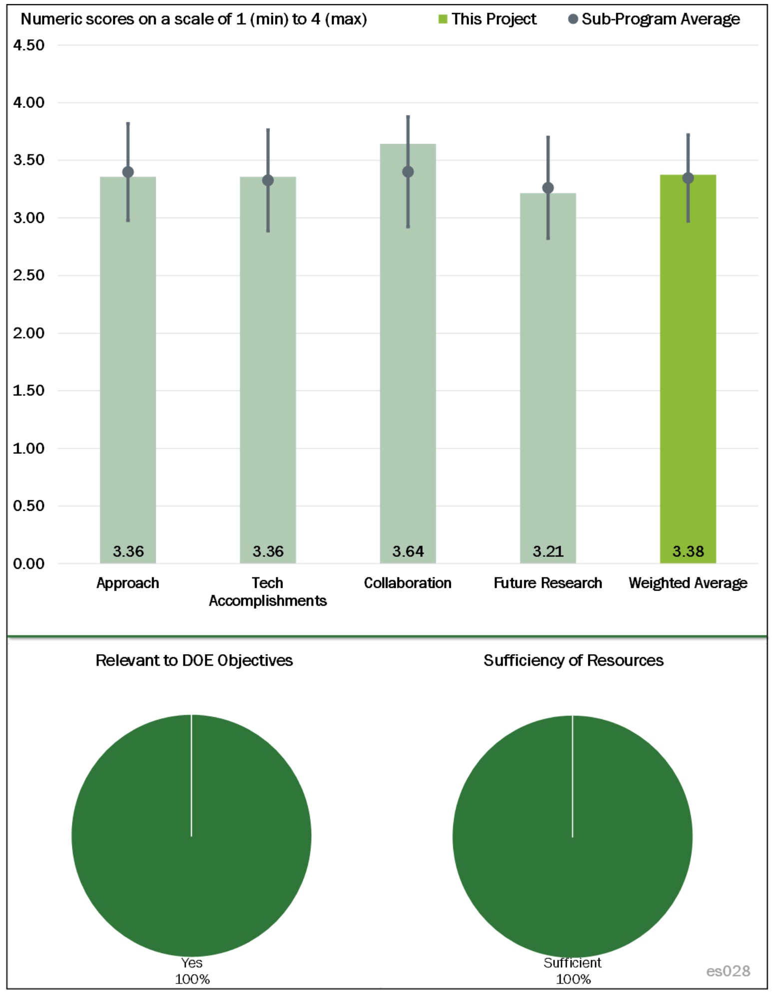

Figure 3-1 – Presentation Number: es028 Presentation Title: Materials Benchmarking Activities For CAMP Facility Principal Investigator: Wenquan Lu (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the goal is to provide developers with a way to benchmark their materials. A powerful suite of tests has been developed.

Reviewer 2:

The approach and materials used to benchmark the material produced at the Argonne National Laboratory (ANL) Cell Analysis, Modeling, and Processing (CAMP) Facility are appropriate and industrially relevant. The identification, characterization, and validation (a.k.a. "benchmarking") of these materials is extremely useful especially when combined with the other activities of CAMP to supply the benchmarked material and serve as a standardization body. This is extremely necessary in order to provide relatable testing between research groups.

Reviewer 3:

The reviewer commented that the project approach is balanced with good fundamental planning and scientific approach combined with practical approach focusing on things that are relevant in the final commercial application.

Reviewer 4:

The reviewer noted that the major issue in the approach is that work seems to be limited to coin cells. Coin cell tests are an acceptable way to identify gross details of cell and material behaviors; they are more limited in assessing subtle differences. Some of the claimed improvements associated with coating NMC532 (nickel manganese cobalt oxide) materials are relatively small. They should be confirmed in larger cells constructed using techniques similar to the techniques used to manufacture vehicular cells.

The reviewer stated that a separate issue is related to the basic nature of this project as this is a benchmarking effort whose goal is to collect data on materials that are already available from commercial sources. The modifications studied in this project, such as coating the NMC and using carbon nanotubes as part of the conductive mix, are not really new—they have been extensively investigated by other laboratories and industry.

According to the reviewer, the major benefit of this effort is that it provides independent data on the performance of "commercial" materials; these data can then be compared with similar data from new materials.

Reviewer 5:

This reviewer would like to have seen different and larger cell formats evaluated after the initial coin cells indicate very positive results.

Reviewer 6:

The reviewer stated that the approach to validate electrochemical performance of high-energy materials using coin cell under test protocol derived from the plug-in hybrid electric vehicle (PHEV) having a 40-mile range (PHEV40) requirement is well designed and feasible. The principal investigator (PI) should provide more information regarding the PHEV40 requirements conversion to C-rate and pulse current for coin cells. The work can be further improved by addressing one of the technical barriers related to cost.

Reviewer 7:

The reviewer found that the project provides validation and support for other DOE-sponsored battery developers, thus providing useful information and integration, but does not focus on new material discovery.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer described the CAMP project as very successful, especially given the limited availability of some of the materials needed to meet the stated DOE goals. The progress in establishing useful evaluation processes for the various components was excellent and should lead to testing and evaluation improvements in the industry.

Reviewer 2:

The reviewer observed that the project studied carbon black (CB) distribution, which is normally ignored, but which can be important. The project provided numerous standard performances for materials of interest.

Reviewer 3:

The reviewer commented that the project has met most of the proposed technical goals.

Reviewer 4:

The reviewer stated that the project has provided useful information on NMC, alumina coated NMC, single-wall carbon nanotubes (SWCNT), and separator materials.

Reviewer 5:

As noted in the discussion of the Approach, this project benchmarks existing materials. The reviewer stated that there is relatively little in this project that advances technology per se. Benchmarking is important because it lets one understand the limits of the state-of-the-art, but benchmarking per se does relatively little to advance the state-of-the-art.

The reviewer remarked that many of the results mentioned in the poster presentation are not new. For example, coating of cathode materials with aluminum oxide (Al_2O_3) has been investigated for years, and the degradation of some commercial separators at higher voltages has been known—at least by the separator companies—for several years.

Reviewer 6:
The reviewer pointed out that the program focused on improved NMC532 materials over the previous year and included relevant results showing improved electrochemical results via the incorporation of Al_2O_3 surface coatings. The choice of materials and coatings is useful, and the results demonstrate the ability to make progress toward DOE goals (improved capacity, rate, and capacity retention with high-energy cathodes). However, the reviewer noted that it is not clear how much energy density improvement will be feasible through the exchange of CB with SWCNT. The reviewer wanted to see a more in-depth analysis and modeling of the benefits.

Reviewer 7:
The reviewer noted that there has been a lot of progress on modifying high energy density cathode materials, pre-lithiated anodes, and carbon additives. The work can be improved by validating more commercialized samples from various industry partners listed in the presentation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that the collaboration between the various groups was excellent. The national laboratory involvement and the broad supplier base were excellent. This reviewer would like to have seen a larger number of high-volume suppliers involved in the project.

Reviewer 2:
The reviewer found the list of collaborators both from academic and national laboratories and industry to be outstanding.

Reviewer 3:
The reviewer praised the extensive collaboration in this project, both internally between groups as well as externally with other research institutions and industrial companies.

Reviewer 4:
The reviewer said that there was a very wide range of collaborators and co-investigators, as with everything in CAMP

Reviewer 5:
The reviewer said that there was collaboration with numerous battery development groups.

Reviewer 6:
The reviewer commented that the poster presentation clearly lists collaborators in industry and other laboratories, but there is no discussion as to how this collaboration functions or the benefits gained from collaboration.

Reviewer 7:
The reviewer described collaboration activities within the national laboratory and with universities as fairly coordinated. The PI should encourage the industry partners to get more involved in the research activity, especially to help benchmarking high energy materials and providing more commercialized samples for testing.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that focusing on a Si-based anode seems logical.

Reviewer 2:
The reviewer stated that the project will expand validation work to other high-energy anode and cathode materials of interest, as well as collaborations.

Reviewer 3:
The reviewer commented that the presentation lists several materials that will be benchmarked in the future. All of these materials are of interest to the battery community.

No specific decision points or barriers were explicitly defined. Given that benchmarking is more "test and evaluation" than it is "research," the lack of decision points and discussion of barriers is not a disabling flaw.

Reviewer 4:
The reviewer commented that the future plan was very logical and fairly complete. This reviewer would like to have seen the inclusion of larger format cells with different cell designs included as part of the plan for future work.

Reviewer 5:
The reviewer stated that appropriate plans have been described, but did not see any efforts to develop new diagnostics that could be valuable for developers, such as post-mortem analyses.

Reviewer 6:
The reviewer observed that the broad future plan appears appropriate, but more specifics are required to accurately determine the quality of the proposed future research. The reviewer suggested that there should be emphasis on higher energy NMC materials and Si-based materials. This project should be aligned with serving to assist in solving the most pressing issues required to advance lithium-ion battery (LIB) technology significantly.

Reviewer 7:
The reviewer asserted that the PI should focus more on validating or studying high energy electrodes and sharply focus on the most critical barriers. Meanwhile, the PI should deemphasize divergent effort on binders and conductive additives.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that there is a high cost associated with reaching the objective of displacing petroleum as the default fuel for transportation vehicles. The only way that this objective can be reached by industry is by support of DOE through such projects as the CAMP Facility. This project allows for innovative processes that can lead to materials developments to be expertly evaluated at a significant cost savings to the supplier.

Reviewer 2:
The reviewer said that the project objectives are very well aligned.

Reviewer 3:
The reviewer acknowledged that the benchmarking activity is important to provide an objective opinion on promising battery materials to battery materials developers. This will accelerate the materials development and EV adoption.

Reviewer 4:
The reviewer stated that implementation of new materials will help improve battery performance to achieve desired commercial adoption of electric vehicles (EVs).

Reviewer 5:
The reviewer said yes. This project aids in the development of new materials for EV applications both directly (benchmarking) and indirectly (collaboration).

Reviewer 6:
The reviewer said that these battery improvements will advance vehicle electrification and thus displace petroleum consumption.

Reviewer 7:
The reviewer noted that in order to meet the overall DOE objectives, new batteries containing new materials will be required. Part of the process of developing new materials is the understanding of the state-of-the-art. This project helps provide that understanding.

The reviewer also commented that this project was reported at the AMR in more than one poster, but this reviewer was assigned to review only this presentation. Reviewing only part of a project may have resulted in overlooking some data included in the other presentations.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the funding provided meets the needs of the suppliers identified.

Reviewer 2:
The reviewer noted that resources are okay.

Reviewer 3:
The reviewer said that the resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 4:
The reviewer noted that resources are sufficient to achieve milestones.

Reviewer 5:
The reviewer found resources and funding to be in line with the work scope.

Reviewer 6:
The reviewer commented that there is no information in the presentation or in discussions with the presenter to indicate that the resources are excessive or inadequate. Funding is such that this is only a part of the larger CAMP effort.

Reviewer 7:
The reviewer found resources and funding to be sufficient for this project but would like to have seen larger cells being tested for benchmarking purposes as well as potentially serving as an independent third-party validator for industrial materials.

Presentation Number: es030
Presentation Title: Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities
Principal Investigator: Andrew Jansen (Argonne National Laboratory)

Presenter
Andrew Jansen, Argonne National Laboratory

Reviewer Sample Size
A total of seven reviewers evaluated this project.

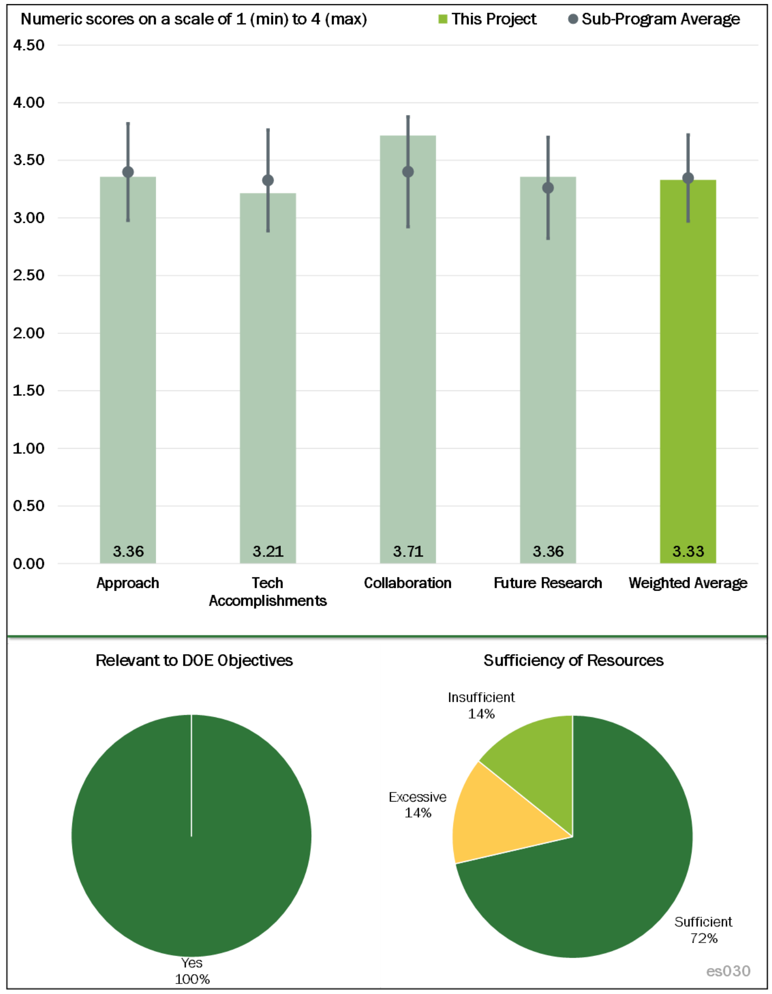

Figure 3-2 – Presentation Number: es030 Presentation Title: Cell Analysis, Modeling, and Prototyping (CAMP) Facility Research Activities Principal Investigator: Andrew Jansen (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the goal is to be a resource for small-scale powder producers so that they can get high quality cells made. Extensive diagnostics are available. An outstanding laboratory has been assembled for these purposes.

Reviewer 2:
The reviewer commented that this project coordinates very well with the other aspects of the CAMP project. The approach addresses some of the areas that this reviewer mentioned as concerns in the ES028 project.

Reviewer 3:
The reviewer remarked that CAMP is providing a useful platform to provide relevant materials across the industry to various academic, industrial, and government institutions. The projects provide the required standardization of many electrode materials.

Reviewer 4:
The reviewer found that the technical barriers are well addressed. The projects, which are designed to validate the materials from coin cell level to pouch cell level, will effectively evaluate the feasibility of the new materials commercialization.

Reviewer 5:
The reviewer observed that the approach is logical and designed to systematically address issues confronting the development of a safe, affordable battery that meets DOE and USABC goals. Materials are tested in realistic pouch cell or 18650 formats.

Reviewer 6:
The reviewer stated that the PI and team are progressing and contributing to the general knowledge base concerning LIBs. However, it appears that work is most all "experimental with no up-front computational work (either Materials Genome Initiative [MGI] or integrated computational materials engineering [ICME])" being first accomplished. As a result, it seems that the experimental approach wanders year to year without a formal go/no-go established to determine when the team should instead prioritize other efforts and move away from Si-Li-ion materials, etc. It is apparent that process and equipment are under a state of constant refinement. However, this creates a significant issue. The reviewer asked when a result is determined, is it due to process refinement or because of materials design. A baseline needs to be established from which all work can be referenced.

Reviewer 7:
The reviewer pointed out that there was too much information in the slides, and that the PI should focus.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked that CAMP has been successfully supporting other DOE projects and collaborating with other DOE laboratories. The validation activity show good progress toward DOE goals.

Reviewer 2:
The reviewer commented that significant accomplishments were made, including evaluations of lithium bis(fluorosulfonyl)imide (LiFSI) and lithium 4,5-dicyano-2-trifluormethyl-imidazolide -based electrolytes and improvements to Si composite anodes.

Reviewer 3:
This reviewer felt that there was significant progress toward this project's and DOE's goals, particularly in the area of understanding and evaluation of degradation in Si anodes. The addition of the evaluation work on some high-energy, high-voltage cathodes and electrolytes to the overall CAMP library helps the battery community narrow the selections to obtain desired performance.

Reviewer 4:
The reviewer stated that an enormous amount of work has been accomplished. It would be even better if the data were analyzed with models that aimed to make predictions for new or modified systems.

Reviewer 5:
The reviewer observed that the team, which to date has not met DOE objectives, does formulate and execute plans to overcome encountered barriers. What remains to be established is whether the principal issue is quality, process, or simply the material set that is being used in support of the project. It seems that the project has "stalled," and the team reports minimal progress. This, of course, is due to a myriad of reasons, such as changing composition, loss of the supply chain for Si materials, an apparent issue with materials variability due to process, etc. If the program is continued, a precise and comprehensive metric set needs be established against which the team must work.

Reviewer 6:
The reviewer commented that the project appears to be making sufficient progress on investigating new nickel cobalt manganese oxide (NCM) cathode materials and various acceptable voltage cutoffs. The Si benchmarking effort seems to be significant, but the progress toward the DOE goals appears limited. The reviewer would like to have seen if CAMP were able to assist technical accomplishments of industrial partners to a noticeable extent.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the group is making a real impact by providing data and guidance to a very large number of clients and commented that this was very, very impressive.

Reviewer 2:
The reviewer asserted that CAMP provides a critical role in developing and supplying standardized materials for various government, research, and industrial organizations. CAMP's collaboration and outreach is significant and extremely necessary.

Reviewer 3:
The reviewer observed that the collaborations are outstanding, and include the national laboratories, numerous industry partners, and universities.

Reviewer 4:
The reviewer commented that the team reports considerable interaction among PIs at Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), and the National Renewable Energy Laboratory (NREL) as well as with subject-matter experts (SMEs) from other sectors.

Reviewer 5:
The reviewer stated that this project lists a wide assortment of collaborators from industry leaders, in addition to national laboratories and various universities.

Reviewer 6:
The reviewer said that CAMP has been successfully supporting other DOE projects and collaborating with other DOE laboratories.

Reviewer 7:
The reviewer warned that the numbers of collaborations was too much, and the PI must select the best institution to meet the DOE goal.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer enthused about not being able to imagine a better list of challenges for future work and hoping to see much progress next year.

Reviewer 2:
The reviewer noted that the proposed future efforts are very outstanding. Efforts will be initiated to understand the limitations of Li-metal anodes. The team will attempt to develop techniques for in-operando detection of Li plating during fast charging.

Reviewer 3:
The reviewer stated that the proposed future research is logical and far-reaching (Si, Li plating; cathodes; conductive binder; electrode processing; etc.). The project serves an important role in ensuring validity of many other ongoing projects within DOE. The reviewer wanted to see more results regarding analysis and prototyping of advanced industrial R&D materials.

Reviewer 4:

The reviewer commented that the team suggests seven tasks for the upcoming fiscal year. Overall, it seems that individually the tasks deserve priority. However, within the scope of this project, that seems overly broad. Instead, the reviewer suggested that the team should select narrowly defined tasks so as to enable focus on the ultimate DOE objective and not be distracted by lower priority issues.

Reviewer 5:

The reviewer opined that during the validation process of the newly developed materials, new technical problems of new chemistries related to the cell designs surely will show up. It is critical for the CAMP PIs to closely work with the developers to close the feedback loop. This should be emphasized in the future plan.

Reviewer 6:

The future work plans address the current concerns and issues that were identified during the project. One comment is that the future plans for this project appear to be beyond the identified current resources for this project.

Reviewer 7:

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that this project moves the materials development needed to meet DOE objectives forward at a faster rate than would be possible without the DOE support to establish and support both industry and national laboratory involvement in this collaborative project.

Reviewer 2:

The reviewer stated that the CAMP activity is important to provide an objective opinion on the promising battery materials to the battery materials developers. This will accelerate the materials development and EV adoption.

Reviewer 3:

The reviewer noted that CAMP serves an important role in developing electrodes to accelerate progress toward vehicle electrification and petroleum displacement.

Reviewer 4:

The reviewer affirmed that this effort is highly relevant to the overall success of the DOE and USABC program.

Reviewer 5:

The reviewer found the project to be very relevant.

Reviewer 6:

The reviewer said battery for EVs and PHEV

Reviewer 7:

Although developing a lightweight, high-capacity “battery” reduces transportation energy need due to weight reductions obtained when introduced to vehicles, it remains a battery focused on energy storage, regardless of generating source.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the resources to be OK.

Reviewer 2:
The reviewer said that the resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 3:
The reviewer said that the funding is sufficient for the current level of effort, but thinks, however, that the funding would not be sufficient for the extensive future plans outlined.

Reviewer 4:
The team has made significant advances in establishing materials and processes set in the fabrication of LIBs. However, it seems that, unless the discovery of new materials yields properties to meet the stated DOE objectives, a compromise needs be made resulting in new objectives for this program that are not quite so ambitious.

Reviewer 5:
The reviewer stated that the project should keep the same resources and focus.

Reviewer 6:
The funding may be slightly on the high side considering that outside parties most likely contribute additional funds for their work done at CAMP. It is unclear if the budget includes funding for related DOE projects (such as ES028) or if they have their own budget as well. Much work in the presentation focused on coin cells (only some anodes tested in pouch cells) although the facility boasted equipment upgrades (2 ampere hour [Ah] pouch cells; 18650).

Presentation Number: es049
Presentation Title: Tailoring Integrated Layered- and Spinel Electrode Structures for High Capacity Lithium-Ion Cells
Principal Investigator: Michael Thackeray (Argonne National Laboratory)

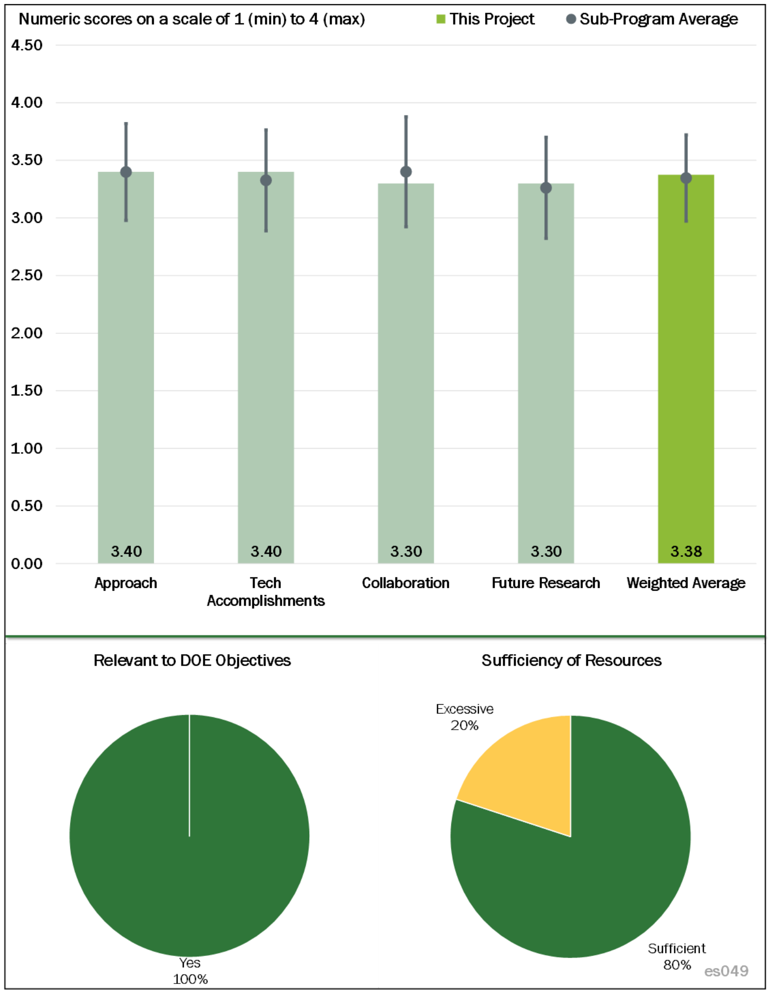

Figure 3-3 - Presentation Number: es049 Presentation Title: Tailoring Integrated Layered- and Spinel Electrode Structures for High Capacity Lithium-Ion Cells Principal Investigator: Michael Thackeray (Argonne National Laboratory)

Presenter

Michael Thackeray, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that, as always, the PI does great hypothesis driven research. The approach is systematic and builds on the learnings as it progresses. There is a nice consideration of the balance of effects as deficiencies in the Li-rich material are addressed.

Changing the spinel component to include cobalt (Co) seems promising and shows the progression of thought in the project.

Reviewer 2:

The reviewer commented that the objective here is to develop structurally integrated cathode structures, specifically layered-layered-spinel (LLS), to overcome the inherent issues associated with the layered-layered (LL) composite cathodes, including voltage fade, poor cyclability and poor rate capability of the Li-rich, manganese (Mn)-rich LL composite oxides. These materials are expected to have comparable performance (i.e., high capacity at high rate) like the nickel (Ni)-rich layered oxides (622 or 811).

There is an advantage with these Mn-rich LLS composites in abuse resistance, but it is not clear if these materials provide comparable capacity (approximately 240 mAh/g) and energy (low discharge voltage) with the Ni-rich layered cathodes with similar surface coatings, especially with comparable electrode loadings (not specified here). Likewise, the development of Co-and Ni-based spinel compounds, as components of these LLS structures, looks encouraging because of their higher voltages, but may also pose more safety issues compared to Mn-rich spinels.

Nevertheless, these studies provide an excellent platform to understand the Mn-rich LLS composite cathodes and also to tune the transition metals (with Co and Ni spinels) to optimize specific energy, cost, and safety.

Low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles, which these LLS composite cathodes will duly address.

The present project is well designed with new cathode structures, feasible as shown by the experimental data, and adequately integrated with the other DOE efforts on the high-capacity LL cathodes.

Reviewer 3:

The reviewer stated that the approach of lattice parameter matching of spinel coatings is reasonable because improving the stability of the previous high-capacity, LL material should be the highest priority.

Reviewer 4:

The reviewer noted that the energy density is significantly increased with over 200 mAh/g at more than 1° Celsius (C) obtained. The stability remains a challenge to overcome.

Reviewer 5:

The reviewer pointed out that the project focuses on finding optimum compositions and atomic arrangements to stabilize bulk and combat internal phase transitions through embedding spinel-type defects. The approach is good for answering the fundamental questions on the limitations of this family of materials, but does not address the practical side. The reviewer asked can these complex compositions be reproduced on the large scale, and what would be the quality control measures.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer pointed out that with spinel coatings, the material appears to have gained some stability over cycles. In addition, the rate capability also has been improved. However, the materials in this series need to be charged to much higher voltages compared to lithium-cobalt oxide (LCO). The stability of material—including decomposition and reaction with electrolytes over hundreds cycles—is still in question.

The reviewer expressed doubt about whether the oxidation states of each transition metal as a function of voltage during charge-discharge cycles have been thoroughly examined. It appeared to this reviewer that it was difficult to explain the large capacity by Ni_{2+} and Ni_{4+} alone. In the case of NMC, many have claimed charge storage on oxygen with no changes in Mn, which was difficult for this reviewer to believe.

Examining the very first charge, i.e., the initial activation of very high capacity using X-ray absorption near edge structure (XANES) and differential electrochemical mass spectroscopy (DEMS) seems to be very important to understand the LL or LLS materials better. The reviewer asked what is basically so much oxidized beyond Ni, and said O_2 evolution creating O_2 deficiency with Mn (III). It is not clear just by looking at the formula.

Reviewer 2:

The reviewer stated that excellent progress has been made in designing the LL cathodes with embedded spinel component. With such embedded spinel component (of 6%), good cyclic stability was demonstrated without reduced voltage fade. It appears that maximum specific capacities of these LLS cathodes with good cyclic stability and low voltage fade are around 220 mA/g, slightly lower than the Ni-rich oxide cathode. The designed composite structures with domains of layered and spinel phases were confirmed through X-ray diffraction (XRD) and high-resolution transmission electron microscopy (HRTEM). New surface coatings have been developed that allow the LLS cathodes to operate at high charge voltages. In addition, new high-potential (approximately 3.5 volt [V]), lithiated Co- and Ni-based spinels have been evaluated as potential components for LLS electrode systems. Also, several good publications have emerged from this project.

The reviewer offered a couple of questions, however. The reviewer asked could the 6% of spinel component be expected to stabilize 94% of the LL structure for extended periods of operation (beyond hundreds of cycles and months of operation), and if there is any direct evidence for the elimination of the transition metal (TM) migration. There is evidence for the local domains of spinel and layered phases, but the reviewer asked would it be possible to verify if the spinel content (in the bulk) is close to the targeted 6%, and are the electrode loadings here are close to the practical values of 30 mg/cm^2.

Overall, the technical accomplishments are significant and demonstrate the progress toward DOE goals.

Reviewer 3:

The reviewer commented that the first objective has been completed. The second one is on track to have improved stability but not yet achieved.

Reviewer 4:

The reviewer noted that the project goals are being met, but asked if perhaps they were not challenging enough. The reviewer thought the learnings in this project can be applied to ultimately exceed the original goals.

The reviewer appreciated the acknowledgment of complexity in processing as it is hard to control both composition and structure, and more work needs to be done here.

Reviewer 5:

Embedding lithiated Co-rich spinels make sense, but the reviewer questioned whether it will also add cost and safety concerns.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer acknowledged that the effort seems to be focused at ANL, which the reviewer thought was actually appropriate as this group is in the best position to solve the challenges in Li-rich NMC.

Reviewer 2:

The reviewer stated that this project team works with colleagues from ANL, Pacific Northwest National Laboratory (PNNL), a university, and also industry for the materials synthesis, characterization, and scale-up tests.

Reviewer 3:

The reviewer remarked that there are good collaborations with several researchers from ANL and also with external researchers in understanding these materials at the fundamental level. It would be more appropriate and timely to collaborate closely with industry, especially the licensees (BASF, Toda, LG, and Envia), to establish the merit and relevance of these materials compared to nickel-cobalt-aluminum oxide (NCA)-based cathodes or Ni-rich cathodes. Such interactions with industry to evaluate ANL's baseline LLS electrodes and surface-treated materials have been initiated.

Reviewer 4:

The reviewer would like to have seen K-edge XANES data through collaborations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the proposed future research is to continue the development of these LLS cathodes with new surface coatings to optimize specific capacity, operating voltage, rate, and cyclic stability. Preliminary results on the new, high-potential (3.5V), lithiated Co- and Ni-based spinels are encouraging and have opened up new opportunities for material development, which will be pursued here.

It is, however, important to demonstrate the benefits of these LLS cathode materials in an industrial environment in comparison with the surface-treated NCA-based cathode to properly the technical barriers in the VTO program. Future efforts will have collaborative interactions with industry to evaluate the baseline LLS electrodes and surface-treated materials.

Reviewer 2:

The reviewer commented that promising results on a Co-based spinel component will be a focus in the future, acknowledgment of characterization and process needs is encouraging, and there is a realistic approach recognizing trade-offs as the material is improved.

Reviewer 3:

The reviewer was interested in seeing any statistical data as they relate to the compositional control.

Reviewer 4:

The reviewer hoped to see more practical data using standard form factor cells in a full cell mode even though in small number of cells are constructed.

Reviewer 5:

First of all, the reviewer noted, Co is toxic and known to be the expensive element to avoid for low-cost electrode making. Thus, the reviewer had reservation in the further exploration of this material in LLS study.

Secondly, the listed future work seems on the optimization of the LLS to achieve the goals. This is necessary. However, to improve the stability, there should be more effort in the surface and structural design rather than only the chemistry of elemental differences in the composition.

Thirdly, the scale-up work would be also industrially interesting to be carried out.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer observed that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High specific energy cathode materials (at high discharge rates) with reduced cost and improved safety are required to address these shortcomings. The LLS composite cathodes with suitable surface coatings are promising to provide stable structures with high capacities at high rates and are being addressed in this project.

This project is thus highly relevant to the DOE goals.

Reviewer 2:

The reviewer noted that energy storage is important for renewable energy supplies. The cheap and high-density cathode material is essential for the development of compact LIBs for energy storage and power supply. The project aims to have the material for the next generation of high-voltage cathode materials for EV applications. This would support the overall DOE objectives of petroleum displacement.

Reviewer 3:

The reviewer commented that any technology development focused on improving energy density of LIBs addresses the overall DOE objective.

Reviewer 4:

The reviewer said yes.

Reviewer 5:

The reviewer agreed that LLS composite structures still hold promise, but Ni-rich cathodes are not in vogue; they have been commercialized.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the resources for the project are well organized.

Reviewer 2:

The reviewer remarked that the first objective of high energy density has been achieved with excessive results over the target value. The second objective of a stable electrode is in progress. The reviewer believes the research can have impressive results in the next part of the project.

Reviewer 3:

The reviewer asserted that a steady, consistent effort on Li-rich is the right way to go. The entire battery community focused on this, with fragmented efforts. As previously stated, this group is uniquely positioned to solve this hard problem.

Reviewer 4:

The reviewer commented that the resources may be slightly in excess for the scope of the project, and was not sure why the funds are divided over two different tasks of composite electrodes and spinel components, which are related.

Presentation Number: es052
Presentation Title: Design of High-Performance, High-Energy Cathode Materials
Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

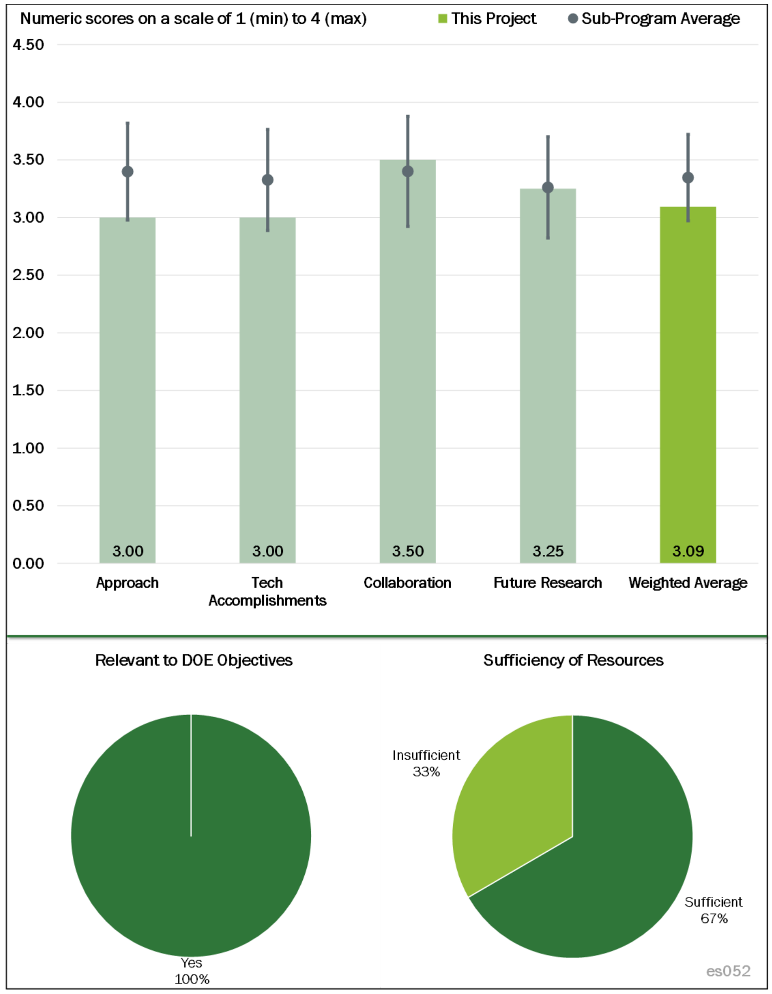

Figure 3-4 – Presentation Number: es052 Presentation Title: Design of High-Performance, High-Energy Cathode Materials Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

Presenter

Marca Doeff, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the objective here is to develop high-performance cathode materials possessing high-voltage and high specific energies, based on NMC formulations synthesized by conventional and novel synthetic procedures (spray pyrolysis). The approach is to utilize various synchrotron (soft X-ray absorption spectroscopy [XAS], X-ray photoelectron spectroscopy [XPS], X-ray Raman, transmission X-ray microscopy [TXM]) and microscopy scanning transmission electron microscopy-electron energy loss spectroscopy [STEM-EELS]) techniques to characterize the bulk properties of the NMC cathodes with aliovalent titanium (Ti)-substitution, graded compositions, and surface coatings to understand the effects of the latter on the cathode performance.

Earlier in the project, it was shown that charging the NMC cathode to a high-voltage (4.7V) would create a reaction layer (cathode electrolyte interfacial [CEI]) due to surface reconstruction with metals being reduced on the surface. Also, it was shown from that there is an elemental composition gradient in an NMC made by spray pyrolysis, with less Ni on the surfaces of particles than in the bulk, which proved to be beneficial for cyclic stability.

The specific objectives in the current year are to understand the surface and bulk characteristics of the NMC622 cathode synthesized by spray pyrolysis and track the changes in oxygen (O_2) reactively, transitional metal ion valence in the bulk, and at the surface of the cathode material. These studies were expected to provide a detailed understanding of the effects of the synthetic method, cycling to (high) charge voltage, and the nature of delithiation on the surface and bulk properties of the cathode and its performance.

Reviewer 2:

The reviewer declared that overall relevance and objectives are adequately stated and technical barriers are properly addressed.

Reviewer 3:

The reviewer stated that it would help if the DOE PIs can have access to the best commercially used high-Ni materials for benchmarking; there are a number of commercial companies that have benefited from DOE funding and should be willing to assist.

Syntheses conditions and choice of precursors all affect the electrochemical performance. For example, pyrolysis seems to produce “gradient” type of materials and should be compared to those in the market.

In general, the project is well designed and is systematic in its approach; the right questions are being asked.

Reviewer 4:

The reviewer asserted that the characterization work in the project is well thought out and well executed—beautiful data from which strong conclusions can be made. Better use of these analytical results to suggest ways to improve the material needs to be made.

The reviewer had a concern that conclusions are specific to the synthesis method, which is not commercially relevant. This should be addressed.

Reviewer 5:

The reviewer pointed out that the design of the high-energy materials is not emphasized. The understanding of the electrochemical behavior of the NMC prepared by different methods has been investigated. The reviewer felt that the PI should first explore the effects of the chemical compositions of the NMC and also the effects of reaction conditions (such as rotational speed of atomizer, slurry flow rate, hot gas flow rate, and temperature, etc.) of the spray pyrolysis. Then, chemical, physical and electrochemical characterization should be conducted with the materials that have shown promising results of “low-cost, high energy density and good stability.”

Reviewer 6:

The reviewer commented that, unlike the title, the material design direction is not quite clear. Much effort was focused on characterization of well-studied materials.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

Overall, in the opinion of the reviewer, this project presents a good set of data on surface characteristics that could explain the high-voltage degradation phenomena of NMC622 material. However, because EV cells having NMC622 are currently under development, it would be very helpful to have benchmarking study results of commercial NMC622 materials to help battery and vehicle industries.

The reviewer asked several questions. The first question pertained to oxidized Ni ions, which are very sensitive to the surrounding environment, e.g., air exposure. The reviewer asked how much impact the PIs think the handling process (opening the cell, preparing the XAS sample, etc.) has on the surface nitrogen and oxygen state, and asked if there are any plans to do the XAS study *in situ*.

Next, the reviewer stated that it would be good to include synthesis condition of the NMC622 materials. The reviewer asked why the material synthesized by spray pyrolysis show lower nitrogen content at the surface than in bulk, and asked if it is controllable.

The reviewer wanted to know, compared to the conventional synthetic method of NMC622, which uses co-precipitation, and if the spray pyrolysis is cost competitive, does the state of charge (SOC) heterogeneity observed from the charged particles homogenize with time or does the inhomogeneity remains with time. Lastly, the reviewer asked what the impact is of the SOC inhomogeneity on the electrochemical performance.

Reviewer 2:

The reviewer noted that good progress has been made in understanding the bulk and surface properties of the NMC622 cathode made by spray pyrolysis. While the bulk structural changes during cycling to 4.7V are reversible, the surface conditions are found to be irreversible. The surface Ni and oxygen (with higher reactivity) behave differently from the bulk species, resulting in surface reconstruction and surface film formation. Interestingly, such surface reconstruction was not observed in the chemically delithiated samples, suggesting that the electrolyte presence is a contributory factor in the surface reconstruction.

There are other differences in the chemically delithiated samples from the conventional electrochemically delithiated samples. The spray pyrolysis method appears to reduce the surface concertation of nitrogen slightly, which is probably good in terms of cyclic stability. Nevertheless, a comprehensive comparison needs to be made between the conventional solid-state method and spray pyrolysis in terms of cathode microstructure, tap density, and the overall material and process costs. If spray pyrolysis is deemed to be superior, it would have been worthwhile to explore using it for NMC811, instead of undertaking chemical delithiation studies, which, the reviewed stated, are not as relevant.

Reviewer 3:

The reviewer said that some materials have been synthesized using the spray pyrolysis method. Core-shell structure has been found not to be good for NMC for this process. Nickel is already poor at the surface using the spray pyrolysis method. The study focused more on the instrumental analysis of the behavior of the NMC material during charge and discharge. Formation of CEI was found. The cut-off voltage was also found important in the stability of the NMC cathode. The results should be useful in guiding further study. The reviewer felt that the material synthesis part should have been conducted in order to obtain more results.

Reviewer 4:

The reviewer stated that the project is hitting its goals and targets, but it still needs to address "ways to improve" based on the learnings.

Reviewer 5:

Titanium and magnesium doping is well characterized and is being commercially used for the LCO materials. It might be worth studying it for the nitrogen-rich systems.

Reviewer 6:

The reviewer inquired as to whether there had been any comparison of NMC synthesized by spray pyrolysis and materials by other methods and asked what the advantages of spray pyrolysis are.

Other comments from this reviewer included stating that TXM may not be an appropriate tool for understanding the issues, particularly the electrochemical behavior of particles (while it is powerful for understanding morphologies, compositions, segregations, etc.) because the electrochemical behavior of particles depends on the local potential, extent of electrolyte wetting, and electronic particle connectivity.

NMC622 does not appear to show "excellent reversibility" because there is a high capacity loss in the first cycle.

Soft XAS data collected in various modes were presented and compared with reference spectra. Likely the reference data were collected in the bulk mode. Thus, the data may not be compared directly with Auger data or total yield mode data. Reference spectra collected in total electron yield (TEY) or Auger mode may be useful.

The reviewer said that it is difficult to believe that Mn is inactive in the voltage range of 2.5 - 4.7V. The reviewer asked about collecting more unambiguous Mn K-edge data using hard X-rays. While it is likely true that the surface Ni is less oxidized than the bulk Ni, the data do not support such a view because the spectra show the Ni^{3+} peak in the bulk looks larger than the surface Ni^{3+}. In addition, Ni_{3+} has a peak at the same position as the carbonate peak.

The carbonate peak (not necessarily LCO) disappears upon charging. The reviewer asked if it is due to carbon dioxide (CO_2) evolution or diffusion into the bulk.

The XANES spectrum for electrochemically charged NMC shows a low energy shift from 50% discharged condition. If the two spectra and the images are not switched, there must be significant electrochemical reaction delays depending on the location in the electrode and interparticle connectivity, which leads to severe non-uniform current distributions. In other words, the non-uniformity in the image can be artificial due to the electrode structure rather than the intrinsic material property.

XANES cannot be more accurate for SOC than coulometry. A SOC is the coulometry itself by definition. The reviewer pointed out that the XANES is measuring the extreme local charge distribution. If there is a slight non-uniformity throughout the electrode space including the way particles are electronically contacted, the reviewer underscored that the spot being probed does not reflect the whole electrode.

The reviewer urged not to forget that the spectrum data collected for chemical delithiation are static while the data during electrochemistry are dynamic. Further, this reviewer suggested collecting spectra for the electrode fully relaxed at open-circuit voltage after charging or discharging, if the project team needs reasonable spectra representing the SOC.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there was outstanding, complicated coordination of work and characterization techniques with a broad variety of organizations and techniques. This project should serve as an example of coordination to others.

Reviewer 2:
The reviewer noted that this project consists of proper collaborators, and role of each collaborator is well defined.

Reviewer 3:
The reviewer said the project looks good.

Reviewer 4:
The reviewer indicated that there are good collaboration activities with several researchers in LBNL as well with external researchers: for example, with Stanford Synchrotron Radiation Lightsource (SSRL), with Brookhaven National Laboratory (BNL) in the basic studies on various NMC materials to understand the nature of the reconstructed surface layers, with NREL on the atomic layer deposition (ALD) coatings, and with University of California at Santa Barbara (UCSB) in the computational work. It is probably an appropriate time to collaborate with an industrial partner to assess the benefits of the spray-pyrolysis process.

Reviewer 5:
The reviewer observed that there were excellent collaborations with national laboratories and two universities on materials characterization. If industrial collaboration is available either from the materials synthesis or the materials application, that should be beneficial to the project.

Reviewer 6:
The reviewer recommended that a commercial partner supply samples for benchmarking.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer opined that the team needs to apply these wonderful characterization techniques to materials synthesized with commercially relevant processes.

Reviewer 2:
The reviewer remarked that it is great to explore NMC811 materials. The conditions in which the materials were obtained should give influential effect on their stability. The PI should explore the experimental conditions in addition to methods for the material synthesis.

Reviewer 3:
Appropriately, the reviewer stated, the future studies will largely focus on NMC811 to understand its surface as well as bulk properties in relation to the compositions already studied likewise (NMC532 and NMC622). These will include studies on the material synthesized using spray pyrolysis and also with different surface coatings and electrolytes (both will have substantial effect in the surface reconstruction). The future studies will also utilize collaborations with internal (at LBNL) and external researchers in exploring approaches toward making nitrogen-rich NMCs more robust.

These studies are consistent with the DOE goals of high specific energy, low-cost, and safe LIBs.

Reviewer 4:
The move to NMC811 is good, but the reviewer suggested that they try to get commercial (or semi-commercial) NMC811 materials and perform experiments as a reference. Also, it would be good to involve collaborators from the commercial sector. The reviewer would hesitate to call spray drying or pyrolysis novel synthesis, but hoped to see if the synthetic technique is viable in an economic sense. In this year's study, they showed the difference between surface and bulk. If the difference has a negative impact on electrochemical performance, the reviewer hoped they suggest ways to mitigate it.

Reviewer 5:
When assessing NMC811 material, the reviewer said that it is important to compare that to the NCA materials with the similar Ni and Co content.

Reviewer 6:
The reviewer stated that the future plan does not show any novel methods.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that storage is very important for renewable energy supply. High density and low-cost, stable cathode materials are the key challenge for the next generation of LIBs. The success of this project will lead to some promising materials for EV battery fabrication. This will be beneficial for the displacement of petroleum consumption, especially in the transportation sector.

Reviewer 2:

The reviewer stated that for widespread use of EVs and PHEVs, it is imperative that LIBs be lightweight, compact, safe, and low-cost. The state-of-the-art materials are inadequate to fulfil these needs. High energy density electrode materials are required to improve the specific energy for Li-ion cells and thus increase the range for the vehicle and reduce overall cost for the battery. The state-of-the-art cathode materials provide capacities of only 170 mAh/g, about half of the capacities possible from the carbon anodes. We need to explore new cathode materials, which the present project is duly addressing.

Reviewer 3:

The reviewer opined that nitrogen-rich layered oxide is the only cathode material that can lead to high-energy cells for now. Developing and understanding the nature and drawbacks of nitrogen-rich layered oxide is quite relevant to the DOE goal.

Reviewer 4:

The reviewer noted that understanding nitrogen-rich materials is very important to ensure their safe commercial use and to establish and define quality requirements.

Reviewer 5:

The reviewer stated that any project focused on improvement of energy density supports DOE objectives.

Reviewer 6:

The reviewer responded, “Likely.”

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer thought that the time limitations of the characterization resources are not necessarily adequate, and it was a tribute to the team that they could accomplish this much given these limitations.

Reviewer 2:

The reviewer remarked that there was too much unnecessary characterization, and there may need to be more synthetic efforts of material surface modification rather than simple coating by ALD or molecular layer deposition (MLD).

Reviewer 3:

The reviewer said that the resources are adequate, if not slightly excessive for the scope of the project.

Reviewer 4:

The reviewer opined that the team obtained an excessive amount of characterization data. The reviewer wished to see better performance materials in terms of stability and energy density.

Presentation Number: es055
Presentation Title: NMR and MRI Studies of SEI, Dendrites, and Electrode Structures
Principal Investigator: Clare Grey (University of Cambridge

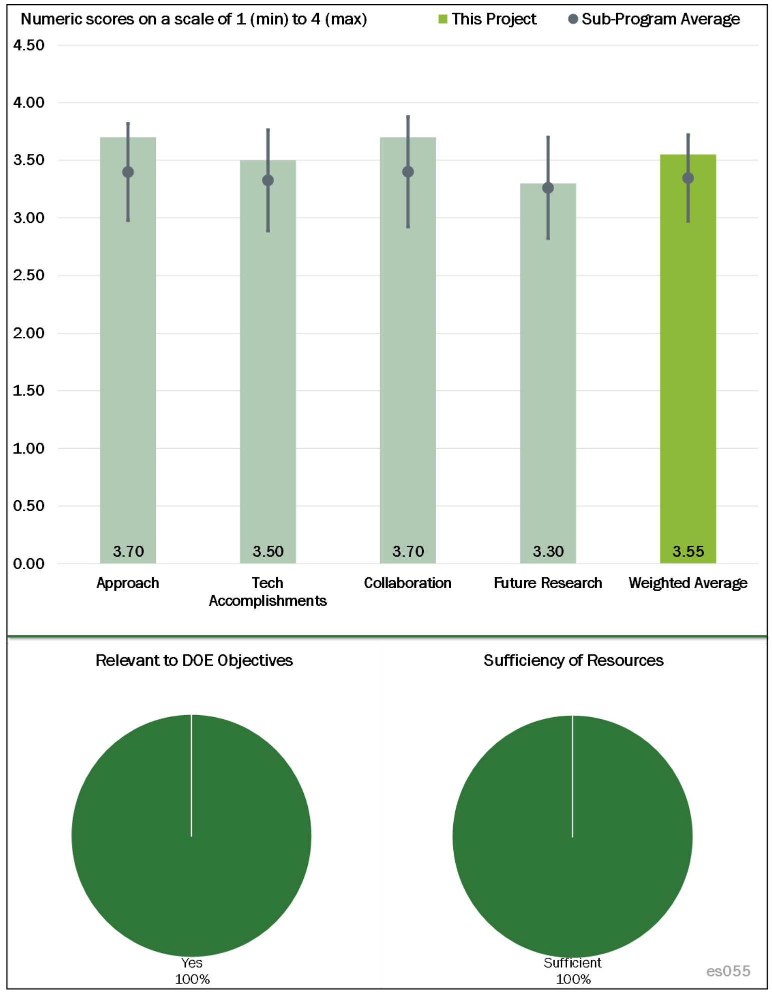

Figure 3-5 - Presentation Number: es055 Presentation Title: NMR and MRI Studies of SEI, Dendrites, and Electrode Structures Principal Investigator: Clare Grey (University of Cambridge)

Presenter

Clare Grey, University of Cambridge

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that Clare Grey is a renowned expert in the field of nuclear magnetic resonance (NMR), and her group applied the unique technique to study Si solid electrolyte interface (SEI). The project team also used other techniques, such as X-ray paired distribution function (PDF) and tomography, in their studies. The project is well designed to address the barriers.

Reviewer 2:

The reviewer commented that developing a better understanding of the initial stages of SEI formation on Si anodes using modern characterization techniques including several spectroscopies is a very good objective that is fully addressed in this work. The second objective is associated with characterization of dendrite formation; although extremely challenging, that is also a key issue in the implementation of Li-metal based cells, which is being investigated by the team using magnetic resonance imaging (MRI) techniques. There are various complementary research collaborations in place.

Reviewer 3:

The reviewer stated that capacity fading and battery performance are correctly focused; experiments yield useful information of fluoroethylene carbonate and vinylene carbonate (FEC and vinylene carbonate [VC]) decomposition. Lithium dendrites and the behavior of the sodium anodes and cathodes are well designed. The reviewer complemented the team's results gotten with NMR on the study of SEI formation with new equipment at the University College London through P. Shearing. Complementary density functional theory (DFT) calculations yielded useful chemical shift trends, guiding the low sensitivity experiments and assignments.

Reviewer 4:
The reviewer found the use of NMR to measure numerous material properties that "should not" be available to NMR to be very creative.

Reviewer 5:
The reviewer acknowledged that the NMR approach is very solid as it provides interpretable data that disclose the chemical structure of each main component of the SEI for Si anodes, Li dendrites, and sodium dendrites. The MRI approach is innovative in establishing the growth of dendrites in three dimensions.

The use of only two additives to date was useful in determining the complicated structure of the SEI in these cases; however, it would be useful to examine other additives in a screening effort to bring focus to developing an improved electrolyte for Si anodes. This would include the presence of more than one additive in the electrolyte. The term "screening" is meant to apply to a less complete and time consuming study of each selected additive to try to select superior additives for more complete study. In other words, the reviewer suggested not trying to do an in-depth study unless the additive shows definite promise for a superior Si electrode.

The reviewer did not see the relevance of dendrite study on sodium anodes. The low melting point of sodium causes very severe safety problems and is unlikely to ever see development in a commercial cell. The reviewer asked why not study sodium in hard carbons or other anode concepts instead.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
With their advanced NMR and MRI techniques, they have characterized Si SEI, identified mechanisms of the growth of Li dendrites, and sodiation of tin anodes. The team is highly productive as shown by their publication records.

Reviewer 2:
The reviewer commented that it is interesting that the research is able to confirm the absence of fluorinated polymers that were debated for a long time. Low coulombic efficiency (CE) in electrolytes containing FEC was shown but not explained.

The reviewer said that It would be good to have summarized and extracted conclusions regarding the effect of the successful additives (VC and FEC) during cycling in Si anodes and the correspondence (if any) to the mechanical degradation of the anode due to volume expansion.

Regarding dendrite formation, the reviewer said that correlation with SEI and electrolyte composition is a great goal. Imaging of dendrite evolution is interesting, but a more quantitative assessment is needed. The reviewer noted that the effect of the presence of magnesium on the octahedral prismatic phase formation was not explained.

Reviewer 3:
After almost 50 years of measuring SEI composition, the reviewer could not think of how any of these measurements really helped build a better SEI. It was not obvious to the reviewer that the present work will be any different. Uniquely, however, Grey has proposed that a highly cross-linked organic layer can prevent transport of solvent to the Si surface. If this is true, it would provide a suggestion for how to make better SEI films. On the other hand, VC and FEC have similar performance. The reviewer questioned whether there is any evidence that VC forms such cross-linked films.

The dendrite work is extremely cool. The reviewer loved it.

Reviewer 4:

The reviewer asserted that the results on determining SEI components on Li and lithiated Si were excellent. Dendrite studies show promise, and the correlation of dendrite onset with the Sand equation is important in trying to unravel this complicated area. It also shows the importance of limiting the current density in any Li-metal cell to prevent the onset of dendrites. The reviewer would like to have seen any further in-depth studies limited to important additives or coatings as determined by screening studies or reports from other investigations because of the time required for such studies as noted by the PI.

Reviewer 5:

The reviewer stated that the team studied the SEI decomposition behavior in a Si anode in order to understand related interactions, finding two mechanisms for the dendritic growth (depending on the current intensity) and showing how sodium is distributed by a combination of phases. There were Interesting developments, such as the decomposition of the FEC and VC. Two mechanisms for microstructures growth were shown. It seems that more time will be required to reach the objectives.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

In order to study new materials to complete objective to design a stable SEI, the reviewer mentioned collaboration with the University of Rhode Island (Brett Lucht), who provided FEC and VC samples for the study of formation of SEI components, such as LiF, LCO, $Li_2C_2O_4$, and organic components. Also, the University of Illinois at Chicago, University of Cambridge, and Binghamton University provided materials. The X-ray tomography and NMR characterization were provided by University College London and NREL, respectively.

Reviewer 2:

The reviewer stated that this group has collaborations with many universities and national laboratories.

Reviewer 3:

The reviewer noted that the PI has extensive successful collaborations with Battery Materials Research (BMR) colleagues and other researchers using complementary techniques.

Reviewer 4:

The reviewer indicated that there was extensive collaboration, including work with tomography.

Reviewer 5:

The reviewer said that the corps of collaborators is very good from the experimental point of view with each contributing to the various techniques applied by the PI.

The reviewer would like to have seen a representative from the battery industry to make recommendations of other additives and what appears to be the most serious aspects of the probes under study.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer concluded that the study with the Si coatings as well as the investigation of the SEI in presence of coatings with NMR are very important because their results could avoid dendrite growth. Also, the study of sodium SEI could advance the development of this material alternative. In addition to the continued studies, the team should work on some high-risk, high-gain solutions.

Reviewer 2:
The reviewer observed that there were very clear statements for how the program will evolve.

Reviewer 3:
The reviewer commented that the proposed work includes logical continuations of the reported studies. The dendrite formation investigation and its ties to the SEI structure and stability could be particularly helpful.

Reviewer 4:
The reviewer stated that their future plans concentrated on NMR studies of Si and sodium SEI.

Reviewer 5:
The reviewer would like to have seen a stop to the work on sodium dendrites unless they are believed to be essential to understanding Li dendrites.

The list of additives to be used should be carefully determined to be sure there is time to study the most important ones.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that SEI is one of the central problems in battery studies. Better understanding of the phenomena of SEI will help make better batteries.

Reviewer 2:
The reviewer stated that this project definitely supports the overall DOE objective of petroleum displacement by building fundamental understanding that will lead to better energy storage devices.

Reviewer 3:
The reviewer commented that the study is clearly relevant to the construction of higher energy density batteries of lower cost by use of Si or Li anodes.

Reviewer 4:
The reviewer said yes, if successful.

Reviewer 5:
The relevance of the sodium transport measurements to battery technology was not clear to the reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer praised Clare Grey as a pioneer in NMR studies on battery materials. Her team, with wide collaboration with other groups, should be able to achieve the stated milestones in a timely fashion.

Reviewer 2:
The PI's laboratory is uniquely equipped to carry out these kinds of studies.

Reviewer 3:
The reviewer found the project to have good equipment.

Reviewer 4:
The reviewer remarked that resources seem sufficient.

Reviewer 5:
The reviewer noted that the experimental work that is the basis of this study requires substantial funding.

Presentation Number: es056
Presentation Title: Development of High-Energy Cathode Materials
Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

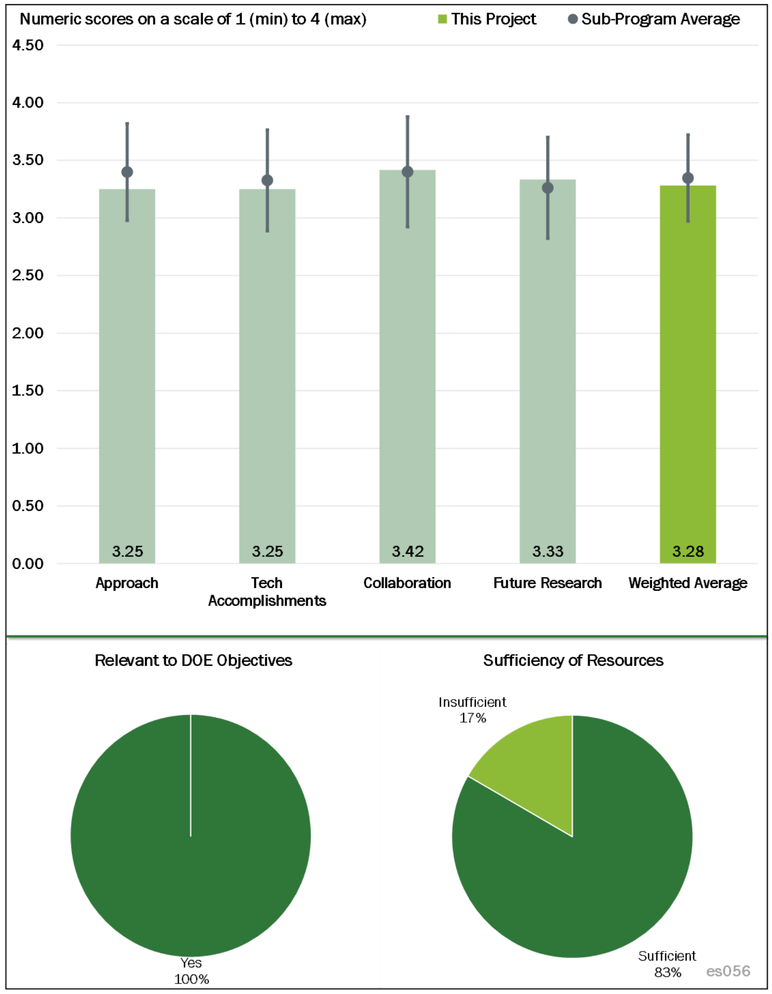

Figure 3-6 - Presentation Number: es056 Presentation Title: Development of High-Energy Cathode Materials Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Presenter

Jason Zhang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the objective here is to optimize the synthesis of Ni-rich NMC cathode materials using co-precipitation methods, to study the effects of lattice doping and solid electrolyte surface coating on the cyclic stability of these materials, and to understand the structural changes occurring therefrom. Various experimental conditions (flow rate, pH, concentrations of metal sulfates, etc.) were to be varied for the hydroxide precursors, which were calcined at different temperatures to get materials of high capacity and good cyclic stability.

This task is well focused on the Ni-rich NMC cathodes, expectedly the optimum choice among the cathode materials for high specific capacity and cycle life; it is also well designed and well integrated with the cathode development in other DOE laboratories, and the approach is feasible.

Reviewer 2:

According to the reviewer, the cathode materials have been optimized in terms of chemical composition and reaction conditions (annealing conditions). High energy density and very good stability were shown for Ni-rich (more than 0.6) materials annealed at 755°C and coated with lithium phosphate (Li_3PO_4). Physical, chemical, and electrochemical characterization has been carried out to elucidate the excellent performance of the materials obtained.

Reviewer 3:

The reviewer pronounced the approach of utilizing Ni-rich NMC to be excellent only if a high-voltage electrolyte is viable in cost and nontoxic.

Reviewer 4:
The reviewer suggested that using a design-of-experiments approach should help with determining syntheses optimization parameters as a function of cathode composition, including choice and amount of dopant and coating techniques.

Reviewer 5:
The reviewer noted that to achieve the DOE goal in energy density, the development and adoption of Ni-rich layered cathode is a good approach. However, there are downsides to Ni-rich layered cathodes, which are safety concerns.

It would have been more desirable if this project also considered material-level safety aspects.

Reviewer 6:
The reviewer said that the coating work looks interesting and promising, but questioned whether this had been done by others. The reviewer also thought that the team had given up on the doping too quickly. The reviewer would like to have seen more characterization work to support the statements about it being surface doped. The reviewer also asked if you need to re-optimize the calcination temperature as the composition changes.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that the milestones were achieved with excellent results either published or patented. The energy density is greater than200 mAh/g for pristine material. The surface coated cathode shows excellent stability at room temperature and is very good at high temperature. The experimental conditions as well as chemical compositions have been optimized. Additives in the electrolyte have been explored with some excellent results obtained.

Reviewer 2:
The reviewer commented that data from efforts of measuring the capacities with composition variation in NMC should be useful although it is expected that the capacity increases with Ni content.

The ALD-annealed material shows strikingly good performance. It needs to be further characterized by focusing on the nature of Li phosphate in the bulk of the secondary particles. Questions still arise. The reviewer asked is Li phosphate spread homogeneously in the particle, does it still remain as phosphate, have any other methods been tried, are there any other effective material, and what is the role of the phosphate.

When Ni is oxidized from 2 to 4, the Ni-O distance changes up to 0.2 angstrom, resulting in a huge lattice stress and particle degradation. The reviewer asked if $LiPO_4$ is a buffer preventing or redistributing the stress. This requires some *in situ* electron microscopy.

Reviewer 3:
The reviewer stated that good progress has been accomplished in synthesizing various Ni-rich NMC cathode materials and identifying the optimum composition as close to 811 ($LiNi_{0.76}Mn_{0.14}Co_{0.1}O_2$), which was shown to exhibit a good combination of capacity and stability consistent with the reported literature. Higher Ni content improves the cycle life but at reduced capacity.

It was demonstrated that surface cation doping has a limited effect in improving the cycling life, but coating with a solid electrolyte, such as Li_3PO_4, improves the cyclic stability, as has been reported with several coatings on layered oxide cathodes.

Washing the electrodes in water understandably affects the performance, which mandates ALD coating and may be expensive to adopt. Instead, there are several aqueous-based coatings that have been reported to be as effective, if not more, for enhancing the cyclic stability of metal oxides especially at high charge voltages.

Interestingly, there is not much reported here on the electrolyte variants, even though the Army Research Laboratory (ARL) has been listed as a collaborator for electrolytes. Also, as pointed out in the remaining challenges, thermal stability and hence safety of the Ni-rich NMC materials may be an issue, which may be mitigated by the surface coatings.

Overall, the progress achieved here is meaningful and relevant to the DOE goals.

Reviewer 4:

The reviewer remarked that this project adopted a good approach for the precursor preparation. Regarding the optimum synthesis condition study, however, it would be expected, from study by a national laboratory like this, that not only "what" temperature is optimal but "why" the material at that temperature shows the best performance. The reviewer asked is it due to primary particle size, internal porosity, or surface transition metal state and oxygen activity. The reviewer asked does the material prepared at 775°C also show optimum performance in other aspects, such as impedance (and its growth) and thermal stability.

The solid electrolyte modification study shows meaningful results that could enhance cycling stability of Ni-rich cathode materials. What kind of phases really formed on the particle surface and at the grain boundaries should be explored. The reviewer believed that the industry has been looking into Ni-rich NMC cathode materials for EV applications, which means there must be commercial battery-grade Ni-rich materials. They should try to get those materials and use them as references.

Reviewer 5:

The reviewer stated that the project seems on target to meet its goals, and the novelty in this approach should be emphasized. The national laboratories should try some new things as the reviewer was not sure that this is new.

Reviewer 6:

The reviewer stated that there was good work on screening compositions of NMC materials, but there were no data on composition optimization. It was not clear what the effect of water-washing was as no conditions were presented. This is a widely used step in industry that leads to improved electrochemical performance. The reviewer asked if the material was dried after treatment. It also was not clear if ALD was performed on a powder or on the electrode. The reviewer asked what the temperature was of annealing. The solid electrolyte enhanced modification sounds overreaching as, according to Slide 11, the solid electrolyte diffuses into the bulk.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that there was excellent use of resources and partners in the project, including the ALD work.

Reviewer 2:

The reviewer said that collaborations with other national laboratories in terms of materials characterization are important for the understanding of the excellent performance of the materials. The collaboration with a university in Canada leads to the excellent surface coating of LP, which gives much improved cycling performance. The collaboration with the U.S. Army laboratory is unique in its electrolyte development, which is very important for the Mn-containing, high-voltage cathode materials.

Reviewer 3:
The reviewer stated that there are good collaborations with several researchers within DOE (ANL and BNL) and elsewhere (Western University and ARL). It is probably appropriate to verify these results in full cells through collaborations with other DOE laboratories (ANL or ORNL) and examine the effects of different electrolytes and surface coatings.

Reviewer 4:
The reviewer praised the collaboration among the partners as well coordinated. It would be much better if they have industry partners, too.

Reviewer 5:
The reviewer commented that the collaboration look okay.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Of the four projects involving NMC cathode materials, the reviewer opined that this is the only one that proposes to tackle high temperature stability of the materials and fabricate the pouch cell. This is the key step toward real application of the materials synthesized. The reviewer wished the PI good luck and expressed confidence that more exciting results will be obtained next year.

Reviewer 2:
The reviewer recommended that *in situ* microscopy be coupled with energy dispersive spectroscopy (EDS) and agreed with testing the full cells in a pouch form.

Reviewer 3:
The future studies will involve continuation of the surface modification studies on the NMC811 cathode, the assessment of electrolyte additives to improve the interfacial stability, and subsequent characterization of the surface layer. Further, the reviewer proposed that the performance of the stabilized NMC be validated in full cells with suitable electrolytes. However, the reviewer commented that it would be more appropriate for this project to focus more on developing suitable coatings and electrolytes for the NMC811 materials in order to improve capacity and cyclic stability instead of the full pouch cells. The proposed studies are consistent with the DOE goals.

Reviewer 4:
The proposed future research looks good, and the reviewer especially liked the proposal of validation of the materials in full pouch cells. The reviewer said that it would be good if material level and cell level thermal stability study would be performed. Also, the reviewer suggested that the project obtain commercial (or semi-commercial) Ni-rich materials, make comparisons, and show the limitations of commercial materials and how those limitations could be overcome using the results in this project.

Reviewer 5:
The reviewer stated that half-cell data will indicate material stability on a large scale, but you really need full cell data to draw conclusions. The reviewer really would like to see more options on doping or coating going forward.

Reviewer 6:
The reviewer suggested that the project should include a thermal stability assessment of the studied compositions. No data were shown to demonstrate doping elements optimization mentioned in the approach; this might be a more practical approach versus ALD.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

For widespread use of EVs and PHEVs, the reviewer noted that it is imperative that LIBs be lightweight, compact, safe, and low-cost. The state-of-the-art materials are inadequate to fulfil these needs. High energy density electrode materials are required to improve the specific energy for Li-ion cells and thus increase the range for the vehicle and reduce overall cost for the battery. The state-of-the-art cathode materials are inadequate and provide capacities of only 170 mAh/g, about half of the capacities possible from the carbon anodes.

New high-capacity and low-cost cathode materials are desired to meet the DOE goals, which this project has been addressing.

Reviewer 2:

The reviewer commented that NMC is an important cathode material for high-energy LIB manufacturing. Such batteries are essential for energy storage for renewable energy supply and also as a power supply for EVs in transportation. This will displace petroleum in its application.

Reviewer 3:

The reviewer stated that any efforts to improve cell energy density support the overall DOE objectives.

Reviewer 4:

The reviewer remarked that enhancing the current EV cell energy density critically depends on cathode materials, given that high capacity anode material (e.g., Si-based) have a long way to go.

Reviewer 5:

The reviewer said yes.

Reviewer 6:

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The results obtained meet the objectives in timely manner. Milestones have been achieved with excellent performance Ni-rich NMC obtained with chemically and operational conditionally optimized conditions.

Reviewer 2:

The reviewer said that the resources are adequate for the scope of the project.

Reviewer 3:

The reviewer stated that a good amount of work has been completed for the funding level of the project, it takes a lot of effort to synthesize different materials and optimize calcination temperature, and more resources would allow exploration of a wider space of compositions and coatings.

Reviewer 4:

The reviewer pronounced that the project looks good.

Presentation Number: es059
Presentation Title: Advanced *In Situ* Diagnostic Techniques for Battery Materials
Principal Investigator: Xiao-Qing Yang (Brookhaven National Laboratory)

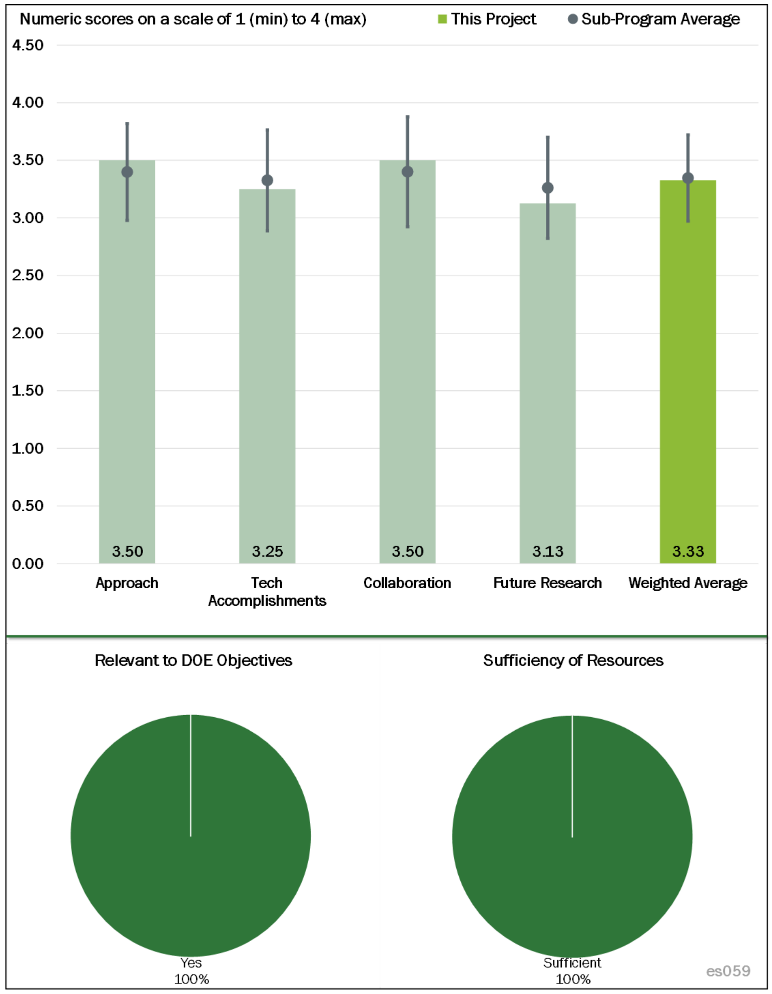

Figure 3-7 - Presentation Number: es059 Presentation Title: Advanced *In Situ* Diagnostic Techniques for Battery Materials Principal Investigator: Xiao-Qing Yang (Brookhaven National Laboratory)

Presenter

Xiao-Qing Yang, Brookhaven National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the team has access to top instrumentation at BNL and other national laboratories. A good combination of experiments has been selected to address most of the technical barriers.

Reviewer 2:

The reviewer said that the combination of techniques leads to unique sets of structural information under conditions reasonably close to real cell results. Even in unusual situations, such as the initial discharging of already discharged materials such as $LiRu_{0.5}Mn_{0.5}O_2$, structure results are obtainable. The project continues this type of important analysis of LIB components.

Reviewer 3:

The reviewer stated that it looks like a successful approach to overcome the technical barriers. Barriers with which they had to deal were to understand the structural changes of cathode materials producing voltage and capacity fading during high-rate charge and discharge cycles. They used PDF techniques to study the effects of multiple cycling for $Li_2Ru_{0.5}Mn_{0.5}O_3$ (lithium- and manganese-rich [LMR]) cathode material with and without pre-lithiation, HRTEM, and TXM to obtain multiple dimensional mapping of new cathode material. Another barrier they had to deal with was to develop a diagnostics study aimed to improve the safety characteristics of batteries; they used time resolved X-ray diffraction and mass spectroscopy, together with *in situ* soft and hard X-ray absorption spectroscopy (XAS) during heating to study the thermal stability of the electrode materials.

In 2016 the Li Ni Mn spinel-lithium manganese nickel oxide (LMNO) material was analyzed due to its good capacity but presented problems of thermal instability; now in the work of 2017, they are analyzing the LMR material that yields greater capacity when pre-lithiated, but at the same time the pre-lithiation increases the loss of voltage due to the microstructures that are formed. At this point the plan of study is not very clear, but the reviewer agreed that different materials with high energy density are being analyzed.

According to the results, the project is feasible and provides a depth of understanding of materials problems to get high energy density. In this case for the LMR material, they have to finish the studies that are pending to determine how to compensate for the loss of voltage when the pre-lithiation process is performed.

This project focuses on the study of new materials for high energy density cathodes; however, it can be integrated as part of the larger study that is being done in the same way for new materials for anodes and electrolytes and their interactions.

Reviewer 4:
The reviewer enthused that the demonstration was a tour de force that combined many different diagnostics. It was impressive that they are able to collect so much data. The reviewer was not sure that it makes sense to claim that these studies will lead to lower cost batteries.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that regarding the objective of DOE to reduce the production cost of PHEV batteries by having a long calendar and cycle life, the project has made considerable progress in the analysis of materials of high energy density, especially LMR materials. The project has obtained results, such as the structural behavior of the material during charge and discharge, that allow the community to have a better idea of how to find the right material for electrodes and especially for the high energy density cathode, which we know has problems of thermal instability. This reviewer commented that with the results obtained in this work, the spinel phase is verified for the pre-lithiated LMR sample along with the loss of its crystallinity via volume expansion at pre-lithiation, which allows the material to form vacancies by releasing oxygen easily.

Reviewer 2:
The reviewer noted that the technical accomplishments are excellent even with the limitations of beam time at BNL due to the new, high resolution, high power line.

Reviewer 3:
The reviewer remarked that voltage fade studies of cathode materials containing excess Li were well characterized using various techniques. It was not clear how the phenomena may depend on particle size and shape, which may alter the kinetics of phase transformation. The reviewer added that there was not much discussion given to the safety aspects.

Reviewer 4:
The reviewer praised the enormous and impressive compilation of data (5 dimensional!), so in this sense, the reviewer saw that great progress has been made. But, the reviewer did not see any new insights yet and did not see how new insights will be forthcoming. The main conclusion so far is that defective material does not perform as well as more perfect material, which is already known.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the use of collaborators was impressive.

Reviewer 2:
The reviewer commented that the overall collaboration is very good. The team should also increase collaborations with battery companies.

Reviewer 3:
The reviewer noted that collaborations are generally excellent, but it is not clear how the industrial partner, JCI, contributes to the effort. This is important because it can focus some of the work to industrially important problems and materials.

Reviewer 4:
The reviewer pointed out the great collaboration with several laboratories and institutions to obtain necessary knowledge to perform certain experiments, especially those working with X-rays because they require a whole process of preparation and tuning in each test. Among the institutions are: the Stanford Linear Accelerator Center (SLAC) to perform TXM, BNL to perform Z-contrast STEM, and the National Synchrotron Light Source II (NSLSII) to perform X-ray powder diffraction (XPD) and hard X-ray nano-probe (HXN) beamlines. However, it is advisable to also get collaborators in the industry in order to have different points of view to make the project progress more significant yet.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that it is important to continue to develop the TXM work, including STEM studies to further understanding of reaction paths of cathode materials.

Also, the XFM method development will give further structural detail to the reactions in the cathode.

Reviewer 2:
The reviewer would like to have seen a clear pathway to gaining new insights. There is an extraordinary amount of information, and the reviewer suggested that using statistical methods might allow an unlocking of subtle “quantitative” relationships between measured properties and battery durability.

Reviewer 3:
The reviewer pointed out the great collaboration with several laboratories and institutions to obtain necessary knowledge to perform certain experiments, especially those working with X-rays because they require a whole process of preparation and tuning in each test: among them, SLAC to perform TXM, BNL to perform Z-contrast STEM, and NSLSII to perform XPD and HXN beamlines. However, it is advisable to also get collaborators in the industry in order to have different points of view to make the project progress more significant yet.

Reviewer 4:
The reviewer stated that the proposed plan was vague and had no focus.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Yes it does. Characterization of materials is an important aspect in the development of advanced energy storage technology.

Reviewer 2:
The project fully supports DOE objectives

Reviewer 3:
The reviewer responded, "Yes." They analyze a high-voltage cathode (LMR material), which features greater capacity when a pre-lithiation process is carried out. However, due to the loss of voltage during charge, discharge cycles, and the release of oxygen, it is still not a cathode suitable for EVs. However, it is helping anyway to understand better what the effects of micro-structural defects are so we will soon find an LMR material with a good capacity whose voltage loss will not be too large.

Reviewer 4:
The reviewer opined yes, but said that the connection is at present very tenuous.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The high cost of maintaining the very sophisticated instrumentation justifies the budget of this and other projects.

Reviewer 2:
The resources are adequate to achieve the milestones in time. Because this work will continue and complete the PDF, STEM, and TXM studies of $Li_2Ru_{0.5}Mn_{0.5}O_3$, as well as develop and apply XFM techniques for battery material studies, the present work already underway with sufficient background will help to perform research with the synchrotron effectively.

Reviewer 3:
The reviewer said that more beam time at BNL would be helpful.

Reviewer 4:
The reviewer pointed out that impressive resources are required for such an ambitious project.

Presentation Number: es085
Presentation Title: Interfacial Processes in EES Systems Advanced Diagnostics
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter
Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

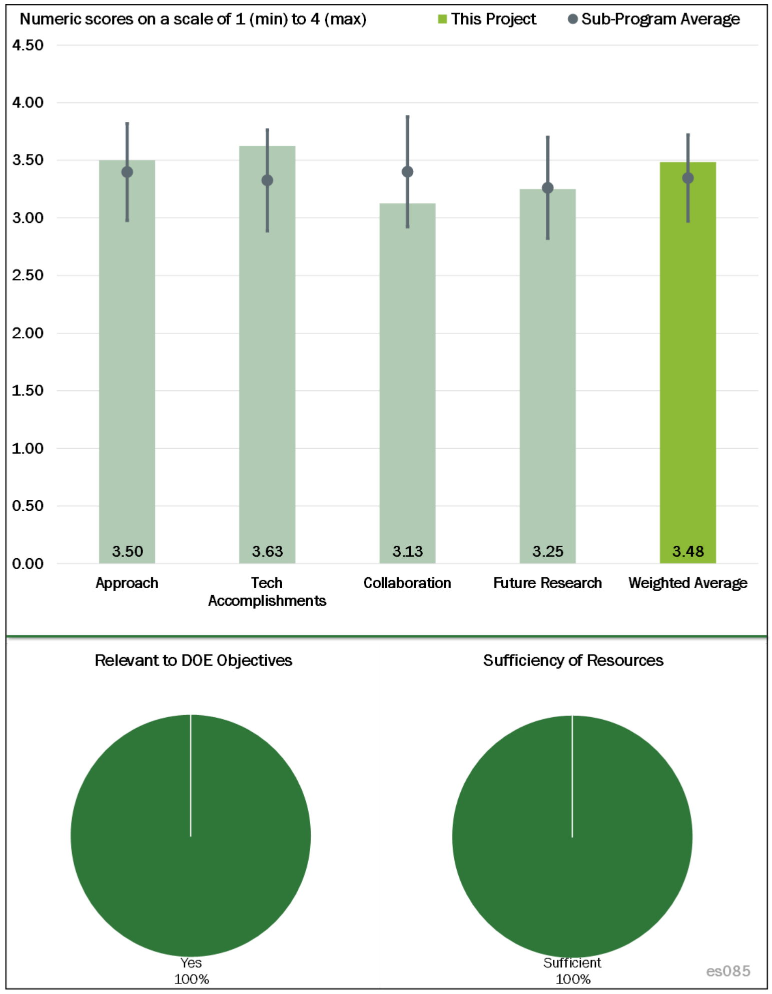

Figure 3-8 - Presentation Number: es085 Presentation Title: Interfacial Processes in EES Systems Advanced Diagnostics Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the project is well focused and is part of larger efforts involving sophisticated characterization methods of interfacial materials and phenomena.

Reviewer 2:
The reviewer stated that the approach is well designed to answer the difficult questions about the reactions on the surface of active cathode materials.

In particular, the X-ray methods combined with Raman spectroscopy are very powerful.

Reviewer 3:
The reviewer noted that the LBNL group led by Robert Kostecki combined an array of advanced characterization techniques (optical, X-ray, and electron) to investigate the structure and function relation of electrode materials in order to better understand the mechanism of their capacity fading.

Reviewer 4:
The reviewer observed that the barriers of low energy and power density, short calendar and cycle lifetimes, and high impedance are being approached by more rational than empirical diagnostic techniques focusing on the kinetic studies at the interface of NMC electrodes with the electrolyte. The project includes well-organized use of state-of-the-art with electrochemical methods. The project achieves success on shedding light on mechanisms of interfacial phenomena and surface reconstruction effects on impedances. Results can be integrated with others developing ALD to coat NMC to get a stable NMC Li-ion cell.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The progress in this period has been very good. The identification of the surface reconstruction layer (SRL) and the suggestions of its chemical composition are excellent steps.

The impedance studies of pristine NMC and NMC with pre-reconstruction of the surface give intriguing results on cycling. If this can be replicated and applied to other cathode materials (particularly NCA, LCO, and lithium-manganese oxide [LMO]) this could be a major finding for LIB technology.

Reviewer 2:
According to the reviewer, the LBNL group has done a great job in investigating the effect of surface reconstruction in NMC electrodes. The artificial SRL seems to have improved the long term cycling properties of NMC. It is still not clear why the artificial SRL acts differently from that formed during charge-discharge cycling, especially because they differ only at later cycles and only in the 2-4.5V range.

Reviewer 3:
The reviewer commented that identification of surface reactivity, film formation, and surface reconstruction at the cathode and electrolyte interface are definite accomplishments of this project.

It would be good to link the characterized interfacial phenomena to achieving kinetic control of the cathode reactivity.

Reviewer 4:
The reviewer commented that the effects of surface reconstruction in NMCs based on impedance spectroscopy perhaps need to be extended to other Ni-rich NMCs besides the 5:3:2 to make a more general conclusion that the performance of these materials is upgraded with an artificial layer (NMC/R). There is no information other than that 5:3:2 NMCs were tested.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project has a large and strong collaboration. The initial (early) calculations to understand the formation of the surface reconstruction as well as the initial NMC structure and composite electrode previously tested by M. Doeff (LBNL) and C. Ban (NREL). The XAS-TEY experiments for this project were developed in collaboration with M. Doeff (LBNL) and Liang Zhang (Advanced Light Source at LBNL). These experiments help support the idea that an artificial reconstruction layer improves the cell performance; thus, these collaborations and interactions require a concerted effort such that different results from different experimental techniques lead to the development of high energy density materials. In addition, they worked with M. Marcus (LBNL) performing XANES experiments and data analysis. Earlier electrode materials were supplied by V. Battaglia (LBNL) and Y. Fu (LBNL), but no information on the new ones is available.

Reviewer 2:
The reviewer stated that this group has wide collaborations with other institutes.

Reviewer 3:
The reviewer said that the project is well integrated with others at LBNL, but there is some degree of duplication with Doeff's presentation.

Collaborations with other institutions and battery companies, although mentioned, were not explicitly explained.

Reviewer 4:
The reviewer mentioned that collaboration with other academic institutions is excellent.

The collaboration with industry could be improved, especially with regard to adding a battery manufacturer. Also, it is not clear what role Umicore plays other than supplying material. They could be helpful in suggesting other, more efficient methods of forming the reconstructed surface.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the group has a well-defined plan for future work. It is important to study the crosstalk and quantify each side reaction in the electrode during the cycling to understand the SRL effects.

Reviewer 2:
The reviewer commented that the proposed future research seems to be well organized and focused on the study of the reactions in a more localized way, implying the development of new experimental techniques. All this is in accord and coherent to obtain a progressive approach to the present state of the project; however, the reviewer pointed out for future work the following: First, as indicated before, because the impedance work is about a 5:3:2 concentration, it should be good to try with another Ni-rich concentration to check if similar or even better behavior using the artificial reconstruction layer is obtained. Next, the thickness of the artificial reconstruction layer was made similar to the one that evolves from electrochemical charging and discharging; however, it could be good to know what happens for different ones. Lastly, although there were very early collaborations, (2013 and earlier) with theoretical groups, it is important to establish intense collaborations with a theoretical-computational multi-scale team able to interact and provide feedback to the experimental approach from the atomistic to the mesoscopic scales. That would be of great benefit to the energy storage community and most likely will accelerate the discovery.

Reviewer 3:
The reviewer said that the proposed future work is very general.

The reviewer felt that the outstanding result of reduced impedance growth of surface pre-reconstruction should be specifically followed up and expanded to other materials if it can be replicated for NMC.

Reviewer 4:
The reviewer stated that the proposed work is vaguely described. More emphasis on the dynamic aspects of the interfacial phenomena is needed in order to achieve the objective of kinetic control. More specific plans should be indicated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer responded yes. One of the main obstacles to developing a high-energy density battery is the reactions that occur at interfaces. For this reason, the study of these interfaces is vital to proposing solutions to eliminate or considerably reduce obstacles.

Because this project shows the reduction of reactions occurring on NMC and electrolyte interfaces, NMC is perhaps a suitable material for Li-ion cells for PHEVs and EVs. NMC improves the performance of these type of batteries, and thus petroleum consumption will be reduced.

Reviewer 2:
The reviewer stated that the project aims to improve the inadequate LIB energy and power density and calendar and cycle lifetimes for PHEV and EV applications.

Reviewer 3:
The reviewer pointed out that characterization of interfacial phenomena is vital to the development of better energy storage materials, which would eventually be a pillar for petroleum displacement.

Reviewer 4:
The reviewer said that an understanding of cathode operation and fading is of vital importance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that with wide collaboration with multiple institutes and the strong research capabilities of LBNL, the team has adequate resource to achieve their goals.

Reviewer 2:
The reviewer remarked that considering the high cost of highly sophisticated equipment maintenance, the resources appear reasonable.

Reviewer 3:
The reviewer noted that $440,000 per year directly supporting the group seems sufficient although no number of supported researchers is reported.

Presentation Number: es091
Presentation Title: Predicting and Understanding Novel Electrode Materials From First-Principles
Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

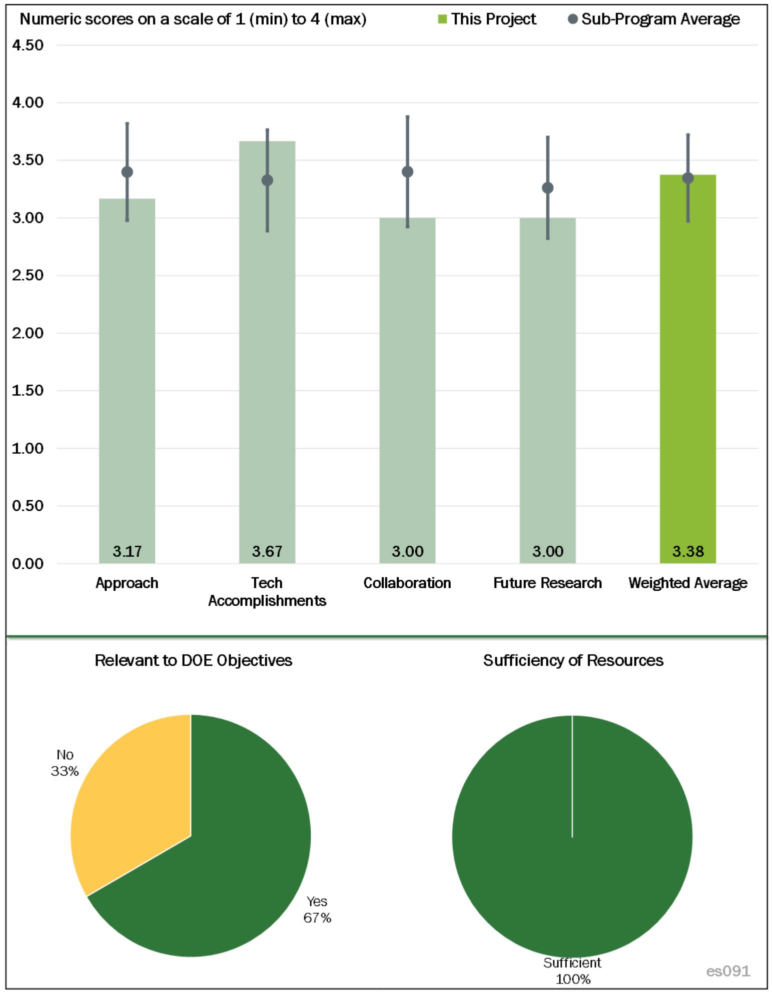

Figure 3-9 - Presentation Number: es091 Presentation Title: Predicting and Understanding Novel Electrode Materials From First-Principles Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

Presenter

Kristin Persson, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer understood the logic of using Li_2MnO_3 as a worst-case scenario, and in some cases that may be the best approach. However, the reviewer noted that earlier theoretical studies indicate that Li diffusion in the bulk material is relatively fast, which is in contradiction to many experimental studies. If the transport in the bulk regions is good, then one may naturally assume that the transition regions may be a problem. Eliminating these regions may be overlooking an issue, and in fact one result of this study is that the surface phenomena are an issue.

Reviewer 2:

The reviewer remarked that this computational modeling approach has been pursued for quite a length of time, yet the fundamental approach has not been effectively solving some of the technical barriers, including stabilities of the energy materials, kinetic pathways for more in-depth understanding of the polarization from surface to the solid bulk, and finding a more energetic solution of new chemistries that can provide higher energy content or better kinetics to deliver energy to power. A fundamental breakthrough on the modeling approach from first principles seems necessary. The reviewer encouraged the investigator(s) to collaborate with more experimentalists and theorists to develop a more detailed model framework to overcome the current barriers within the model for more fruitful outcomes that can benefit the research community.

Reviewer 3:

The reviewer commented that extensive modeling work was performed to systematically screen surface doping atoms that can increase oxygen retention on the surface of Li_2MnO_3 and asked if there is any plan to valid the model prediction experimentally.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer found the PI's scientific abilities and techniques to be of the highest quality and the work is excellent. The reviewer found the PI's willingness to propose solutions to improve performance very impressive.

Reviewer 2:
The reviewer said that the predicted surface dopants are a nice accomplishment that provided new material design directions on how to stabilize high-capacity Li-excess NMC cathode materials. This is highly relevant and important for meeting DOE energy density goals.

Reviewer 3:
The reviewer stated that it seems clear that the interfacial properties of the cathode materials in relevance to the bulk, the interactions with the electrolyte species (including solid electrolyte interphase), and the surface coating materials and their migration into the near surface region or dissolution are very complicated phenomena even for experimentalists to gain sufficient understanding from the experimental results. The challenge is much higher for modeling efforts. It is not clear if this first-principles approach is the right approach to deal with this technical area of interest or not. Without a clear justification why this approach will provide a reasonable outcome, it is almost impossible to see if a goal can be established with a reasonable expectation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer found that good collaborations exist.

Reviewer 2:
The reviewer pointed out that collaboration within LBNL is fine, but there are no obvious collaborations outside the laboratory.

Reviewer 3:
The collaboration seems limited within the Berkeley community between LBNL and the University of California at Berkeley (UCB). More external collaboration with other theorists and experimentalists is encouraged to gain access to a broader research community for inputs and reliable data to validate the approach.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the proposed work is a good extension of the present results. If the focus is continuing with Li- and Mn-rich materials, then the reviewer would prefer to have seen some effort to examine LMR-NMC materials.

Reviewer 2:
The reviewer stated that surface coating and experimental work related to the characterization of any effects is quite difficult to reproduce, and that many of these effects might not be straight to chemical nature. It is not comprehensive how this first-principles approach will resolve these possible variations that may render

inconclusive results to conform to a universal understanding in first principles. Defects and amorphous state(s) could be even more challenging to model. It is not clear how these issues will be resolved and modeled with sufficient clarity and fidelity.

Reviewer 3:

The reviewer said that it will be useful to have some strategy on how to compare experiments at multiple places, for example which surface is more stable in terms of oxygen retention.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked that this research is very much related to petroleum displacement as it will help to enable higher energy batteries.

Reviewer 2:

The reviewer said that the work is relevant.

Reviewer 3:

The reviewer acknowledged that although in general, the battery technology is intended to reduce reliance on fossil fuels, all research activities supporting a better battery design could contribute to that goal. It is not clear though how the direct relevance of this project to support that goal can be qualified or quantified through this project. If a more tangible outcome can be identified, the relevance would be clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources are sufficient.

Reviewer 2:

The reviewer observed that the resources needed for the project probably rely more on the quality of the data available for validation. It is difficult to read how much resources are needed for this project in general.

Presentation Number: es106
Presentation Title: High-Capacity Multi-Lithium Oxide Cathodes and Oxygen Stability
Principal Investigator: Jagjit Nanda (Oak Ridge National Laboratory)

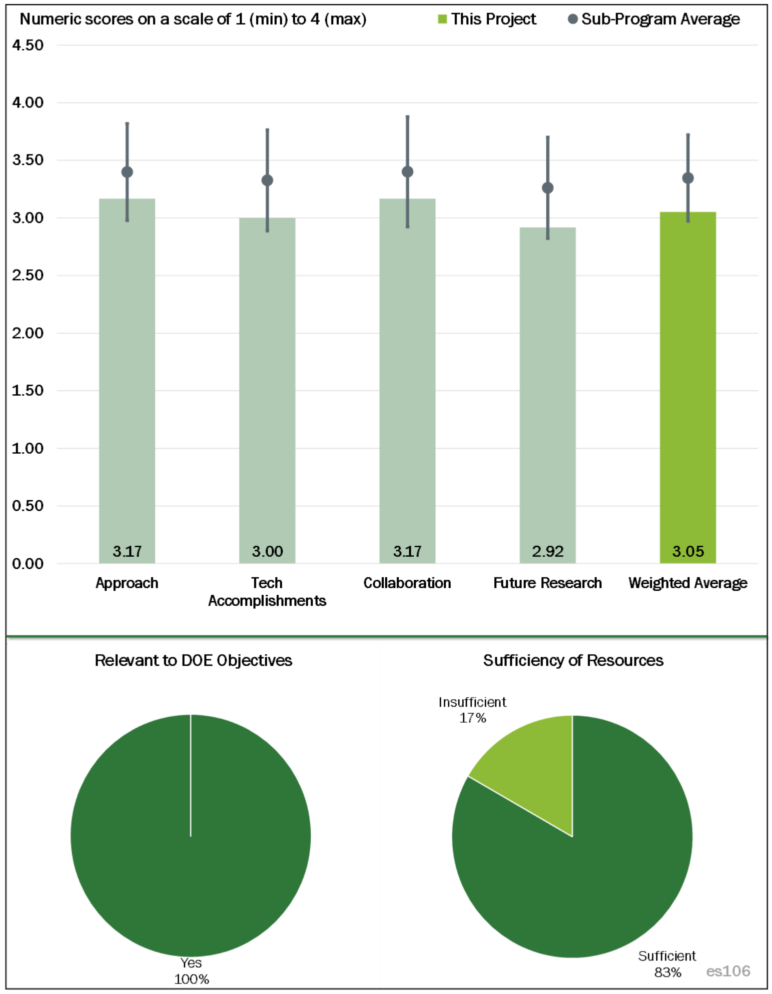

Figure 3-10 – Presentation Number: es106 Presentation Title: High-Capacity Multi-Lithium Oxide Cathodes and Oxygen Stability Principal Investigator: Jagjit Nanda (Oak Ridge National Laboratory)

Presenter

Jagjit Nanda, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project offers interesting insights into Li-rich systems and is excellent diagnostic work.

Reviewer 2:

The reviewer found the approach to be solid and addresses technical barriers key to the advancement of LIBs. Cathode materials that can cycle more than one Li^+ per transition metal could allow DOE to meet its energy density goals (500 mAh/g). The team will synthesize promising high-voltage, high-capacity cathodes using computational analysis. This will be followed by cycling cells and spectroscopic diagnostic and analytical techniques to identify chemical and structural changes that prevent cells from achieving high capacity and long cycle life. The plan to develop methods to stop lattice oxygen loss and improve cathode structural stability is highly relevant.

Reviewer 3:

The reviewer pointed out that adopting multivalent metals for higher capacities is reasonable as long as the voltage is low enough not to decompose or continuously react with electrolytes.

Reviewer 4:

The reviewer acknowledged that, for improving the specific energy of the cathode materials in Li-ion cells and thus achieving cell level specific energies of 400-500 Wh/kg, the Ni-rich NMC cathodes and NMC cathodes with concentration gradient (Mn-rich on the surface and Ni-rich in the core) are the most likely candidates. These materials cathodes sustain either oxygen loss or redox behavior during cycling, which results in irreversible capacity or structural changes.

The objectives here are to understand the oxygen activity and its role in the redox processes, the loss of oxygen, and the resultant structural changes in the high-voltage and high-capacity cathodes. The approach involves developing high-voltage, high-capacity oxide cathodes with suitable anionic substitution and advanced coatings for interfacial stability and understanding the interface and bulk structure using various microscopic and spectroscopic techniques. Specific materials studied here include Ni-rich $Li_2Cu_xNi_{1-x}O_2$ and $LiMoO_3$, which has improved lattice oxygen stability for Li-excess composite high-voltage cathodes.

The objective was to access the higher oxidation states of $Cu^{2+/3+}$and $Ni^{3+/4+}$, but the oxygen evolution presented this from happening. The synthetic methods yielded either surface impurities or local inhomogeneities. The idea of assessing oxygen redox activity in the high-voltage cathodes is highly relevant, but the $LiMoO_3$ may not be the right material due to its low capacity and conversion to amorphous state after the first cycle.

Reviewer 5:
The reviewer stated that the project was a thorough, multi-faceted approach to improved materials and generated a lot of data to suggest improved materials. However, the reviewer would like to have seen a pathway or strategy toward using the learnings for future work. The reviewer thought the conclusion on disordered materials is a good one, but asked what was learned here that would help that effort beyond what has already been published on these types of materials.

Reviewer 6:
To achieve higher capacity from a given cathode material, charging the cathode to higher voltage is considered a straightforward and effective way. However, in addition to the electrochemical stability issue of the electrolyte system, surface instability of oxygen is a critical issue, which significantly affects structural stability and cycling performance of the cathode upon repeated high-voltage cycle as well as the inducement of safety issues. In these respects, understanding oxygen stability of cathode materials at high-voltages is highly needed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented about the excellent progress achieved this past year. A paper was published in *Chemistry of Materials* describing the mechanisms of electrochemical activity and degradation of $Li_2Cu_xNi_{1-x}O_2$ cathodes. This information will help guide the team to identify more stable, high-performance cathode materials.

Reviewer 2:
The reviewer suggested that reasonably good progress has been made in determining the chemical and structural changes that occur in $Li_2Cu_{0.5}Ni_{0.5}O_2$ using *in situ* TXM-XANES. There is a shift in the copper (Cu) and Ni edge to lower energies at greater than or equal to 4V, though it is not clear what this may be attributed to (not Cu^{+2} to Cu^{+3}). It is also surprising that oxygen evolution starts occurring at 3.9V, though we do not observe this in the conventional cathodes (LCO, nickel cobalt oxide, NCA, or even NMC) at this voltage. The reviewer wondered if the presence of Cu was catalyzing O_2 evolution.

Detailed studies have been made to understand the electrochemical activity and degradation of $Li_2Cu_xNi_{1-x}O_2$ cathodes using a combination of X-ray and neutron diffraction, *in situ* Raman spectroscopy, electrochemistry, gas evolution experiments, and transmission electron microscopy (TEM). The results, however are not quite encouraging in terms of utilizing the second Li from this material.

The cyclic stability of $Li_2Cu_xNi_{1-x}O_2$ has been marginally improved as shown in previous report, but the (low) voltage profile and low capacity are not attractive. Further, fairly good efforts were made in synthesizing and characterizing the molybdenum analogue of Li_2MnO_3 with greater oxygen stability through electrochemistry, XRD, and Raman. But, the initial results do not hold promise for this to provide much insight in the oxygen redox behavior due to its low capacity, low efficiency (suggesting O_2 loss), and conversion to an amorphous state.

Overall, the progress is good and directed toward DOE goals.

Reviewer 3:

This project studied interesting oxide compounds of Li-rich Li_2MO_3 and Li_2MO_2. However, the reviewer could not see what merits these types of oxides have in developing high energy cathode materials.

At first sight, these oxides look interesting because they contain two Li per transition metal, but they cannot cycle reversibly once delithiated over a certain degree. Also, in developing high energy cathodes, one should also consider redox voltage, not only capacity. According to the cycle results, the average redox voltages are too low so that the overall energy they deliver is not high enough although the gravimetric capacity seems high.

From a materials science perspective, the proposed or studied oxides are interesting, but from high energy battery development perspectives, they are not attractive.

Some analytic tools they used are good, but the reviewer did not see significant differentiation from other projects.

Reviewer 4:

The reviewer commented that it is important to consider that different Li-salt precursors might be required when the Ni content varies; that could the main reason for the poor performance of low versus high-Ni content materials.

Reviewer 5:

The reviewer stated that the Li extraction associated with Cu redox changes requires very low voltages, even below 2.0V. XRD shows drastic changes at the initial low voltage charging, indicating irreversible crystal structural changes and question in the quality of the material. Extreme local HRTEM does not mean much. The reviewer pointed out that researchers can always pick a wanted feature from garden variety.

The reviewer did not agree with the interpretation of Cu XANES microscopy. The pristine material appears to contain some Cu^{3+} as indicated by the pre-edge peak, which requires confirmation by regular *in situ* XANES. The reviewer believed there are oxidation state changes in Cu. The low energy shift upon charging could be due to carbonate formation, CO_2 evolution, or oxygen evolution, leaving Cu^{2+} from pristine Cu^{3+}. It also shows phase changes or decomposition. The molybdenum-compound is not viable and may not be further pursued.

Reviewer 6:

The reviewer said that the project seems to be on track, but the goals are vague—make materials and evaluate—so the reviewer was not sure how one would assess progress. The metrics are not quantitative. The project would benefit from some focus.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer pronounced the collaboration with other organizations to be excellent. Collaborators include PNNL, BNL, SLAC, and LBNL.

Reviewer 2:

The reviewer said that the collaborations “looks good.”

Reviewer 3:
The reviewer commented that there are good ongoing collaborations with the other DOE laboratories (PNNL, BNL, and LNBL) and SSRL for material characterization and modeling.

Reviewer 4:
The reviewer said that there was good collaboration on characterization methods, but it would be good to have more collaboration with others working on the same fundamentals as it seems like there is overlap with other groups.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that future work is aimed at exploring new high-capacity cathode materials utilizing two lithiums, such as: $Li_2M_1M_2O_3$ and $Li_2M^IM^{II}\ O_3$ where M^I and M^{II} are either Ni, Cu, molybdenum, manganese, or chromium. In addition, various Li-excess disordered compounds, such as Li_{1+x}(Mn, Co, Ni)O_2, $Li_{1+x}MoCrO_2$, $Li_{1.25}Nb_{0.5}Mn_{0.5}O_2$, and $Li_{1.2}Mn_{0.4}Ti_{0.4}O_2$, will be studied to increase oxidative stability and attain extra capacity, understand the role of disorder in increasing the Li diffusion pathways, and quantify oxygen participation in the redox process.

These studies are relevant to and address DOE goals.

Reviewer 2:
The reviewer suggested that the investigators first develop a rationale behind the proposed Li-excess disordered compounds and had many questions. The reviewer inquired about whether the delithiated structures of the proposed compounds are stable, and what the redox voltage will be so that what energy density should be expected. The reviewer did not understand why the investigators suggest looking into such compounds as $Li_{1.25}Nb_{0.5}Mn_{0.5}O_2$ and $Li_{1.2}Mn_{0.5}Ti_{0.5}O_2$. The reviewer asked whether they were selected based on sound theoretical consideration, and whether niobium and Ti are electrochemically active with a decent redox voltage.

Reviewer 3:
The reviewer asserted that it is not clear how the model is driving the synthetic approach of this investigation.

Reviewer 4:
The reviewer said that except for the molybdenum compounds, all are mundane and already extensively studied. As mentioned earlier, molybdenum compounds may not be viable due to poor performance and their cost.

Reviewer 5:
The reviewer's response was that there was a similar theme here and therefore comments similar to those previously made: if this is a make-evaluate-learn project, set some metrics about range of materials, variables, etc. Otherwise, establish a path toward improvement of the materials based on the learnings.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
For widespread use of EVs and PHEVs, the reviewer stated that it is imperative that LIBs be lightweight, compact, safe, and low-cost. The state-of-the-art materials are inadequate to fulfil these needs. High specific energy cathode materials are required to improve the specific energy for Li-ion cells and thus increase the

range for the vehicle and reduce overall cost for the battery. The state-of-the-art cathode materials are inadequate and provide capacities of only 170 mAh/g. New high-voltage and high-capacity cathodes, such as Ni-rich and Li-rich NMC formulations, are promising to meet the DOE goals, which this project has been addressing. Because oxygen loss or redox activity is an integral part of these cathodes, it is crucial to understand their effects on the structure of these cathodes.

Reviewer 2:
In the sense that the investigators are trying to develop high-energy cathode materials and to apply fine analytic tools, the reviewer would agree that this project is relevant to DOE objectives.

Reviewer 3:
The reviewer said, "Yes." The reviewer further stated that the project is relevant because the aim is to develop better rechargeable batteries and reduce the nation's dependency on petroleum.

Reviewer 4:
The reviewer pointed out that fundamental understanding is key to the development of higher energy density batteries, which supports the overall objectives of the DOE program.

Reviewer 5:
The reviewed said resources are fine.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the resources are adequate for the scope of the project.

Reviewer 2:
The reviewer asserted that the theoretical approach is simply copied from other sources and does not show a clear purpose.

Presentation Number: es164
Presentation Title: Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing
Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Presenter
Jianlin Li, Oak Ridge National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

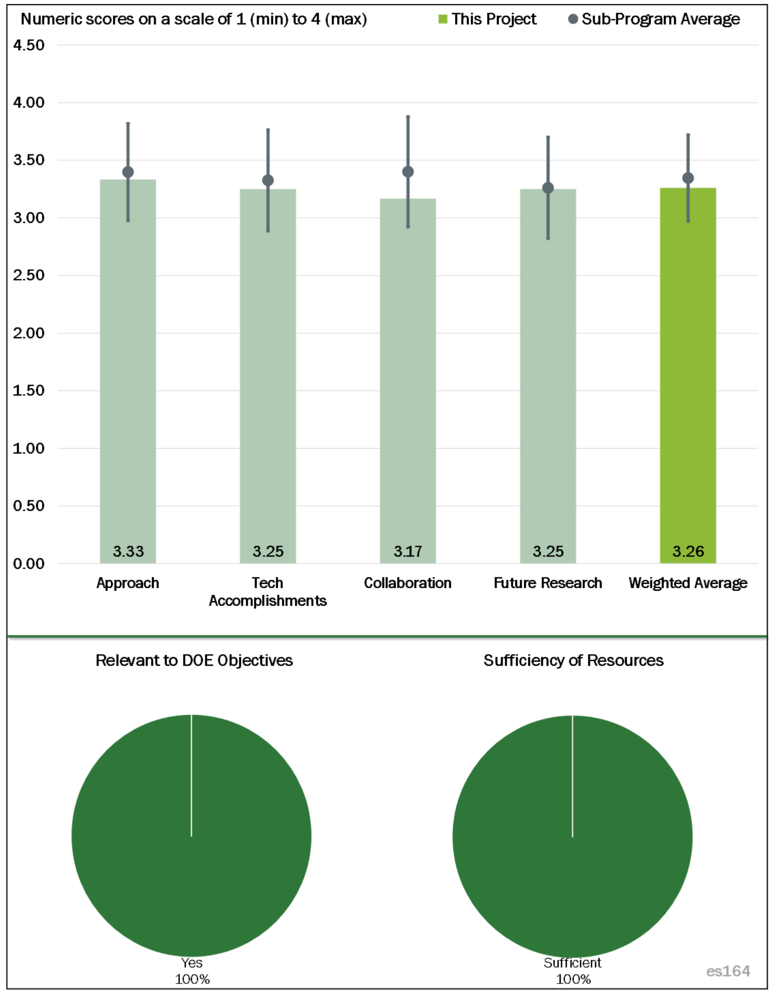

Figure 3-11 - Presentation Number: es164 Presentation Title: Thick Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked that the approach is well defined to address the barriers, and it is integrated with the efforts from other teams. The objectives are also realistic and practical.

Reviewer 2:
The reviewer noted that the project is aimed at increasing energy density and decreasing costs by moving to aqueous-based, thick cathode electrodes. The project is using a high Ni-content cathode (NMC532). The project is well designed using industrially relevant materials, and the goals are feasible and aligned with efforts from other projects.

Reviewer 3:
The reviewer stated that the approach is good and works with reasonably sized cells made using equipment that is representative of what is used in manufacturing. The approach has identified barriers, especially retaining to performance at higher rates, and is addressing them.

Because this project is addressing electrode processing technologies (thick, water-based coatings), it is reasonable and appropriate to use commercially available, state-of-the-art materials, such as NMC532 in developing the new technologies.

Reviewer 4:
The reviewer commented that the approach is effective from the point of view of exchanging the n-methyl-pyrrolidone (NMP)-based slurry on the water-based or water-alcohol mixture. As a result, this reviewer explained, battery-pack, processing, and capital costs are reduced. However, using the proposed multiple coating for obtaining thick electrodes does not accomplish the task with maximum cost reduction.

Reviewer 5:
According to the reviewer, the project approaches the goals from multiple angles and addresses the cost and performance barriers. However, some of the directions may be straying from the goals. For example, it is not clear if the laser structuring of the electrode will not completely cancel the cost advantages and throughput of aqueous processing. An approach based on slurry formulation and coating conditions would be less inexpensive in mitigating the power and polarization issues.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed that the program appears to be progressing well and has successfully made thick NMC532 electrodes with aqueous-based mixed solvent system, with impressive results.

Reviewer 2:
The reviewer commented that the project has made good progress toward goals.

Reviewer 3:
The reviewer stated that several barriers and challenges, such as cracking and effective electrolyte wetting, have been identified, and the team is making progress in solving these problems.

Reviewer 4:
The reviewer mentioned that using the aqueous process for cathodes without compromising the performance of the cell seems to be a big challenge. The team has made significant progress toward avoiding cracking the cathode and improving the electrode integrity.

Reviewer 5:
The reviewer pointed out that currently, the electrochemical performance of water-based electrodes does not overcome or reach the performance of NMP-based electrodes. If water-based electrodes have the same C-rate capabilities, then their cyclability is less. And, for the opposite case, if cyclability is good, then the C-rate is not.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the project has a substantial list of partners and collaborators across many different parts of the project.

Reviewer 2:
The reviewer commented that a broad group of partners is working on this project, the roles of several of the partners are specifically identified, and the future roles of industrial partners are mentioned.

There are no explicit details about how the partners actually interact or how often.

Reviewer 3:
The reviewer said that the team members have different capabilities and strengths. It looks there is not enough interactions among the collaborators.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the project has specific future work planned and milestones to determine future decision points and includes alternative development pathways to mitigate risk. It is well aligned with contributing to advancements in other DOE projects.

Reviewer 2:

The reviewer said that specific future work for next year and tentative work for the final year of this 4-year project have been identified.

Reviewer 3:

The reviewer commented that the microstructure of the electrolyte, including the porosity and tortuosity, might impact the battery performance significantly. The team should include that as one of the future directions as well.

Reviewer 4:

The reviewer pointed out that laser structuring for electrolyte transport inside electrodes will improve C-rate capabilities, but also will have a negative impact on energy density and cost of electrodes. The reviewer asked if it were possible to quantify these impacts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer pointed out that this program is focused on decreasing costs and increasing energy density. Success in one or both of those areas may lead to accelerated EV adoption, which assists petroleum displacement.

Reviewer 2:

The reviewer answered yes and stated that the manufacturing process is a green and low-cost process, which might reduce the cost per watt-hour.

Reviewer 3:

The reviewer observed that the battery community has recognized that development of techniques to coat thick electrodes using water-based technologies offering the promise of improved energy density, improved specific energy, and reduced cost relative to current technologies using thinner coatings and NMP.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources seem to be appropriate for this project. ORNL seems to have adequate facilities (dry room, etc.) and equipment (coaters, etc.). Collaborators offer access to other research, development, testing, and engineering (RDT&E) facilities.

At almost $4 million, the budget is significant. Without more detailed data, one cannot assess if the level of spending is cost effective relative to other organizations.

This project is scheduled to receive more than twice the funding allocated for the related project (ES207) on thick, low-cost electrodes produced with electron beam (EB) curing. ORNL is the lead on both projects; many of the same people are involved in both projects, so one assumes that the costs of labor and facilities are similar for the two projects. The presentations seem to indicate that the two projects are using some of the same facilities. The challenges facing the two projects are of similar magnitude—if anything, the EB project is more challenging.

If this Aqueous Processing project is appropriately funded, then the EB project is probably underfunded. Of course, if the EB project is properly funded, then this Aqueous Processing project may be overfunded.

Reviewer 2:
It is the reviewer's opinion that the researchers are doing substantial work and making progress considering the project's funding allotment. The reviewer asserted that the project team is a good example of what can be achieved its funds, and exclaimed that it is significantly more efficient than other projects.

Reviewer 3:
The reviewer stated that the team and collaborators have complementary strength and can accelerate the progress.

Presentation Number: es166
Presentation Title: Post-Test Analysis of Lithium-Ion Battery Materials
Principal Investigator: Ira Bloom (Argonne National Laboratory)

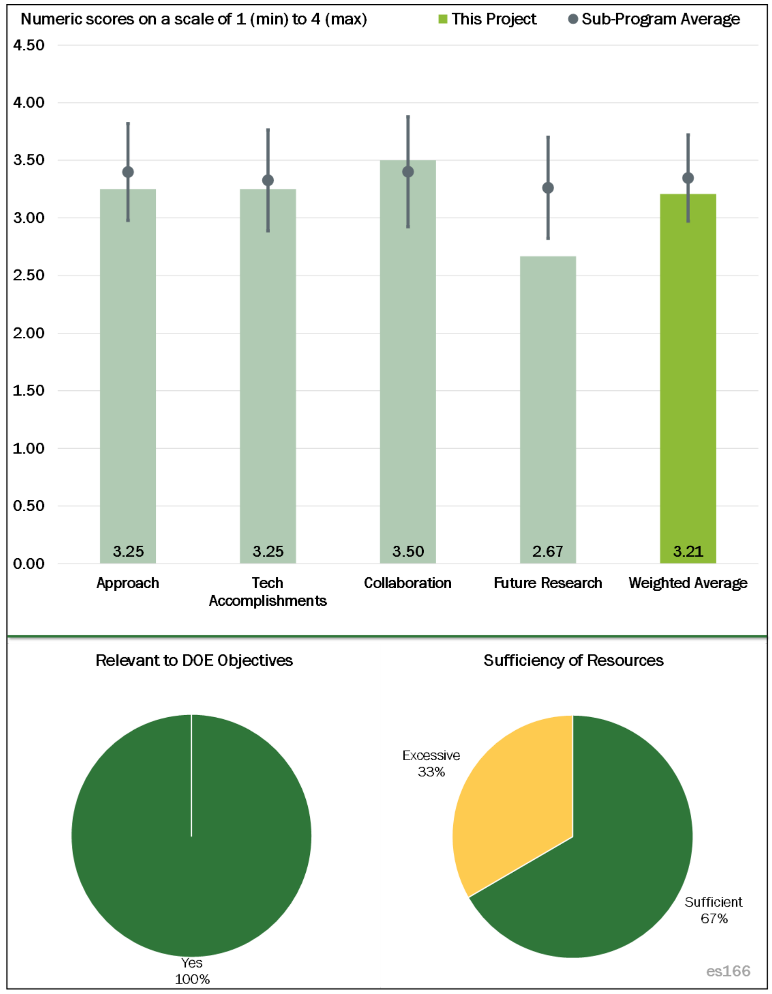

Figure 3-12 - Presentation Number: es166 Presentation Title: Post-Test Analysis of Lithium-Ion Battery Materials Principal Investigator: Ira Bloom (Argonne National Laboratory)

Presenter

Ira Bloom, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the concerns, issues, and the goals were clearly defined. The method to evaluate the final product was also clearly identified.

Reviewer 2:

The reviewer said that the approach is good and is following standard methodology (test, dismantle, observe, and perform diagnostics).

Reviewer 3:

The reviewer noted that the investigative approach was determined during development of the project. Overall, experimental means used appear logical and have yielded the ability to conclude the behavior of a LIB package as it is subjected to intentional abuse.

Reviewer 4:

The reviewer commented that this is an effort to develop an understanding of how cells react to abuse using two different cathodes and two different binders. Another question was how processing affects abuse tolerance. The approach has been carefully laid out.

Reviewer 5:

The reviewer pronounced the approach of the post-test analysis to be good, and it addresses important issues related to abuse events. However, the reviewer believed the materials used should be more aggressive, especially the selection of a carboxymethyl cellulose (CMC)-graphite anode. This material is not advanced, and the approach is most likely repeating substantial work that has been covered by various other organizations. Emphasis on higher energy anodes and cathode pairs is advisable as well as alignment with new materials from CAMP or the Advanced Manufacturing Facility.

Reviewer 6:
The reviewer commented that only one type of abuse tests (i.e., overcharge) was performed. The work can be improved by leveraging Sandia National Laboratories (SNL) facilities and performing more types of abuse tests (e.g., thermal and mechanical abuse tests).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that the PIs made good progress on comparing physical and chemical response of batteries with different types of binders under battery abuse conditions.

Reviewer 2:
The reviewer stated that good progress had been achieved by the ANL, ORNL, and SNL team this past year. ORNL made cells using two different binders and processes, SNL performed abuse testing, and ANL conducted post-mortem analysis.

Reviewer 3:
The reviewer stated that excellent progress was made toward program goals as they were outlined. The cell manufacturing, testing effort, and analysis work proceeded almost as scheduled.

Reviewer 4:
The team designed work and performed experimental efforts to meet established objectives for the fiscal year. However, some delays in outcome are reported. It remains for the team to establish a plan to address these delays.

Reviewer 5:
The reviewer observed that this project is in the very early stages so there are only a modest number of results. A number of diagnostics has been carried out on the two binders, and differences are observed, but it is too early to develop insights, in the opinion of the reviewer. A good question has been raised—what causes grain boundary corrosion—for future analysis. Transition metals were seen at the anode, which can be a useful diagnostic of abuse along with details of the morphology. Plating can be observed, but quantitative trends are hard to make out. One interesting result this reviewer noted is that binder failure seems to be important.

Reviewer 6:
The reviewer found that the project is making sufficient progress toward identifying binder-dependent physicochemical changes due to abuse conditions. A more rigorous statistical set of samples (replicates, large batch size) would help confirm the reproducibility and overall validity of the results.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that while each national laboratory may have been able to do this complete program, the strengths of each national laboratory were used to their full advantage by collaborating to meet the program goals.

Reviewer 2:
The reviewer stated that the team reports considerable interaction between PIs at ORNL, SNL, and ANL as well with SMEs from other sectors.

Reviewer 3:
The reviewer called the collaboration arrangement excellent, with ORNL, ANL, and SNL each contributing their expertise.

Reviewer 4:
The collaboration is excellent as it includes three national laboratories (ANL, ORNL, and SNL).

Reviewer 5:
The reviewer said that all national laboratories are fully engaged in the research.

Reviewer 6:
The reviewer noted that ANL has partnered with ORNL to make the cells and SNL to abuse the cells. More collaboration to receive more types of cells and materials (cathodes, anodes, and electrolytes)—either through ORNL's part or other avenue—might accelerate the objective of understanding physical and chemical responses of battery materials under battery abuse conditions.

Question 4: Proposed Future Research - the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the effort is projected to end in September 2018. The successful approach taken thus far will continue until completion.

Reviewer 2:
The reviewer commented that the slides include some indications of future research. The summary of future work is missing.

Reviewer 3:
The reviewer noted that there are no stated future plans other than what is stated in the objectives. Ideally, a “Future Plans” slide that included details on the points in the objectives would have been excellent.

Reviewer 4:
The reviewer commented that the poster presents a rather generic “milestone chart.” Further detail would have been useful. A slide depicting future work was not found within the poster slide deck.

Reviewer 5:
The reviewer stated that no future research slides were provided although this project continues until September 30, 2018 (only 50% complete). This appears to be an unfortunate oversight on behalf of the PI. Additionally, the proposed future work from the 2016 presentation was not addressed in this 2017 presentation.

Reviewer 6:
The plan is to look at Li-iron-phosphate (LFP) composition next year with different combinations of binder. It was not clear to the reviewer whether the plans will yield new insights, especially at a fundamental level.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer mentioned that understanding the potential negative response to real world abuse scenarios for this technology and identifying ways to significantly reduce that response are critical to public acceptance of this technology. This project fully supports that need.

Reviewer 2:
The reviewer asserted that the introduction of LIBs into the transportation sector will result in lightweighting of designed vehicles, which serves to conserve energy, whether it be petroleum or other energy source. However, this project is one that is focused on energy storage, regardless of generating source.

Reviewer 3:
The reviewer viewed battery safety as critical for widespread adoption of EVs and the displacement of petroleum. Projects such as this serve as a tool to determine overall safety and post-cycling analysis.

Reviewer 4:
The reviewer stated that an effective post-analysis procedure is important for battery development and will help accelerate the EV adoption.

Reviewer 5:
The reviewer remarked that the project supports DOE objectives. It is important to perform failure analysis on batteries so that we can move forward in the development of an affordable battery that can meet DOE goals.

Reviewer 6:
It seems useful, but it was unclear to the reviewer how knowing the various responses to abuse will help make safer batteries. The reviewer further noted that the project team will test different additives, but again, was unsure how looking at morphology changes will add knowledge.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the funding needed to have these three national laboratories provide their expertise to a project is sufficient.

Reviewer 2:
Based on the results obtained this past year, the reviewer remarked that it appears the investigators have sufficient resources to successfully complete the project.

Reviewer 3:
The reviewer noted that the collaborative laboratory team has access to a wide variety of tools and resources to support conduct of this effort.

Reviewer 4:
The reviewer said resources are okay.

Reviewer 5:
Based upon the presentation, a small set of cells were produced for testing (fewer than 30 cells), abuse, and subsequent characterization. The reviewer would like to have seen additional anode or cathode chemistries or a larger representative set of cells with the time and resources available to them. This would help solve their stated objective of elucidating physical and chemical response of battery materials under battery abuse conditions.

Reviewer 6:
It seems to the reviewer that most analysis presented so far (especially just overcharge abuse test) can be done in coin cell instead of pouch cell.

Presentation Number: es167
Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials—Gradient Cathode Materials
Principal Investigator: Greg Krumdick (Argonne National Laboratory)

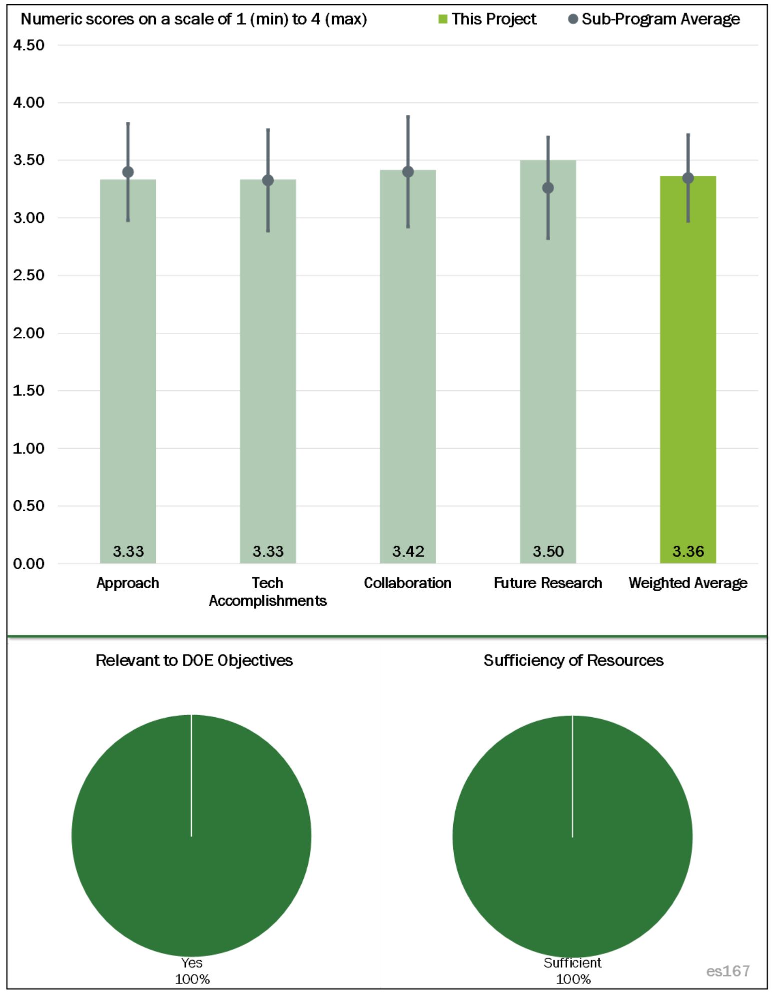

Figure 3-13 - Presentation Number: es167 Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials—Gradient Cathode Materials Principal Investigator: Greg Krumdick (Argonne National Laboratory)

Presenter

Youngho Shin, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach is excellent and is the type of study needed if DOE is to improve batteries for electric drive vehicles. The effort undertaken is a conduit among identifying advanced battery materials in the laboratory, market evaluation of the materials, and high volume manufacturing.

Reviewer 2:

The reviewer stated that the objective of the project is to perform systematic studies in order to define the optimum concentration of gradient cathode materials and to develop processes for the scale-up of these high energy cathode materials. The project has a sound approach in evaluating various types of gradient cathode particles and in developing synthesis processes for the production of large quantities of materials.

Reviewer 3:

The reviewer remarked that the approach to making gradient materials is sound and based on scalable technologies, allowing the work to potentially make a large impact on the field.

Reviewer 4:

The reviewer commented that the project is carefully planned and technical barriers are addressed.

Reviewer 5:

The reviewer found the approach to be reasonable to scale up the materials and to reduce cost by transitioning from batch process to continuous synthesis process.

The core-shell and core gradient approaches have been studied for the last few years to mitigate stability issues while achieving high energy density cathodes. There is still no convincing full cell data on the benefit of the core gradient or core shell materials. Because the surface is porous, it remains unclear why the electrolyte will not diffuse into the interior and react with the less stable core material. They should provide some quantifiable energy density gains (Wh/l and Wh/kg) at the full cell level.

Reviewer 6:

The reviewer asked that the target material be defined: gradient cathode material with greater than 220 mAh/g with greater than 95% capacity retention at 100 cycles. The best gradient cathode material does not reach 220 mAh in the voltage range tested. The reviewer would like to have seen the voltage range extended to achieve greater than220 mAh/g, at least within the first five cycles. The reviewer would also like to have seen at least three cells tested for each lot to achieve some reasonable statistics, especially for the scaled-up lots where there should be plenty of sample for coin cell tests.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that excellent progress was achieved this past year (622 gradient material characterization, 811 gradient material synthesis, and comparison of 811 gradient material with commercial NMC333 at various temperatures).

Reviewer 2:

The reviewer stated that the gradient NMC material seems to offer a real technical breakthrough. The reviewer asked how the gradient material described in this work is different than existing commercial gradient material offered by TIAX.

Reviewer 3:

The reviewer remarked that progress is excellent, but suggested that more consideration of crystal homogeneity in the materials produced needs to be demonstrated.

Reviewer 4:

The reviewer said that various types of gradient materials are synthesized, and their electrochemical performances are compared. Microscopy and spectroscopy techniques are used to characterize the synthesized particles. The findings of the project show that the synthesized core-gradient and core-shell compounds exhibit better performance (capacity retention and rate capability) compared to the available commercial NMC cathode materials. Thus, gradient compounds are promising to improve the performance of LIBs; however, as mentioned by the team, their commercialization needs further improvement of manufacturing methods. The project needs to place more emphasis on the scale-up of concentration gradient oxides.

Reviewer 5:

The reviewer observed that there was good use of analytical tools, such as EDS and XAS, to characterize and validate the concentration gradient or compositions in the gradient or core-shell materials.

They showed better rate capability and limited cycling performance in half cells using their 811 core gradient material. However, they ultimately need to validate the performance advantage of the 811 core gradient material in a full cell.

Reviewer 6:

The reviewer commented that progress toward actually making a core gradient material that cycles well is good, but it is not clear what the fading mechanism is. The C/10 results are almost identical for the core shell and core gradient materials and almost meet the cycle test even at 55°C, but there is a divergence between the two at C/2 cycling. It is important to do some diagnostic tests, such as impedance measurements to seek the reasons for this difference. It would be good to be certain that there are no porosity differences between the two types of cathodes.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer asserted that there are excellent collaborations on this project.

Reviewer 2:
The collaboration that exists is excellent. It includes academia (University of Illinois and Technical University Braunschweig), national laboratories (BNL and ANL), and industry (Laminar).

Reviewer 3:
The reviewer commented that the project team has various collaborations with DOE national laboratories, universities, institutions, and companies.

Reviewer 4:
The reviewer stated that there was good collaboration, and the roles of each collaborator were specified.

Reviewer 5:
The reviewer observed that collaboration seems good by virtue of the Materials Engineering Research Facility (MERF) at ANL.

Reviewer 6:
The reviewer observed that there was a good list of collaborators, but noted that adding other industrial collaborations may further strengthen this project. The reviewer noted that adding other industrial collaborators may further strengthen this project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future work is well thought out and logical. It includes investigation of the promising 811 cathode material. A Taylor Vortex Reactor continual process is being developed that will result in higher quality, more affordable material.

Reviewer 2:
The reviewer particularly liked the plans for the vortex reactor and described this as cutting edge.

Reviewer 3:
The reviewer noted that development of continuous synthesis process is one of the critical aspects of future work.

Reviewer 4:
The reviewer commented that future research is well planned and is in line with the objectives of the project.

Reviewer 5:
The reviewer wanted to see more effort devoted to demonstrating performance in full cells in order to validate the benefits of core-shell or gradient materials.

Reviewer 6:
The reviewer would like to have seen an expanded voltage range to achieve the 220 mAh/g target added to the future research proposal.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Because the project aims to scale up the production of layered Li transition-metal oxides that exhibit high energy storage, low-cost, non-toxicity, and abundant elements, the reviewer remarked that it thus facilitates the transition from a fossil fuel based economy to one that may be driven by a mixture of fuels.

Reviewer 2:
The reviewer observed that this project is highly relevant to DOE objectives. New advanced cathode materials are generally synthesized on the gram scale without quality control and reproducibility. These materials need to be tested and validated in large format prototype cells before going to high-volume manufacturing. This project allows synthesis of sufficient material for in-depth characterizations that eventually allows transition to the car manufacturer.

Reviewer 3:
The reviewer pointed out that high-capacity cathode materials are crucial to the success of DOE programs.

Reviewer 4:
The reviewer opined that this work improves U.S. technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 5:
The reviewer said that a stable, high-capacity cathode is relevant to DOE's objectives.

Reviewer 6:
The reviewer stated that this project meets DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the project team has access to sufficient resources and collaborations in order to perform the proposed tasks.

Reviewer 2:
The reviewer noted remarked that $1.7 million should be sufficient for the proposed effort.

Reviewer 3:
The reviewer stated that there are sufficient resources to accomplish the proposed milestones.

Reviewer 4:
The reviewer said that the resources seem appropriate.

Presentation Number: es168
Presentation Title: Process Development and Scale-Up of Critical Battery Materials—Continuous Flow Produced Materials
Principal Investigator: Greg Krumdick (Argonne National Laboratory)

Presenter

Krzysztof Pupek, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

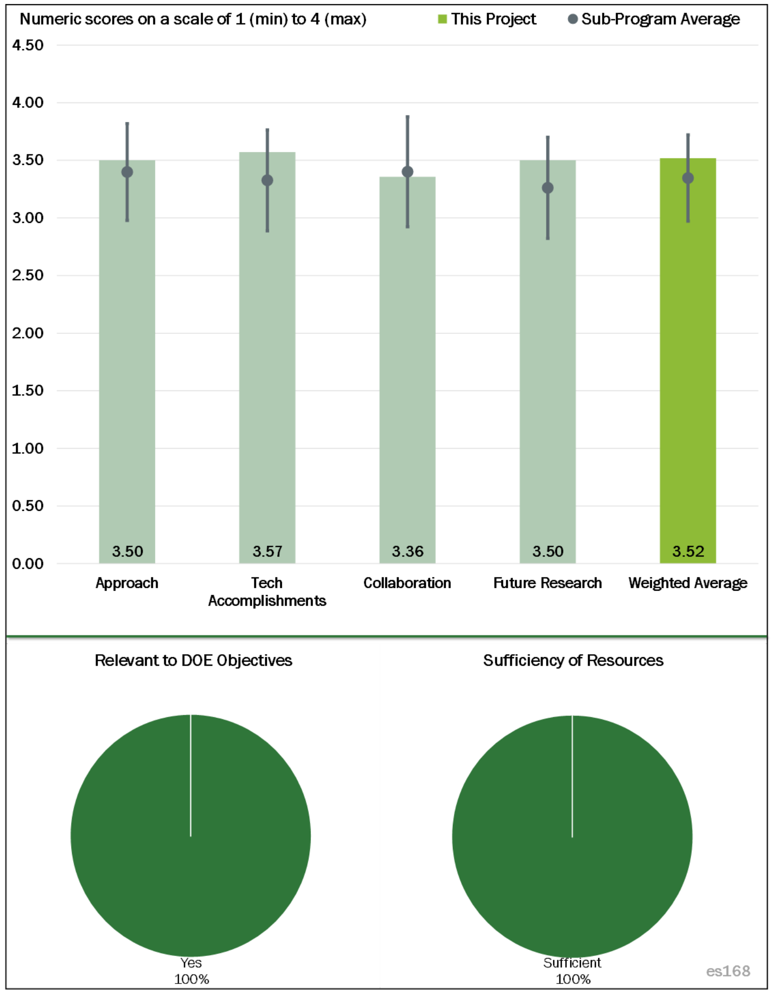

Figure 3-14 - Presentation Number: es168 Presentation Title: Process Development and Scale-Up of Critical Battery Materials—Continuous Flow Produced Materials Principal Investigator: Greg Krumdick (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

In so far as the goals of this program include evaluating manufacturing technologies, developing cost effective processes, producing sufficient materials quantities for evaluation, and determining effect of purity profiles on battery performance, the reviewer observed that this group has made great progress. Materials have been distributed to several partner research groups for evaluation, and the new flow reactor setup provides a means of scale-up with advantages over non-flowing reactors, including improved mass and heat transfer kinetics. This continuous system has been used to synthesize several electrolytes that have been demonstrated as useful additives in LIBs. Analysis of a trimethylsilyl-functionalized carbonate shows that this scalable additive may be useful as an LIB solvent. Catalysts for effective reactions were identified in batch versus flow conditions, resulting in the identification of alumina as a low-cost catalyst.

Reviewer 2:

The reviewer reiterated that the goal of the project is to develop cost-effective processes for the manufacturer of large quantities of organic solvents for LIBs. Continuous flow reactors for production of organic solvents have been successfully tested, the basic properties of the products are evaluated, various catalysts are examined, and the process has been optimized. The new materials synthesized using flow reactors seem to be promising as future solvents and could enable safer liquid-based electrolytes for LIBs. The project team is planning to perform additional experiments to confirm the safety of the solvents.

Reviewer 3:

The reviewer acknowledged that this is very relevant work for materials development, and the approach is relatively unique in being agnostic to the source and targets of the proposed materials.

Reviewer 4:
This reviewer liked the stated concept of trying to develop new processes that will take some risk away from industry and also provide small quantities of new materials for testing

Reviewer 5:
The reviewer commented that the work was interesting.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
By providing large quantities of materials with consistent quality, the reviewer pointed out that this program meets a critical need by linking the discovery of advanced battery materials with market volume and high volume manufacturing. The consequence of these accomplishments includes industrial validation of materials in large format cells, which may lead to further advances in research projects involving new materials inspired by results of cycling data obtained from the same batch of materials.

Reviewer 2:
The reviewer said that the development of a cost-effective process for the synthesis of organic solvents, screening the effect of various catalysts, and evaluation of several new solvents for LIBs is the main accomplishments of the project. The outcome of the project at this point is toward the development and scale-up of novel manufacturing processes for battery materials.

Reviewer 3:
The reviewer mentioned that developing a process for the methyl ((trimethylsilyl)methyl) carbonate MTMSMC solvent seems like a good choice to test concepts of this program. The team has made excellent progress.

Reviewer 4:
The reviewer noted that many materials were scaled up, especially in the field of electrolyte solvents.

Reviewer 5:
The reviewer said that good progress has been made.

Reviewer 6:
The reviewer had a question about not fully understanding the role of alumina catalyst.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project team has various collaborations with DOE national laboratories, Army laboratories, and leading companies. The collaborations are at both scale-up and materials evaluation levels.

Reviewer 2:
The reviewer noted that there is appropriate collaboration with other institutions.

Reviewer 3:
The reviewer mentioned that several partners are identified (ORNL, ANL research groups, and Dellatech), and more are identified as providing support (ARL, LBNL, PNNL, SolidEnergy Systems, and Toyota Technical Center).

The nature of collaborations and support is not well identified on the slides provided. After forgetting to ask about collaborations at the poster session, the reviewer wanted the participants to be more specific about the nature of their collaborations and supportive interactions.

Reviewer 4:
The reviewer remarked that many partners are listed; however, it is not clear how each one is participating in the project.

Reviewer 5:
This reviewer commented that adding industrial collaborators would strengthen this project.

Reviewer 6:
The reviewer did not see evidence of strong collaborations on the production and distribution of MTMSMC and inquired if there is a ready market for this product.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that remaining challenges and barriers are discussed, and future activities are well detailed and are sound. In particular, the proposed plan to investigate the effect of chemical purity on electrochemical performance carries significant benefits for optimum manufacturing of materials.

Reviewer 2:
The reviewer said that good future work was proposed.

Reviewer 3:
The reviewer asserted that targeting approximately five new materials for process R&D, investigating purity versus electrochemical performance, and evaluating new technology platform are reasonable. Perhaps more detail could be provided on how materials are selected for scale-up and evaluation.

Reviewer 4:
The reviewer commented that the list of new materials and research directions seems to be too long for the remaining time of the project.

Reviewer 5:
The reviewer stated that the current project is essentially complete and would like to have seen more specifics in planning what is next.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that decreasing LIB cost and improving performance allow for the increased incorporation of fluctuating renewable energy resources onto the electrical grid.

Reviewer 2:
The reviewer stated that the project will significantly impact the manufacturing of critical materials for energy storage and thus facilitates the transition from a fossil fuel based economy to one that may be driven by a mixture of fuels.

Reviewer 3:
The reviewer noted that this work improves U.S. technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 4:
The reviewer said yes, because of the battery for EVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project team has access to sufficient resources and collaborations in order to perform the proposed tasks and is expanding its collaborations and scale-up efforts.

Reviewer 2:
The reviewer said that the resources appear to be adequate.

Reviewer 3:
The reviewer observed that the resources are sufficient.

Reviewer 4:
The reviewer found the resources to be sufficient for the project to achieve.

Reviewer 5:
The reviewer commented that resources seem sufficient based on previous year spending. However, time may be too short for all remaining tasks.

Presentation Number: es183
Presentation Title: *In Situ* Solvothermal Synthesis of Novel High-Capacity Cathodes
Principal Investigator: Feng Wang (Brookhaven National Laboratory)

Presenter

Feng Wang, Brookhaven National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

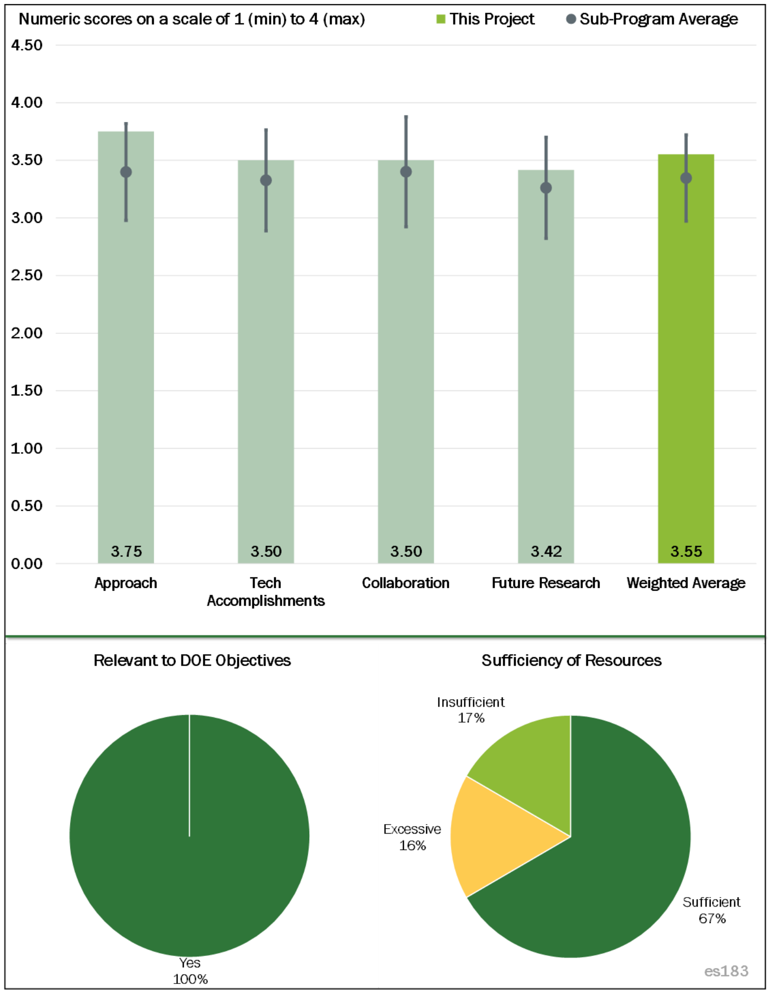

Figure 3-15 - Presentation Number: es183 Presentation Title: *In Situ* Solvothermal Synthesis of Novel High-Capacity Cathodes Principal Investigator: Feng Wang (Brookhaven National Laboratory)

Reviewer 1:

The reviewer observed that studying the synthetic conditions by *in situ* methods is an outstanding approach, guiding toward the optimal condition for highly tuned materials.

Reviewer 2:

The reviewer summarized the objective of this project, which is to develop low-cost cathode materials with an energy density of greater than660 Wh/kg and electrochemical properties (cycle life, power density, and safety) consistent with USABC goals.

Designing and synthesizing specific cathode materials have proven difficult due to the complexity of the reactions involved in chemical synthesis and high sensitivity of the phases, stoichiometry, and morphology to the synthesis conditions (such as pH value, Li content, sintering temperature and atmosphere, and heating and cooling rates). The effort in the current year has focused on developing Ni-rich layered oxides ($LiNi_{1-x}M_xO_2$ where M=Co, Mn, etc.) through synthetic control of the phase, stoichiometry, and morphology, all of which determine the cathode performance.

To control these key parameters, new tools and techniques are being developed for *in situ*, real time studies of synthesis reactions, for example, using *in situ* solvo-thermal synthesis for LFP cathodes. For the Ni-rich cathodes, a similar *in situ* technique being developed here would enable the tuning of the structure and property with Co and Mn substitution; it would also track phases and cation ordering in the intermediates and thereby quantify thermodynamic and kinetic parameters governing the synthesis process.

Because the high-capacity cathode undergoes considerable structural changes in the bulk, with cation disorder and phase transformations, an *in situ* study is an excellent tool to track these changes and formulate reaction mechanisms. The approach here addresses the technical barrier of understanding the structural changes in the high-capacity cathode in Li-ion cells.

The project is well designed, feasible, and well integrated with other effort.

Reviewer 3:

The reviewer said that this project starts high-energy, low-cost, and stable NMC cathode materials from monitoring at the molecular level to establish the synthesis-structure-properties relationship. The smart system of *in situ* synthesis has proven to be a power technique in identifying the key parameters affecting the structure and properties of the products obtained. The change from precursors to the end products has been quantitatively documented for people to alter the experimental conditions to obtain what one desires. The reviewer said that this is remarkable.

Reviewer 4:

The reviewer observed that we spend a lot of time and resources understanding how materials work or fail in a battery. We characterize materials in an attempt to understand how they work. But, cathode materials made via different processes perform differently—and this is a much less studied field. If we want to make the best performing, lowest cost materials, this type of work is critical and should be increased.

The reviewer stated that it would be great to extend this to other synthesis methods—even if they had to be *ex situ* with sampling of materials as a function of time. It needs to include commercially relevant processes.

Reviewer 5:

The reviewer commented that a thorough understanding of the synthetic mechanism and high temperature thermo-chemical aspects are greatly needed for successful development of high-energy cathode material. This project aims to develop tools and techniques to identify the reaction pathways to obtain materials with desired phases and properties.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

All milestones have been completed with some excellent results. Quantitative measurement of the chemical composition as well as the structure of the materials obtained are superbly demonstrated. The temperature effect has been convincingly shown from the synthesis process as well as the product performance.

Reviewer 2:

The reviewer called out good progress toward goals and was glad that the team added another synthesis capability. The calcination studies are also important and interesting, and the team has done a lot of work here.

Reviewer 3:

The reviewer gained great insights concerning the local and long range structures of transition metals in NMC family materials but would like to have seen some correlations between these synthetic variations and stability over cycles and more detail about the capacities.

Reviewer 4:

The reviewer asserted that good progress had been made in developing *in situ* techniques during the synthesis of cathode materials, which enable us to identify reaction pathways and intermediates and to quantify thermodynamic and kinetic parameters governing the synthesis process.

This process was utilized earlier for LFP cathodes, and this year methods were developed for making a series of Ni-rich layered oxides. Specifically, *in situ* reactors specialized for solid-state synthesis under controlled atmosphere and new synchrotron-, neutron-based *in situ* probing techniques were developed. The techniques were then applied to identify the phases being formed in the layered and spinel composites in Ni- and Co-rich systems with tuned electrochemical properties.

Similarly, structural evolution details, such as phase transformation, layer ordering, Li-Ni mixing, slab distance, etc., were identified as a function of temperature during synthesis of Ni-rich oxide ($LiNi_{0.8}Co_{0.2}O_2$) and determined optimal conditions for synthesizing $LiNi_{0.8}Co_{0.2}O_2$ with low cationic disordering.

Later, this method was used to determine the dependence of the reaction pathway on precursors in the synthesis of Ni-rich layered oxides with different precursors and different temperatures (850ºC has been identified with fast ordering kinetics and yields material of high electrochemical activity).

Finally, NMC71515 was synthesized with low cationic disordering and high reversible capacity through synthetic control of the kinetic reaction pathway. Though there is good understanding of the materials synthesized here, the performance is not particularly impressive, the capacities are low, and the cycle life is moderate with these materials. Nevertheless, this synthetic approach with *in situ* characterization is an excellent tool to develop new materials with known properties.

Overall, the progress is quite good and well directed toward the DOE goals.

Reviewer 5:
This project successfully developed *in situ* probing techniques to understand factors that affect resulting crystallographic structure of cathode materials, which could help precisely correlate structural-electrochemical properties of synthesized cathode materials. Instead of synthesizing a bunch of compositions and simply testing them, the reviewer expected this kind of study from national laboratories to have given a fundamental understanding of targeted cathode materials.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed a great job and congratulated the team for having many collaborators. This reviewer also praised the team as using the unique capability of BNL to work very effectively with a wide variety of partners, and encouraged the team to keep it up.

Reviewer 2:
The reviewer pronounced the coordination to be good.

Reviewer 3:
The reviewer acknowledged that there are good ongoing collaborations with the other DOE laboratories (ORNL, LBNL, and ANL) and with the universities.

Reviewer 4:
The reviewer commented that collaborations with other national laboratories are important for materials characterization. The collaboration with three universities leads to the good selection of synthesis conditions to start with. Some of the collaborators have extensive industrial experience with large scale materials production as well as battery manufacturing.

Reviewer 5:
The reviewer said that collaborations are clearly demonstrated and organized.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the PI knows what he is doing. In addition to having even more powerful *in situ* monitoring of the reaction process, the PI also proposed to test other high-energy, low-cost, and stable materials. The reviewer opined that this is quite logical and explained that the team can also achieve the planned research with research that others can only envy.

Reviewer 2:

The reviewer remarked that future studies will continue to provide an understanding of the synthetic process of high capacity cathode materials through *in situ* solvo-thermal synthesis. Specific plans are to continue to work on *in situ* probing and synthetic control of the structural ordering in NMC cathodes by focusing on Co and Mn effects on the structural ordering, cooling effects on the cationic ordering and electrochemical properties, local oxidation process of Ni versus Mn-Co within single particles, and morphology control through tuning synthesis conditions. Later, these methods and the optimized set of experimental conditions will be extended to the Li-rich LL and LLS composite oxides.

These studies are quite relevant to bringing the project to a closure and addressing the DOE goals.

Reviewer 3:

According to the reviewer, future work is well stated. The reviewer highly recommended that efforts continue to advance this year's work and develop new *in situ* techniques for thorough mapping of synthetic parameters and resulting structure and electrochemical properties. Close collaboration with other BMR projects on materials development should be done.

Reviewer 4:

The reviewer suggested that the project expand its capabilities in order to learn more.

Reviewer 5:

As mentioned earlier, the reviewer recommended gaining strong correlation among synthetic condition, structural information, capacity, and stability.

Reviewer 6:

The reviewer commented that it will also be important to study the effect of Mn in the high Ni NMC materials and compare that to the NCA materials with the similar Ni content.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

For widespread use of EVs and PHEVs, the reviewer stated that it is imperative that the LIBs be lightweight, compact, safe, and low-cost. The state-of-the-art materials are inadequate to fulfil these needs. High specific energy cathodes with low-cost are required to improve the specific energy for Li-ion cells and thus increase the range for the vehicle and reduce overall cost for the battery. Nickel-rich and Li-rich NMC cathodes are promising to provide the required high energy densities, but these materials are difficult to synthesize because structural properties and a good fundamental understanding of the structural aspects, phases changes, and cation ordering are unknown, which this project has been addressing. This project is expected to result in cathode materials that will make LIBs more acceptable for EVs and PHEVs, which in turn reduces petroleum dependence.

Reviewer 2:

The reviewer commented that this project not only gives novel products for high-energy, low-cost, and stable cathode materials of LIBs, it also provides a powerful tool for people to optimize the synthesis conditions for other materials. The synthesis-structure-properties relationship can be quantitatively monitored with the variation of experimental conditions. Thus, it will also help many researchers in the field to obtain their desired products within a shorter period of time. The materials, if used in battery applications, can definitely benefit the renewable energy storage or power supply for EVs. Both applications would displace petroleum.

Reviewer 3:

Ultimately, according to the reviewer, processes to make lower cost or more consistent materials will support the overall DOE objectives. This project has a good balance of fundamental understanding and practical application.

Reviewer 4:

The reviewer said yes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that all milestones have been completed with outstanding results. An excessive amount of useful data has been obtained. The reviewer commented that the synthesis-structure-properties relationship has been established for a couple of materials, and noted that the approach can be applied to many other materials. Additionally, this reviewer described the developed tool as very powerful.

Reviewer 2:

The resources are adequate for the scope of the project.

Reviewer 3:

The reviewer said yes.

Reviewer 4:

The reviewer noted that the practical limitations on beam time may impede this project.

Presentation Number: es201
Presentation Title: Electrochemical Performance Testing
Principal Investigator: Ira Bloom (Argonne National Laboratory)

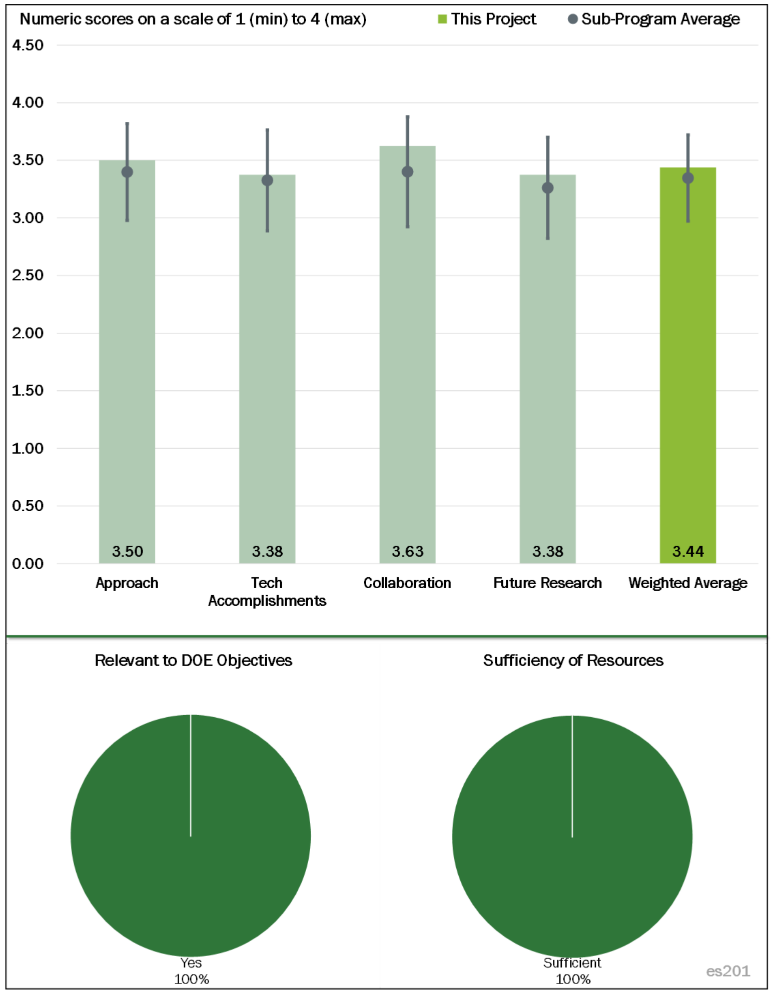

Figure 3-16 – Presentation Number: es201 Presentation Title: Electrochemical Performance Testing Principal Investigator: Ira Bloom (Argonne National Laboratory)

Presenter

Ira Bloom, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

According to the reviewer, the use of very public methods to provide a highly competent and independent evaluation of cells of many sizes is just what is needed.

Reviewer 2:

The reviewer said that the project is well designed and integrated with other efforts, particularly as a validation for USABC projects. The reviewer understood the desire for testing support results to be maintained as confidential information; however, this does make it difficult to truly see how and whether barriers are being addressed by cells delivered by the USABC programs.

The publicly available results on fast charging are indeed interesting and promising. It would be useful in the future to show what percentage of the budget is spent on projects that result in data that cannot be shared publicly and on the decision process for how the budget is appropriated for testing and results that can and are shared publicly.

The comparison to activities in China is very interesting, and the presenters' stated desires to test more relevant chemistries were encouraging. It may be useful in these cross-geography studies to test batteries produced in China with the developed protocols. As EVs become more prevalent on U.S. roads and infrastructure (with presumably an increasing number of cells and packs produced outside the United States), it may be useful to fully characterize imported automotive batteries on an ongoing basis alongside emerging USABC program batteries.

Reviewer 3:

The reviewer remarked that the fast charging development for an EV battery is important. The time to fast charge is assumed to be equivalent to internal combustion engine (ICE) fueling.

Reviewer 4:

The reviewer commented that the project is well designed, but not very feasible, so far. This reviewer further opined that this kind of battery test or characterization work depends on how to secure the various batteries on time. Otherwise, it would change all technical approaches. The reviewer also indicated that no clear or solid information is shared about how to approach performing the work.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer pointed out that the technical accomplishments toward the DOE goals are excellent, and it is clear that the sustained investment in high quality facilities and experienced personnel is required to continue ongoing success of this project.

Reviewer 2:

While the poster focuses on the new China work, the reviewer stated that the Chinese continue to do a great deal of independent evaluation. Both are quite valuable. China is a major market and having a reliable testing agency there giving results similar to U.S.-based testing is of value to industry.

Reviewer 3:

The reviewer stated that the issues of fast charging are addressed thoroughly.

Reviewer 4:

The reviewer opined that because many similar studies have been reported, the technical accomplishment is very minimal.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer responded, yes. Many different cell suppliers along with various chemistries are an outstanding outcome of this project.

Reviewer 2:

The reviewer found the collaboration with USABC, China, and other DOE projects and national laboratories to be excellent. It would be interesting to have seen more about the process for coordinating with confidential programs after data are generated. As an example, this reviewered asked whether only data are transmitted back to the parties or whether conclusions, recommendations, and follow-on testing are also part of the process. It would be interesting to evaluate how a more robust, fee-for-service approach could be cultivated. The reviewer believed this exists, but it is unclear how frequently this is utilized. Such a service could enable smaller companies and venture-backed startups working on emerging technologies to also participate and utilize laboratory resources outside the direct pathway of receiving a major DOE project.

Reviewer 3:

The reviewer acknowledged that the work with China is more than might be expected given their core mission.

Reviewer 4:

The reviewer commented that the meeting with vehicle developers, battery developers, charger developers, and others was held successfully.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project is doing what is needed; there is no real change expected or desired in the work they do.

Reviewer 2:
The reviewer found the future research plan to be compelling. The only thing that could be interesting is to better document the future research options that were not pursued and why this was the case.

Reviewer 3:
The reviewer said that the variables for fast charging are addressed. However, the resultant energy density and specific energy also should be reported.

Reviewer 4:
The reviewer stated that the future plan must be more organized in regard to the project's final objectives.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said yes. All this work is very relevant to the DOE overall goal to reduce petroleum usage and reduce all environmental issues.

Reviewer 2:
The reviewer noted that the work is highly relevant. Without independent verification, progress to the marketplace would be much slower.

Reviewer 3:
The reviewer observed that the fast charging aspects of this program are intended to overcome not just technical barriers, but psychological barriers as well (e.g., "refueling" time and habits with respect to conventional systems).

Reviewer 4:
The reviewer responded affirmatively and suggested that faster recharging will make deeper penetration in vehicle market acceptance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the resources appear to be sufficient.

Reviewer 2:
The reviewer noted that all resources are very sufficient except for industrial support for the program.

Reviewer 3:
The reviewer opined that the researchers seem to be able to do the job with the funds, but there would be value in more capital and accompanying annual funds to buy more cyclers and man them so more cells could be handled.

Reviewer 4:
The reviewer noted that the design of cells and battery pack development will be done at USABC.

Presentation Number: es202
Presentation Title: INL Electrochemical Performance Testing
Principal Investigator: Matt Shirk (Idaho National Laboratory)

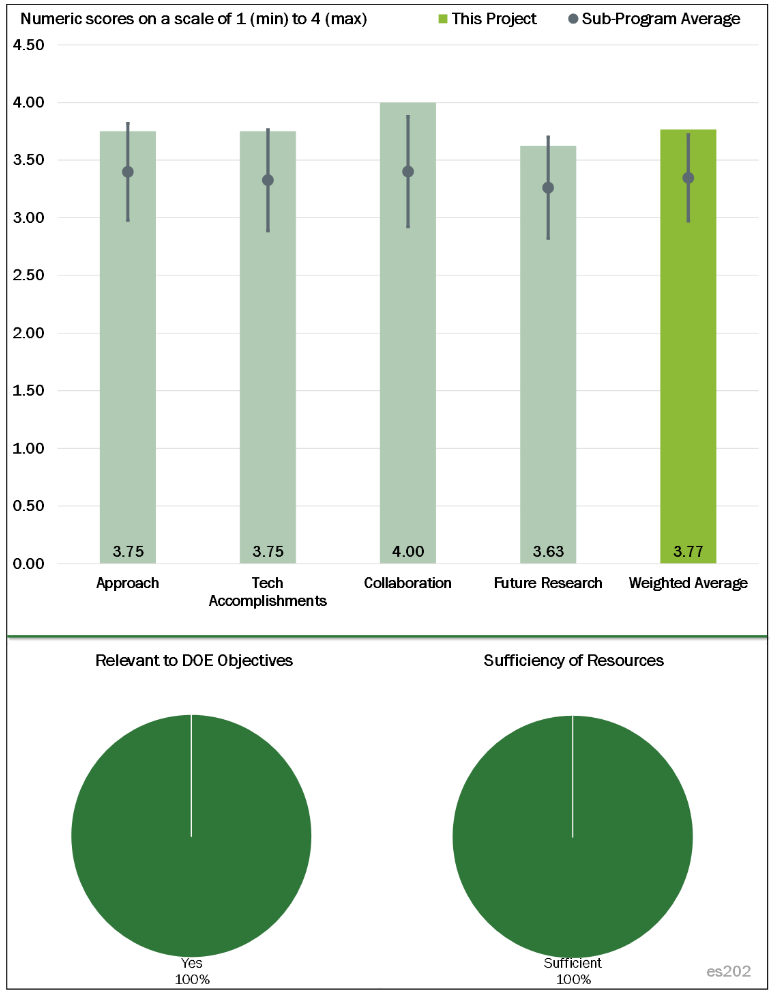

Figure 3-17 – Presentation Number: es202 Presentation Title: INL Electrochemical Performance Testing Principal Investigator: Matt Shirk (Idaho National Laboratory)

Presenter

Matt Shirk, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer found the performance testing at many different batteries levels to be very significant for the future of batteries.

All these technical approaches are very feasible and integrated into other projects easily.

Reviewer 2:

The reviewer called out the work as not only a first class independent evaluation of any type of cell but also the development of new test processes and "maintenance" of existing ones that helps the whole industry.

Reviewer 3:

According to the reviewer, Idaho National Laboratory (INL) supports testing, evaluation, and validation successfully.

Reviewer 4:

The reviewer commented that INL continues to be a high-quality, state-of-the-art test facility that has the technical capabilities to fully evaluate all aspects of cells, modules, and packs with the acumen and experience to lead test manual developments for the DOE. It is somewhat unclear as to how benchmarking with ANL ties into the overall program objectives, the value this brings to the program itself, and the percentage of the program that is diverted to such activities. The program seemed already well integrated into many DOE and industry-oriented efforts.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that impressive progress has been made through a project year and more valuable technical work will be accomplished in the near future.

Reviewer 2:
The reviewer said that there was good throughput of cells and the testing was of excellent quality. Also, the development of more test manuals is basically providing a full spectrum of cell testing methods.

Reviewer 3:
The reviewer observed that INL appears to be maintaining a proactive stance to emerging energy storage technologies and systems with the release of the 48V test manual, testing of relevant chemistries, and supporting fast-charging initiatives.

Reviewer 4:
The reviewer stated that INL has tested all USABC and other deliverables for validation of the progress of each program.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pronounced the collaboration through industrial partners, universities, and the other national laboratories to be excellent.

Reviewer 2:
The reviewer commented that INL worked with many industry and academic groups in setting test manuals and with many suppliers in testing.

Reviewer 3:
The reviewer mentioned that INL collaborates with USABC members, developers, and other interested suppliers.

Reviewer 4:
The reviewer noted that coordination and collaborations are very good.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that future research is appropriate to mission.

Reviewer 2:
The reviewer commented that future research directions are positive and had no recommendations for changes.

Reviewer 3:
The reviewer noted that INL continues to support testing and validation in the future.

Reviewer 4:
The reviewer wanted to have more detail about future plans with regard to the project final objectives.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer responded yes and pointed out that all this work is very relevant to the overall DOE goal to reduce petroleum usage and reduce all environmental issues.

Reviewer 2:
The reviewer noted that the ability to give independent evaluation of cells gives industry the confidence to take them into product plans.

Reviewer 3:
The reviewer remarked that all efforts are highly oriented toward supporting the DOE mission of petroleum displacement.

Reviewer 4:
The reviewer stated that the continuation of verification of new developments supports DOE's objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer asserted that the laboratory capabilities and resources are sufficient.

Reviewer 2:
The reviewer noted that all resources are very sufficient except the industrial support for the program.

Reviewer 3:
The reviewer commented that there are enough resources to run existing facilities, but if the facility could be expanded, they could lower the backlog or keep cells on test longer.

Reviewer 4:
The reviewer stated that current resources appear to be sufficient; however, increasing a portion of the budget to support WFO agreements with industry would be advisable.

Presentation Number: es203
Presentation Title: Battery Safety Testing
Principal Investigator: Leigh Anna Steele (Sandia National Laboratories)

Presenter
Leigh Anna Steele, Sandia National Laboratories

Reviewer Sample Size
A total of four reviewers evaluated this project.

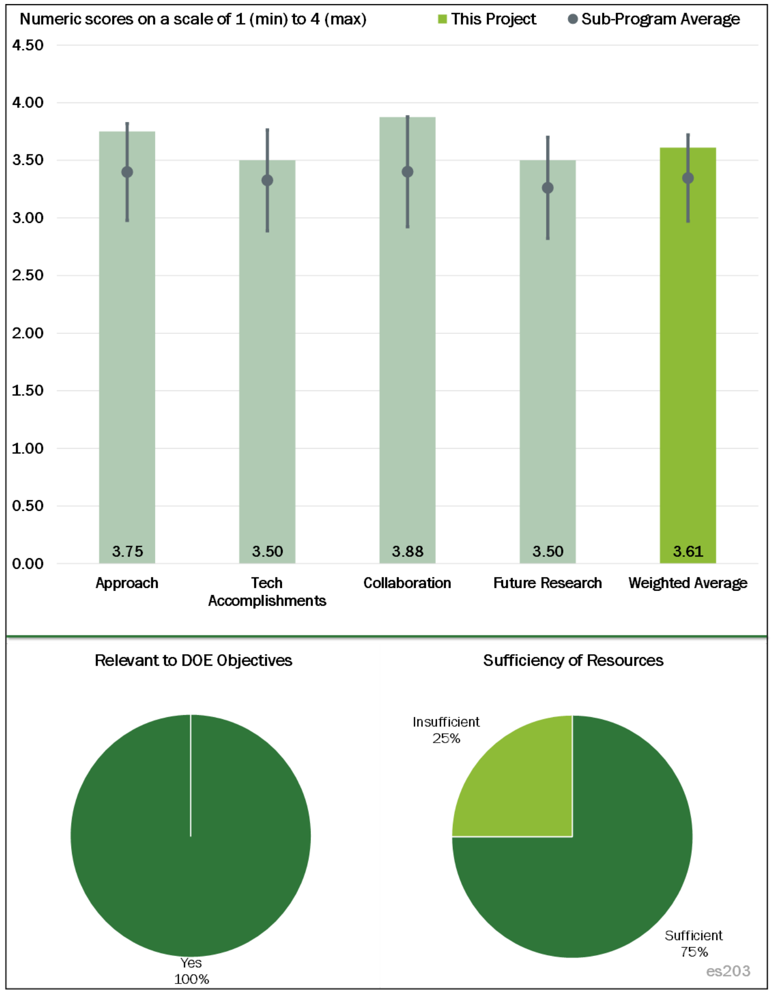

Figure 3-18 – Presentation Number: es203 Presentation Title: Battery Safety Testing Principal Investigator: Leigh Anna Steele (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that SNL and this program team continue to provide the gold standard in safety testing. The approaches to safety testing are sound, and the continued focus on providing and updating test manuals and best practices is highly relevant and inherently integrated with other testing efforts.

Reviewer 2:
In the reviewer's view, the research is a key facet of all DOE battery work and the gold standard worldwide.

Reviewer 3:
The reviewer said that SNL works with USABC developers to meet abuse testing protocol and targets.

Reviewer 4:
The reviewer stated that the goal of the project is well defined but not well designed due to unpredictable circumstances. The approach to understanding thermal behavior of cell or module and pack is of great importance. However, the designed experiment really depends on how to procure those cells from industry. Most of the results gained from tests are very limited by cell or pack design, including cell chemistry.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that SNL has tested all USABC deliverable cells and modules to validate abuse performance.

Reviewer 2:
The reviewer commented that the new test manual will be a boon to all and did not come easily. Propagation is an important topic and while implementation dependent, the research team has shown some mitigation techniques. The new large site is a great addition to the existing capabilities.

Reviewer 3:
The reviewer asserted that there were two critical technical accomplishments, the first being internal short circuit stimulation using laser initiation and the second being thermal failure propagation studies with Al and Cu spacers. Impressive results have been made through this year. However, the reviewer still needed to understand why the PI chose the metal foil spacers rather than other materials that can be used as a heat sink more widely.

Reviewer 4:
The technical accomplishments are incredibly positive and appear to have kept pace with the increasing demands associated with increasing energy density, faster charge rates, and the screening of new materials. The one aspect of "safety" that could be improved would be an attempt to quantify the "value" and/or cost in terms of $/kWh, based upon some heuristic with guidance from industry. It seems difficult to identify a quantitative value proposition for safety-related sub-components, yet these will be fundamental to life safety as EVs become more prevalent in the United States.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there was excellent collaboration.

Reviewer 2:
The reviewer remarked that just the work with USABC alone shows great collaboration on important work.

Reviewer 3:
The reviewer stated that high quality collaborations are already in place and the work is well coordinated with USABC efforts.

Reviewer 4:
The reviewer noted that SNL collaborates with USABC and cell and module developers successfully.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found the future research to be appropriate given their funding and mission.

Reviewer 2:
The reviewer commented that quality future research has been proposed, particularly efforts to feed data back into models to refine these for crashworthiness, etc.

Reviewer 3:
The reviewer stated that SNL plans to continue to support USABC, test deliverable cells, and provide support for future activities.

Reviewer 4:
The reviewer mentioned that the future plan must be more organized with regard to the final project objectives. It is not very clear how to reach the project goal with all these spot-to-spot activities.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said yes, and noted that the thermal characterization with two unique approaches is very impressive and can be easily applicable to the DOE final objectives.

Reviewer 2:
The reviewer stated that safety is always relevant, especially so in batteries.

Reviewer 3:
The reviewer observed that safety testing is paramount to ensuring that the widespread adoption of EVs will not be accompanied by public relations (PR) nightmares and major shifts in public opinion away from a desire to displace petroleum.

Reviewer 4:
The reviewer stated that safety of EV batteries is important to make EVs acceptable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that it looks as if all resources are sufficient to do this project. The reviewer stated that SNL is very oriented to do this kind of thermal characterization at many different levels of batteries and provides critical information to the public.

Reviewer 2:
The reviewer said that the laboratory capabilities and resources are sufficient.

Reviewer 3:
The reviewer commented that the team could possibly use another person on staff to help with the backlog, but sufficient is a good description.

Reviewer 4:
The reviewer suggested that, in order to be prepared for the eventual inflection point of EV adoption (perhaps in the next 2-3 years), additional resources should be devoted toward safety testing (particularly testing of imported batteries that will likely become commonplace due to a lack of domestic manufacturing capacity).

Presentation Number: es204
Presentation Title: Battery Thermal Characterization
Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

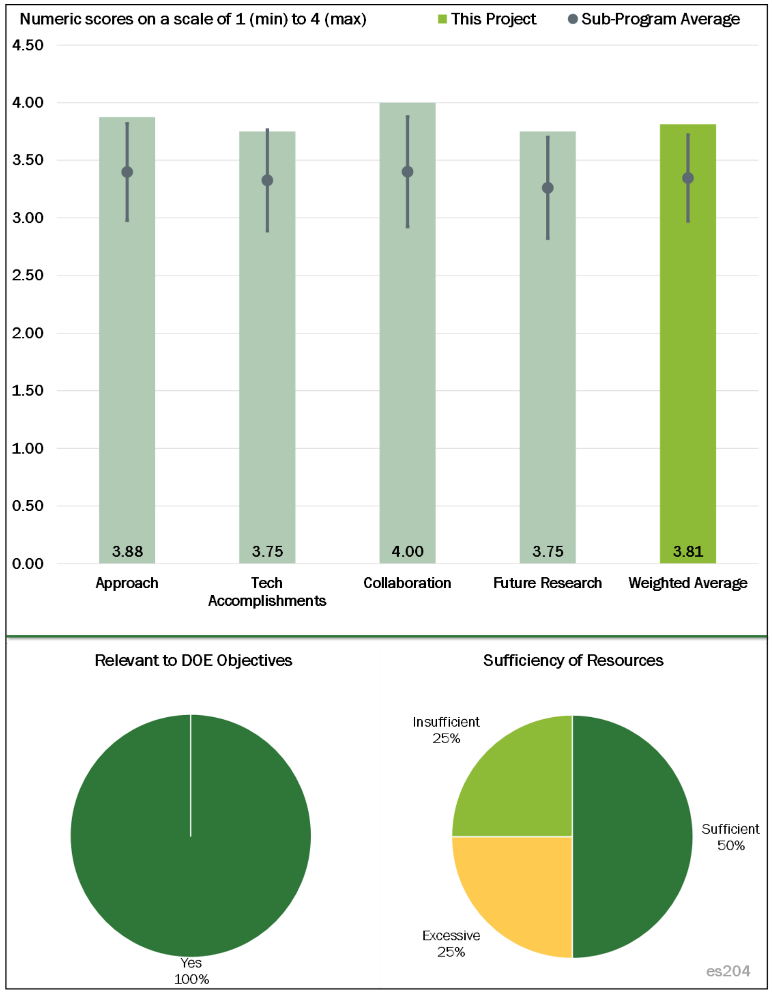

Figure 3-19 – Presentation Number: es204 Presentation Title: Battery Thermal Characterization Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

Presenter

Matthew Keyser, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that all these technical approaches are greatly welcome to the battery industry to understand battery failure mechanisms thermally over the life of the battery. The tools, which include calorimeters, thermal imaging, and others, are impressive.

Reviewer 2:

The reviewer asserted that the project has world class equipment and staff used to good advantage for science and industry.

Reviewer 3:

The reviewer commented that there is a high quality approach to this program. The thermal aspects of batteries are fundamental, particularly for the higher energy and faster charging cells that are on the DOE roadmap. The reviewer stated there was very interesting emerging work on the thermal implications of fast charging.

Reviewer 4:

The reviewer observed that thermal testing of cells, modules, and packs and testing results provide needed feedback to battery suppliers.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that progress and technical contributions made through the project year are excellent and expected to see more valuable technical aspects accomplished in the near future.

Reviewer 2:
The reviewer commented that the project was able to show how entropy impacts batteries and supercapacitors and could demonstrate the impact of specific additives that help users tune products at the pack and cell level. It is a nice mix of application and science.

Reviewer 3:
The reviewer stated that the accomplishments include all USABC battery thermal characterizations and supporting information.

Reviewer 4:
The focus on incorporating modeling with experimental data has been a nice evolution of this program. It would be interesting to see more solid electrolyte cell testing and studies. It would also be useful for DOE to consider engaging NREL with ongoing projects at an earlier stage (i.e., understanding the thermal performance in smaller cells and during the cell design process).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that there was excellent collaboration through industrial partners, universities, and other national laboratories.

Reviewer 2:
The reviewer stated that there were many collaborators and benefits going both ways.

Reviewer 3:
The reviewer opined that there was outstanding collaboration and coordination, particularly for such a relatively small budget.

Reviewer 4:
The reviewer enthused that the collaboration with USABC members and battery developers is excellent.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the correlation between experimental work and the battery usage model with the calorimeter is great. The reviewer looked forward to seeing more applicable result in the future.

Reviewer 2:
The reviewer found the funding level to be appropriate for the area they are assigned to cover.

Reviewer 3:
The reviewer said that the thermal aspects of fast charging are very timely and relevant.

Reviewer 4:
The reviewer stated that the continuation of USABC and partners is well planned.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer responded yes, and pointed out that all this work is very relevant to the overall DOE goal to reduce petroleum usage and reduce all environmental issues.

Reviewer 2:
The reviewer observed that heat transfer and heat generation are key to function, longevity, and safety for batteries and so this is key to electrifying vehicles for petroleum reduction.

Reviewer 3:
The reviewer asserted that a comprehensive understanding of the thermal implications of EV batteries is required for widespread adoption.

Reviewer 4:
The reviewer said that the NREL testing and characterization battery provides the road map to long lasting batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that all resources are very sufficient.

Reviewer 2:
The reviewer remarked that they get the job done with what they are given, probably sufficient funding.

Reviewer 3:
The reviewer concluded that the testing facility and resources are sufficient.

Reviewer 4:
The reviewer suggested that it would be useful for DOE to consider engaging NREL with ongoing projects at an earlier stage (i.e., understanding the thermal performance in smaller cells and during the cell design process).

Presentation Number: es207
Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes
Principal Investigator: David Wood (Oak Ridge National Laboratory)

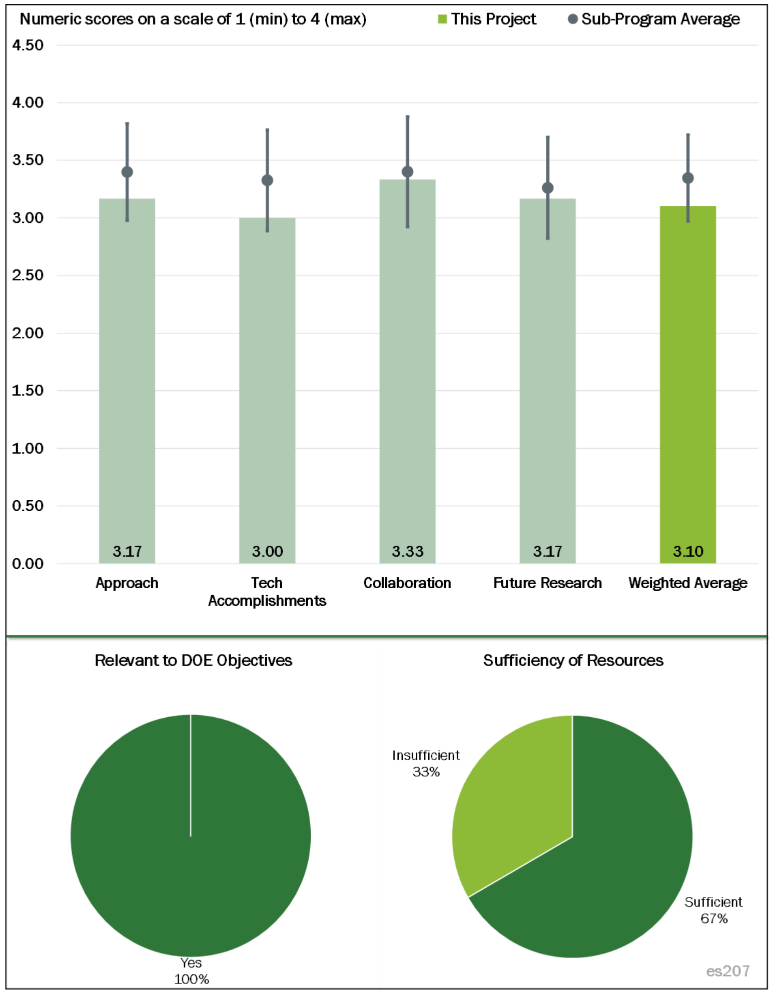

Figure 3-20 - Presentation Number: es207 Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes Principal Investigator: David Wood (Oak Ridge National Laboratory)

Presenter

David Wood, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the approach is feasible, and if it is successful, it could significantly improve manufacturing efficiency.

Reviewer 2:

The reviewer asserted that there seem to be many technical barriers, including, in no particular order: excluding oxygen from the curing process, getting proper size particles of the resin, and refining an appropriate method of coating the proposed thick coatings without a solvent.

There is also the barrier of convincing a battery manufacturer to adopt a technology that would require major modifications in the conventional manufacturing processes. All of these issues are mentioned in the presentation, but the route to solving them is sometimes vague.

Reviewer 3:

The reviewer stated that the approach is effective in removing or eliminating any solvent (NMP and water) from the process of electrode fabrication. This could lead to a substantial reduction in EV cost.

The reviewer pointed out that it would have been nice to include a comparison to the similar DOE project, ES132 (“Utilization of UV or EB Curing Technology to Significantly Reduce Costs and VOCs”), which finished in 2014 with ORNL as a partner, because the reviewer wanted to know whether this work builds on that previous effort. [DOE Program Clarification: Although ES132 and ES207 share similarities, these projects are not directly related.]

Reviewer 4:
The reviewer stated that the project aims to develop alternative electrode processing procedures (solvent-less electron beam curing) to significantly decrease EV battery cost and increase electrode thickness (and therefore energy density). Milestones and go/no-go decisions are sparse. The approach seems to be complicated and dependent on success of many independent subprojects.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer referenced prior comments, and stated that the project does seem to have made progress in many areas.

Long-term cell performance data and detailed analysis of the proposed cost savings still need to be done.

The importance of the goal of reduced cost is well recognized, but the specific data, calculations, and modeling to support the presentation's assertions as to the savings that may be realized with EB technology are limited.

Reviewer 2:
The reviewer observed that good progress was demonstrated and a lot of tasks were accomplished; the percent of completed tasks corresponded to the time line of the project. But, some important tasks were not finished or not mentioned in the 2017 report. For example, the 2016 report demonstrated (Slide 27) that initial irreversible capacities for EB electrodes are more than two-fold larger compared to the baseline. The reviewer wanted to know how this issue was solved and whether this is the result of EB influenced by active material selection.

Reviewer 3:
The reviewer noted that significant progress has been made on improving coating properties. However, progress toward their main objective of significant process energy savings was unclear to the reviewer. Additionally, electrochemical performance seems to suffer with low capacity retention observed for samples.

Reviewer 4:
The reviewer mentioned that progress has been made in addressing previous year challenges, such as poor adhesion of coated electrodes. However, it is not clear if the impact on goals (cost) of the proposed solutions has been evaluated.

Reviewer 5:
The reviewer asserted that the team made some progress; however, it has not shown promising results yet. It looked to the reviewer as if the rate capability is not really better compared to the baseline shown on Slide 11.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that collaborative activities and involvement of each partner are clearly described.

Reviewer 2:
The reviewer observed that the program appears to be making good use of collaborations on various coating technologies and raw materials suppliers. Validation of this novel approach by a Top 3 cell producer should be performed to ensure a pathway to success and implementation.

Reviewer 3:
The reviewer commented that there seems to be good collaboration with industrial partners, especially those with expertise in coating and EB curing. The collaboration with materials' suppliers and battery manufacturers

is mentioned, but in less detail. The battery manufacturing partners are legitimate members of the battery community, but neither of them has a significant market position in batteries for consumer vehicles. XALT seems to be focusing on non-vehicular applications, such as marine uses, and Navitas is focused on military vehicles.

There is no mention of significant collaboration with academia or other national laboratories.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the proposed future work does a good job of focusing on the issues identified in the presentation. It will be a challenge to combine coating and curing on a high speed line in a way that produces uniform, high-performing electrodes.

Reviewer 2:
The reviewer commented that future work should show improvements in current high-speed cured coatings to achieve better performance of electrodes and to transfer technology to mass production.

Reviewer 3:
The reviewer observed that mechanical integrity could be one issue because the binder could have weaker interfacial bonding with active materials from the electrostatic spray process.

Reviewer 4:
The reviewer commented that proposed future research lacks an economic analysis of their main objective—to reduce process energy via the EB curing process. Proposed future work seems to lack a clear process focus or decision points for process downselection.

Reviewer 5:
The reviewer opined that the project does not seem completely decided on one or two high-speed manufacturing methods to be explored. A significant amount of time that can be used for developing a method will be spent on looking for other potential methods.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said, yes, success should lead to reduction in EV costs and wider adoption in the market."

Reviewer 2:
The reviewer remarked that this project clearly supports DOE's goals. For electric drive vehicles to be adopted voluntarily (with minimum regulatory requirements) in the U.S. market, the cost of the batteries needs to be reduced and their specific energy and energy density need to be increased. High speed, solventless coating of thick electrodes (that perform well) will help meet these goals.

Reviewer 3:
The reviewer stated that decreasing process costs can lead to lower cell costs and hence accelerated vehicle electrification and therefore petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the project is accomplishing significant amounts of work considering the project funding ($350,000 for FY 2017). This reviewer observed a good job, and asserted that this is an efficient use of funds for amount of work performed.

Reviewer 2:

The reviewer noted that plans for future work, including evaluating other high-speed manufacturing methods, seem very ambitious for the amount of resources allocated to the project.

Reviewer 3:

The reviewer pointed out that this project is scheduled to receive less than half the funding allocated for the related project (ES164) on thick, low-cost electrodes produced with aqueous processing. ORNL is the lead on both projects so one assumes that the costs of labor and facilities are similar for the two projects. The presentations seem to indicate that the two projects are using some of the same facilities. The challenges facing the two projects are of similar magnitude, and this reviewer added that, if anything, this EB project is more challenging.

The reviewer said that if the Aqueous Processing project is appropriately funded, then this project is probably underfunded. Of course, if this project is properly funded, then the Aqueous Processing project may be overfunded.

Presentation Number: es220
Presentation Title: Addressing Heterogeneity in Electrode Fabrication Processes
Principal Investigator: Dean Wheeler (Brigham Young University)

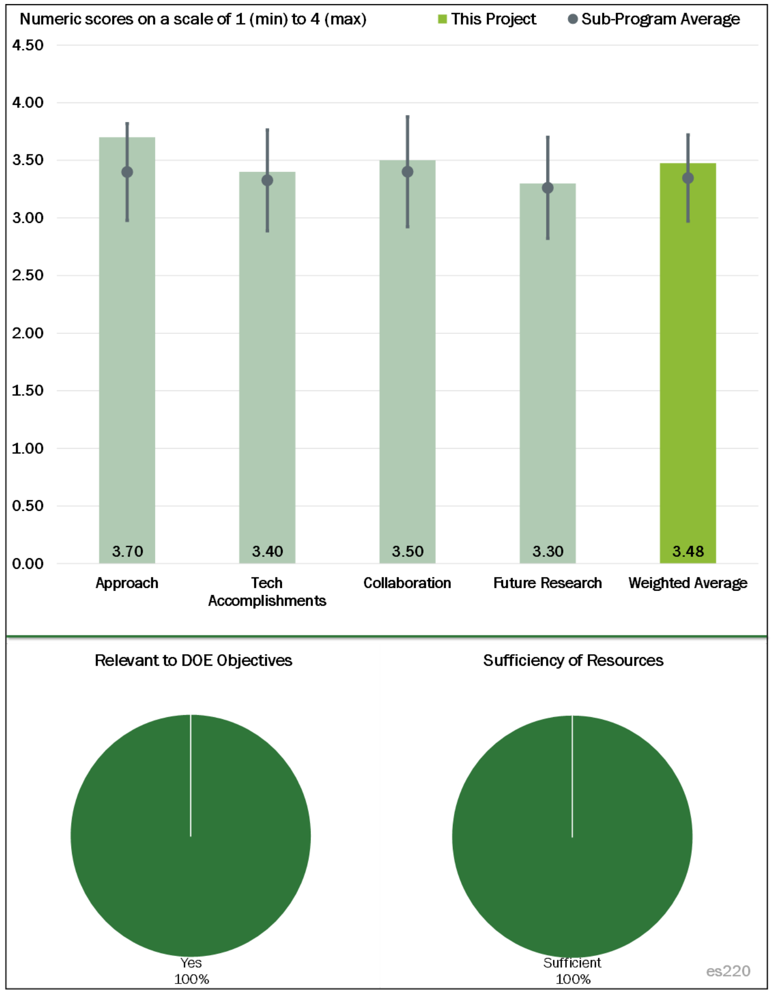

Figure 3-21 – Presentation Number: es220 Presentation Title: Addressing Heterogeneity in Electrode Fabrication Processes Principal Investigator: Dean Wheeler (Brigham Young University)

Presenter
Dean Wheeler, Brigham Young University

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked that Wheeler has done an outstanding job coming up with a new technique that may ultimately address industrial needs for improving electrode fabrication. Development of a flexible probe will make the technique more feasible. Coming up with a model that goes from fundamentals to electrode fabrication is very ambitious.

Reviewer 2:
The project is bringing deep understanding to electrode processing and developing tools that industry can use. The reviewer found the presentation very effective and the ideas being pursued, including the model for manufacturing, very compelling. The reviewer thought that this project was very good and has the right balance between the need to help industry versus not repeating what industry does best.

Reviewer 3:
The reviewer stated that the PI has an excellent approach to this challenging problem.

Reviewer 4:
The reviewer commented that measuring the conductivity of anode and cathode electrodes is a good measure of heterogeneity and is also critical for battery performance so this is a good approach. The attempt to correlate structural features with conductivity seems reasonable but is not yet yielding good results.

Reviewer 5:
The reviewer pointed out that the PI designed and fabricated a micro-sensor using microfabrication technology. The conductivity sensor was tested to measure the local surface and bulk conductivities of a coated electrode web. Modeling was also used to estimate the microstructure. In-line conductivity measurement could

be used as a quality control tool in the production line. The micro-probe is a great approach for the task. The design is simple to fabricate, easy to implement, and feasible for in-line applications.

The argument is the representation of the measurement of the limited area for the whole electrode web, which is related not only to the homogeneity of the electrode coating but also the morphology of the electrode surface. The PI should utilize the modeling tool to optimize the design, especially the size of the probe.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the PI's outstanding job improving his technology. He has advanced his probe by making it flexible, which could allow its use in industry. He has provided a highly plausible explanation for the variability in cathode conductivity. And, his highly ambitious model for electrode fabrication has made good progress.

Reviewer 2:
The reviewer saw steady progress on this problem. The PI is focusing on techniques that can be adapted in most laboratories. The modeling effort has refocused on a new method, but it was not clear to the reviewer that it will be successful. It is not clear what properties will be obtained from the acoustic technique.

Reviewer 3:
The reviewer found it interesting that ionic conductivity increases with cycling while electronic conductivity decreases.

Reviewer 4:
The reviewer noted that the project progressed as planned. The flex probe was developed and made. The measurement by the flex probe was in good agreement with that of the non-flex counterpart. A mathematical model for particle mixing was established and tested.

The area that the PI could improve is that the fix pressure imposed on the electrode web may not be the best solution. The PI should test the change of resistance with the change of pressure exerted on the probe and the electrode. The reviewer suspects the resistance-force curve would change between electrodes because the contour of the electrode surface and hardness of various battery material would have significant impacts.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer mentioned that the PI has adequate collaborators ranging from the battery industry (e.g., A123 and LG) to academia and national laboratories, which cover the ground of both scientific collaboration and application.

Reviewer 2:
The reviewer saw good collaboration and exchange of materials and expertise with some leading battery developers and material suppliers

Reviewer 3:
The reviewer observed that the PI has extensive collaborations across industries and laboratories.

Reviewer 4:
The reviewer stated that there are a good number of collaborators, but it is not clear which collaborators are doing what and how involved they are in the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the PI has an excellent plan.

Reviewer 2:
The reviewer found the work to be relevant and well thought out. In the near future, it will be critical for the PI to begin more intensive collaborations with industry. It is not at all clear that the processing conditions leading to greater or lesser heterogeneity that are being discovered with laboratory made electrodes have any relevance to real commercial products. The reviewer hoped that the PI can begin to provide processing feedback and guidance soon.

Reviewer 3:
The reviewer saw a clear path forward for this work. Specific problems that may be encountered and what work-arounds might be available were not discussed much.

Reviewer 4:
The reviewer observed that the proposed future work covers most of the critical areas, especially the correlation between the modeling results and experimental data.

The PI is encouraged to do more work on the representation of the results from a micro-size probe to a large electrode.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer agreed that this project is relevant because electrode homogeneities could be significant contributors to cell fade now and will likely become even more important as DOE and the car manufacturers begin to introduce fast charge capabilities. Another factor impacting electrode non-uniformities is the push to thicker electrodes, which could exacerbate these issues.

Reviewer 2:
The reviewer observed that there is a plausible and well-defined pathway to take this work—either measurements or models—to industry. This would allow a method for improving the homogeneity of electrodes, which should lead to longer lived cells.

Reviewer 3:
The reviewer said yes. The project could lead to better battery production quality control, which is one of the critical area of reaching low-cost and reliable production.

Reviewer 4:
The reviewer found the PI's work to be relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the PI has done a good job of living on the cheap.

Reviewer 2:
The reviewer noted that PI can access adequate resources to conduct the proposed tasks.

Reviewer 3:
The reviewer stated that the resources are appropriate for the work done and a good value for the investment here.

Reviewer 4:
The reviewer said that the resources are sufficient.

Presentation Number: es225
Presentation Title: Design and Synthesis of Advanced High-Energy Cathode Materials
Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

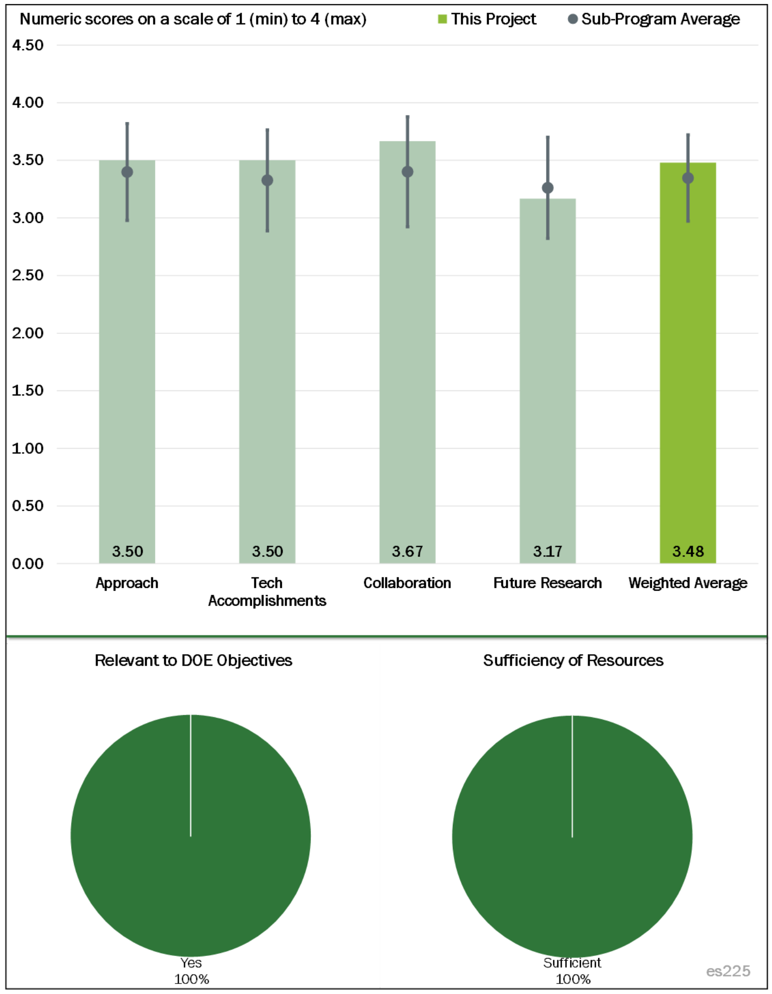

Figure 3-22 - Presentation Number: es225 Presentation Title: Design and Synthesis of Advanced High-Energy Cathode Materials Principal Investigator: Guoying Chen (Lawrence Berkeley National Laboratory)

Presenter

Guoying Chen, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer pointed out that the PI has an excellent approach. While the approach is rather simple, the PI has found an important niche to work in and be very productive.

Reviewer 2:

The reviewer noted that high energy cathode materials are still needed for the next generation of LIB development. This project tackles some of these materials with Li-excess transition metal oxide structures to understand their chemical and crystal structure stability as a function of composition and temperature in order to understand the origins of performance limitation. Through collaboration, a variety of characterization techniques was used to help elucidate the mechanisms related to degradation and develop rational design of such materials for improved performance.

The project seems to take a logical approach to address challenges related to interfacial stability issues. The analysis and synthesis of the experimental data into a coherent understanding of the issues are still premature to give any useful guidance for further work. The PI should develop a more robust hypothesis to help analyze the data and develop a rationale to elucidate what mechanism dominates the limitation on performance.

Reviewer 3:

The reviewer stated that this was interesting research to correlate synthesis with Li-excess cathode morphology (shape, size, and exposed surfaces) and performance. The goal is to achieve rationalized design of material.

The reviewer asked that the PI please consider more direct comparison with modeling.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the PI developed well-formed crystals of materials that enable studies otherwise impossible.

Reviewer 2:
The reviewer found the selection of a single valence transition metal compound doped with niobium to be a clever approach. However, the changes in the phase transformation are much more complex than originally thought. With a significant amount of work in the research community on NMC cathodes, a coherent understanding of the cathode structure stability remain lacking. Using a systematic approach is appealing. However, a comprehensive understanding remains challenging. It is not clear if this project would be able to accomplish this objective.

This reviewer would like to encourage the investigator to develop a more tangible hypothesis to guide the work so that the systematic approach can be realized. The reviewer expressed the sentiment of looking forward to more accomplishments as the research progresses.

Reviewer 3:
The reviewer acknowledged that extensive work was performed by the research team. However, the summary is rather vague. The reviewer asked if this comprehensive study can provide some conclusive remarks on which surface, size, or shape is preferred.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the PI has extensive collaborations across the laboratory system. The PI is very effective at leveraging her work.

Reviewer 2:
The reviewer found the collaboration with the characterization groups to be excellent and encouraged more collaboration with theorists to develop better hypotheses for experiments. A more focused systematic approach is the right track for better outcomes.

Reviewer 3:
The reviewer noted that this project involved extensive collaborations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that an aggressive plan is being put forward.

Reviewer 2:
The reviewer inquired if one can predict and correlate materials synthesis and processing methods with the final structures and properties.

Reviewer 3:
Although the proposed future work seems logical and necessary, it did not appear to the reviewer that there was clear guidance to effectively tackle the challenges. This deficiency also was reflected in the data analysis

because no clear guidance was developed to tackle the issues that caused the structure instability in the phase transformation.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer acknowledged that this research is very much related to petroleum displacement as it will enable higher energy density batteries.

Reviewer 2:

With model crystals there is always a question as to relevance, but the reviewer thought that the PI has worked to effectively address this issue.

Reviewer 3:

The reviewer asserted that finding a stable high-energy cathode material is critical for the development of the next generation of LIBs. This project directly feeds to the advancement of this objective. However, without a clear guidance for improving the search of a reliable cathode and mechanism to stabilize the performance, the impact of this work is undermined.

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Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are sufficient.

Reviewer 2:

It was not clear to the reviewer what additional resources the investigator would be seeking to gain better knowledge and improve the impact of this project. The existing support should be sufficient for carrying out the current and future work as explained.

Presentation Number: es226
Presentation Title: Microscopy Investigation on the Fading Mechanism of Electrode Materials
Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Presenter

Chongmin Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

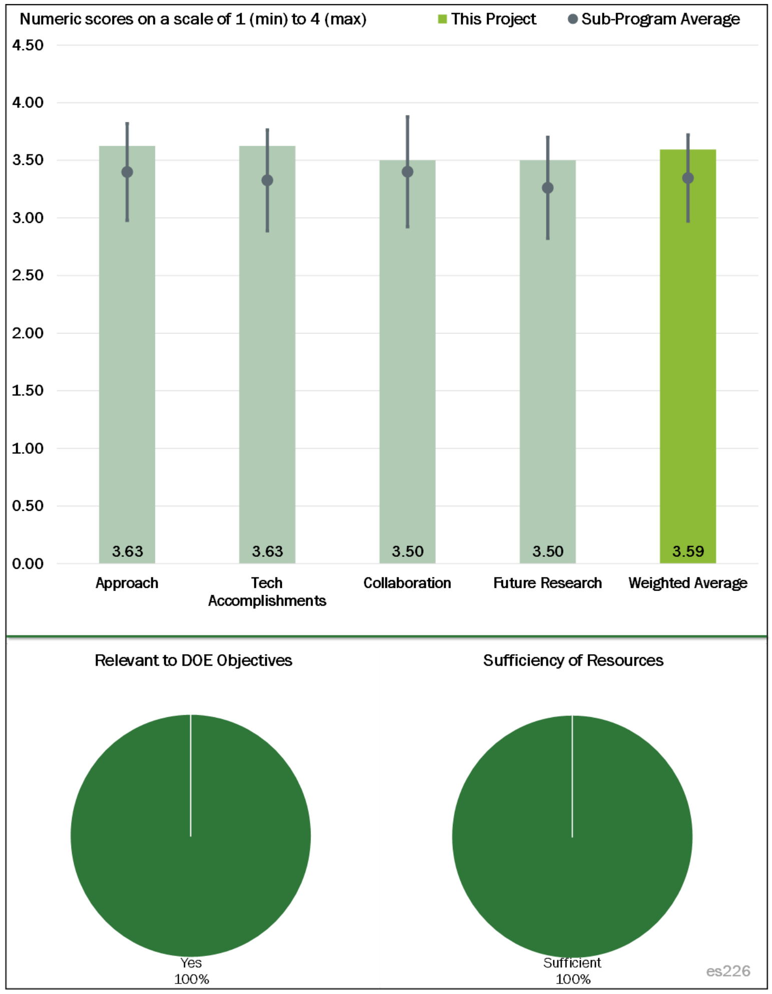

Figure 3-23 - Presentation Number: es226 Presentation Title: Microscopy Investigation on the Fading Mechanism of Electrode Materials Principal Investigator: Chongmin Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that *in situ* and in-operando HRTEM is a unique and effective tool to study atomic scale structure and morphology of electrodes. It is very well suited to address the barriers.

Reviewer 2:

The reviewer stated that there was outstanding development of technologies that provide critical data for understanding battery materials.

Reviewer 3:

According to the reviewer, the project covers a variety of battery problems, from high-voltage cathodes in LIBs to Li-air systems. Characterizing surface and interfacial phenomena using highly sophisticated *ex situ* and *in situ* tools is a good approach. Establishing collaborations is listed as part of the approach; however, the collaborators are only providing materials and support for synthesis.

The project covers a variety of battery problems, from high-voltage cathodes in LIBs to Li-air systems. Characterizing surface and interfacial phenomena using highly sophisticated *ex situ* and *in situ* tools is a good approach. Establishing collaborations is listed as part of the approach, however the collaborators are only providing materials and support for synthesis.

Reviewer 4:

The reviewer commented that the general approach is excellent, but it would be helpful to have seen more detailed steps. For example, for the progression of materials, the reviewer asked what additional studies might be made, and so on.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer loved the data showing liquid penetrating secondary particles. Intragranular cracking as a function of voltage is also wonderful and would greatly benefit from collaboration with theory. There are many other excellent accomplishments.

Reviewer 2:
The reviewer noted that the PNNL group led by Dr. Wang has done some very interesting work on charging induced intragranular cracking and the SEI of layered cathode materials using advanced electron microscopy (EM) techniques. These works are sharply focused on challenges stated in the overview, the fading mechanism of electrodes.

Reviewer 3:
The reviewer posits that the discovery of intergranular cracking as a function of the charging potential range is very important.

Reviewer 4:
The reviewer opined that this project partly overlaps with ES085 and possibly others. The reviewer added that it would be good to have a better interaction among these groups. The electrolyte also becomes depleted at the anode, and this reviewer suggested that it would be good to connect these degradation phenomena. The reviewer further recommended that the longer cycling effect of the Al_2O_3 coating should be addressed (e.g., coating lithiation and reactivity, and electronic properties).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the PI has a long list of collaborators including national laboratories, universities, and industrial companies. The reviewer would like to encourage the group to develop collaboration with institutes where characterization techniques are complementary to EM, such as synchrotron X-rays.

Reviewer 2:
The reviewer pronounced the collaborations to be excellent.

Reviewer 3:
The reviewer enthused about terrific collaboration.

Reviewer 4:
The reviewer referenced prior comments, and said that a more integrated collaboration beyond just exchange of materials and support for synthesis would be helpful for the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The list of future work involves understanding critical battery properties. The reviewer was hugely impressed and looking forward to this future work.

Reviewer 2:
The reviewer commented that the proposed future work is well planned to tackle the remaining challenges and barriers within the scope of EM techniques.

Reviewer 3:
The reviewer found the listed objectives for FY 2018 to seem somehow disconnected. The first listed item for FY 2018 is unclear.

Reviewer 4:
In addition to the proposed future work, the reviewer said it would be important to see the effects of preconditioning of the electrode by restructuring the surface as shown by Kostecki in this year's review to see if there are beneficial effects on particle cracking.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project is very well designed and conducted to support DOE objectives, with more fundamental approaches to tackle the capacity fading problems of electrodes for LIBs.

Reviewer 2:
The reviewer noted that the mechanism of cathode impedance growth is of great importance to DOE objectives.

Reviewer 3:
The reviewer responded, “Yes.” Characterization of interfacial phenomena is a good way of understanding the behavior of battery materials and developing strategies to improve them, therefore supporting the objective of petroleum displacement.

Reviewer 4:
The reviewer said that the PI’s samples come from a wide variety of sources, from universities to General Motors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that the resources seem sufficient for the proposed objectives. The goals complement other efforts

Reviewer 2:
The reviewer stated that this is a strong team in the EM field.

Reviewer 3:
The reviewer said that the PI develops state-of-the-art technology.

Presentation Number: es231
Presentation Title: High-Energy Density Lithium Battery
Principal Investigator: Stanley Whittingham (Binghamton University-SUNY)

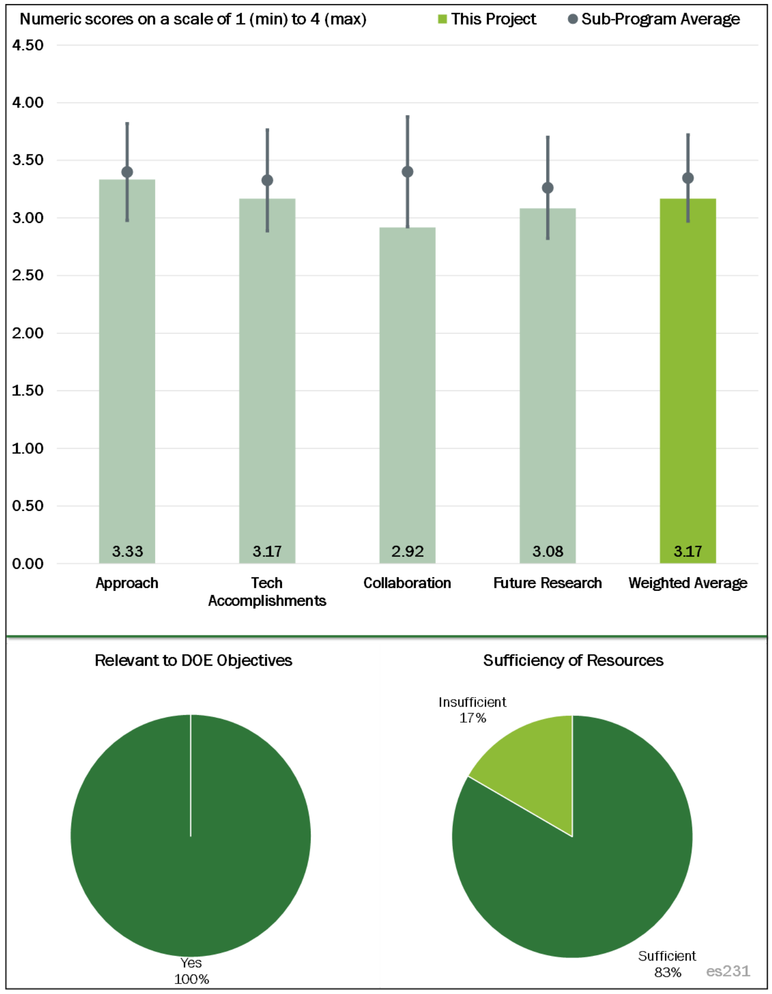

Figure 3-24 - Presentation Number: es231 Presentation Title: High-Energy Density Lithium Battery Principal Investigator: Stanley Whittingham (Binghamton University-SUNY)

Presenter

Stanley Whittingham, Binghamton University-SUNY

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the objective of this task is to identify and develop new, high specific energy and energy density anode and cathode materials for improving the energy densities and costs of LIBs. For improving the energy density of the graphite anode, conversion reaction materials (especially tin-based alloys [Sn_xFe]) are safer and lower cost; they also have lower volume expansion and two-three times volumetric and specific capacities. However, this material has high irreversible capacity and requires pre-lithiation, which is a challenge. Similar materials (Cu-tin alloys, for example) were studied for several years at ANL with little at the end.

Likewise, for improving specific energy of the conventional intercalation (one Li) cathodes, two types of conversion/intercalation cathodes with multiple lithiums (i.e., copper (II) fluoride [CuF_2] with twice the specific energy of LCO and vanadium phosphate [$VOPO_4$] with 1.5 times the capacity of LFP) are being developed. While achieving good reversibility and durability with metal fluorides is a huge challenge, the vanadyl phosphate cathodes have been under development for several years without much success. Even though they have higher capacity, the voltage profile is sloping and the discharge voltages are much lower than today's Li-ion cathodes. Overall, the approach has limited novelty in materials, but the project is well designed to examine feasibility of these materials and integrated with the DOE goals.

Reviewer 2:

The reviewer highly recommended developing the following to further improve energy density of current LIBs: non-carbonaceous anode materials and ways to maximize layer cathode materials; or a new class of cathode materials. This reviewer asserted that project objectives are well aligned with this.

Reviewer 3:

The reviewer said that the approach is good and is attempting to solve one of the major technical barriers for EVs—the low volumetric energy density of today's LIBs. The team is focusing on cutting in half the volume of the anode and identifying a cathode that has a capacity over 200 Ah/kg. Conversion reaction anode materials and cathode materials that react with less than or equal to 1 Li per transition metal under investigation are high risk, but are also high payoff if successful.

Reviewer 4:

The reviewer commented that while the concept is excellent, the candidates are limited. Vanadium oxyphosphate does not look very attractive. The reviewer asked why not continue to pursue CuF_2 by preventing Cu^{2+} dissolution.

Reviewer 5:

The reviewer observed that DOE should be funding more projects like this that are exploring novel active materials. We need to have new materials in the pipeline. The project does an excellent job incorporating background knowledge to efficiently move forward. The project may be too ambitious by working on both a new cathode and anode.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer reported that excellent progress was made this year. The team identified that cuprous transport on charging is a major issue for the long-term cycling ability of the CuF_2 system.

Reviewer 2:

The reviewer found the research to be candid and systematic with a clear path forward.

Reviewer 3:

The reviewer noted that good progress has been made with Sn_xFe anodes and CuF_2 and vanadyl phosphate cathodes in demonstrating their high capacities and reversibility in half-cells and later in laboratory full cells. CuF_2 shows high capacities of 350-450 mAh/g with reasonable rate capability. The capacity is further improved by blending with vanadyl phosphate (with lower voltages). But, the dissolution and migration of Cu to anode is a challenge in liquid or even in polymer electrolytes. The Sn_xFe anodes (Sn_2Fe and Sn_5Fe), synthesized by mechanical and polyol methods, show good capacities of 400-500 mAh/g and decent rate capability, but the improvement in specific energy over a graphite anode may be marginal due to their (Sn_xFe) higher anode potentials. Besides, these materials have high irreversible capacities (200%-300%), which necessitate a pre-lithiation.

Pre-lithiation with stabilized Li-metal powder has been attempted here, as was done by many in the past, but this is not a method viable for implementation in the Li-ion cell production. Performance of these anode and cathodes in full cells is not very encouraging either, even with this pre-lithiation.

Nevertheless, based on the challenges associated with these materials, the progress is deemed good and well directed toward the DOE goals.

Reviewer 4:

The reviewer would like to have seen data for $VOPO_4$ alone, particularly for the voltage profile, and asked whether it is really worthwhile to continue. The tin-iron-carbon anode may not be practical although it has a very high capacity. This reviewer also noted that the voltage is sloping too much even at low rates compared to that for graphite at the same extent of charge. The reviewer also observed at least 300 mV more positive, lowering the cell voltage by the same at very a low rate.

The reviewer understood that the rate capability and cycle performance are looking good overall for the alloy and composite anodes. The reviewer asked what the energy density of the cell built is, and why the data would not be normalized by weight or volume. Even at the extremely low rate, the upper plateau (greater than 3V) fades quickly. For continuing with this pair, some approaches of alleviating such shortcomings should be proposed.

Reviewer 5:

The reviewer pointed out that this project demonstrated some improvement in capacity and cycling stability of $VOPO_4$ cathode and Sn_yFe anode materials. However, the practical electrode density of a $VOPO_4$ cathode should be reported so that its volumetric capacity and energy could be compared with the state-of-the-art cathode materials. Also, even though the Sn_yFe anode material shows high capacity, it is not clear how much gain in terms of energy density is achieved by using the Sn_yFe-$VOPO_4$ couple. For this electrochemical couple to really work, effective methods of pre-lithiation also need to be established.

Also, the reviewer found that there are results that are exactly the same as in the previous year's report: page 11 right plot is the same with 2016 page 13; page 12 is exactly the same with 2016 page 15; page 13 is the same with 2016 page 16; page 15 is the same with Page 17; and Page 16 is the same with Page 19. This reviewer commented that very limited progress was achieved during one year if the reused results are excluded.

Reviewer 6:

The reviewer called this project "challenging," but stated that good progress has been made. The reviewer suspected that (given the challenges of this project) it will be difficult to be close to the performance of current materials and hoped that this does not reflect poorly on the project—as it is so important to work on these new materials. The reviewer did not think the overall project goals of full cell cycling are achievable in the remaining timeframe and suggested that you gave up too early on the CuF_2.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that there are good, ongoing collaborations with the DOE Laboratories (BNL and ANL) in the characterization of the cathodes and with universities on compatible electrolytes. Efforts are underway to have industrial participation through the New York Battery and Energy Storage Technology Consortium (NYBEST).

Reviewer 2:

The reviewer commented that the State University of New York (SUNY) team has excellent collaboration with national laboratories (BNL and ANL), academia (University of Colorado, University of Michigan, and University of Rhode Island), and industry (NYBEST).

Reviewer 3:

The reviewer pointed out that collaboration could be extended and improved; however, because few people are working on such novel materials, it is harder to find partners.

Reviewer 4:

The reviewer suggested that it would be helpful to collaborate with industry to ensure availability and manufacturability of the proposed new electrode materials.

Reviewer 5:

The reviewer inquired as to where the data are from the collaborators. It appears many national laboratories are involved. The reviewer asked where the characterization data are.

Reviewer 6:
The reviewer asserted that it is difficult to see what each partner's contribution was.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found the future plans to be logical and well thought out. They are designed to conclude the effort this year.

Reviewer 2:
The project is coming to an end in a few months. Plans in the next few months call for continuing the studies on the tin-iron-carbon composite, Sn_2Fe, to complete the characterization and on vanadyl phosphate, $LiVOPO_4$, to extend the cyclability beyond 100 cycles. Additional work will continue on the full cell $Sn_2Fe//LiVOPO_4$ to evaluate extended cycling and demonstrate alternative pre-lithiation processes and, to a lesser extent, on Cu fluoride to identify possible electrolytes. These studies are relevant to bringing the project to a closure and addressing DOE goals.

The project is coming to an end in a few months and the work planned in the next few months is continuing the studies: on the tin-iron-carbon composite, Sn_2Fe—to complete the characterization; on vanadyl phosphate, $LiVOPO_4$ to extend the cyclability beyond 100 cycles; on the full cell $Sn_2Fe//LiVOPO_4$ to evaluate extended cycling and demonstrate alternate pre-lithiation processes; and to a lesser extent on Cu fluoride, to identify possible electrolytes. These studies are relevant to bringing the project to a closure and address the DOE goals.

Reviewer 3:
The reviewer suggested that if the suggested chemistries really provide advantages in terms of energy density and not only capacity, they should be seriously examined.

Reviewer 4:
The reviewer wanted to have seen more efforts on CuF_2, focusing on such approaches as preventing dissolution.

Reviewer 5:
Although kudos were offered for stretching, the reviewer warned that the work was too ambitious for the remaining time. This reviewer suggested that the project focus on either the cathode or the anode.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that for widespread use of EVs and PHEVs, it is imperative that the LIBs be lightweight, compact, safe, and low-cost. The state-of-the-art materials are inadequate to fulfil these needs. High specific energy cathode and anode materials with low-cost are required to improve the specific energy for Li-ion cells, thus increasing the range for the vehicle and reducing overall cost for the battery. Specifically, the present volume intensive carbon anode needs to be replaced with a high energy density Li alloy anode, and the present cathodes with one Li intercalation need to be replaced with cathodes having more than one Li reaction per transition metal. This project addresses both these aspects to make LIBs more acceptable for EVs and PHEVs, which in turn reduces the petroleum dependence.

Reviewer 2:
The reviewer commented that to enhance the driving distance of EVs, some breakthroughs are needed to advance the energy density of a Li-ion cell. For that purpose, advanced anode and cathode materials are needed. This project aimed to develop alternative active materials that surpass current state-of-the-art active materials, layered Li-metal oxide cathodes, and carbonaceous anode materials.

Reviewer 3:
The reviewer responded yes. If the volume of the anode could be cut in half and the cathode could demonstrate a capacity of over 200 Ah/kg, then the cell energy density could be increased by over 50%. The technology would aid in DOE's goal of promoting EVs.

Reviewer 4:
The reviewer said yes.

Reviewer 5:
The reviewer asserted that this would be a very high energy couple, one necessary for a step change in LIB energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the resources are adequate for the scope of the project.

Reviewer 2:
The reviewer stated that the resources are sufficient in order to successfully complete the effort in a timely manner.

Reviewer 3:
As stated previously, the reviewer said that this was a challenging, ambitious project. The reviewer did not mean to be discouraging. However, it would be difficult to complete this project with the budget and time established.

Reviewer 4:
The reviewer said that it looks like resources are sufficient.

Presentation Number: es232
Presentation Title: High-Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions
Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

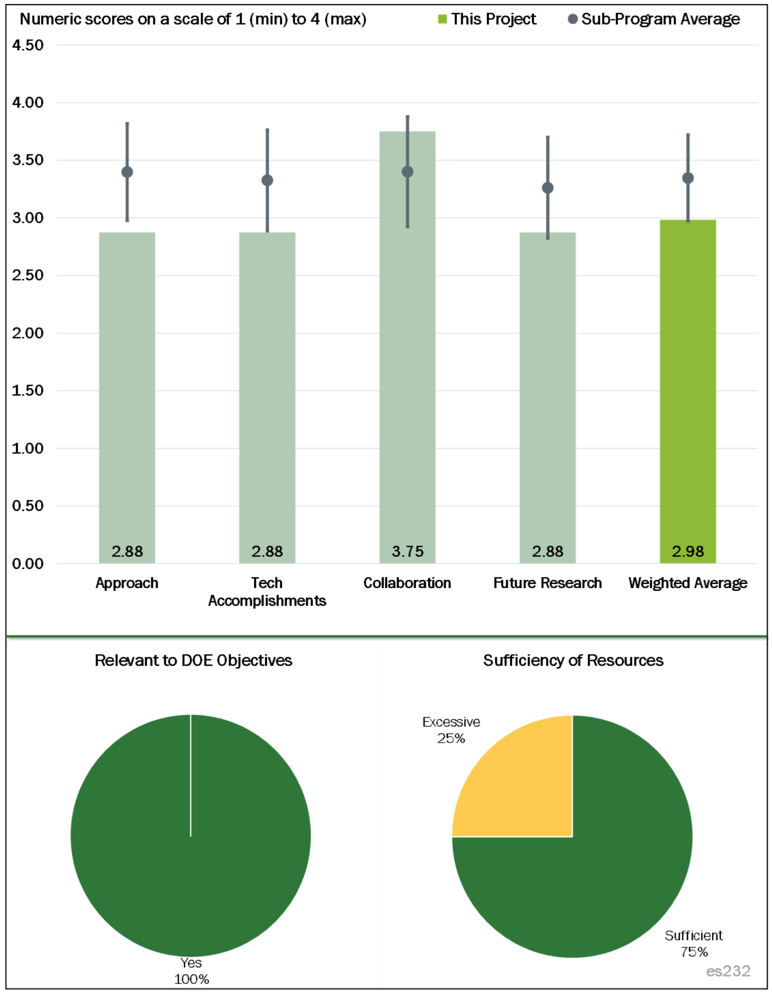

Figure 3-25 – Presentation Number: es232 Presentation Title: High-Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

Presenter

Vincent Battaglia, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the approaches are adequate to address one of the most critical problems associated with electrode production processes. Making thick and dense electrodes is important for making high energy cells. The PI tries to understand the impacts of fundamental material aspects on the electrode coating process.

Reviewer 2:

While the PI's overall goal is good, the reviewer remarked that the overall approach needs some improvement. It is not clear that the PI's choice of binders was focused on binders developed for thick flexible electrodes. It also looked like slurry mixing was not considered, which can be quite important for electrodes with low binder content. In general, it is not clear that the PI has the resources to adequately conduct this study or that this study should be conducted within the Advanced Battery Research (ABR) program.

Reviewer 3:

The reviewer expressed concern about the way this work is being carried out. Drying electrodes overnight and then evaluating their properties makes this work of limited interest. The critical value that national laboratories can bring to industry is to investigate processes and materials of relevance to industry, but then to explain the phenomena in terms of fundamental understanding. That is lacking in this project. The experiments that are being done are likely done by industry already, and the insight into the results is lacking. For example, material developers have dealt with NMC flattening during calendaring for the past 10+ years, and they have addressed the issue. They do not need to know that this is happening, but rather why and what can be done to prevent it in new materials.

Reviewer 4:

The project is addressing the important topic of electrode processing. Industry has largely followed an empirical approach. Science can help in a variety of ways, including making thick electrodes. However, the problem is that research effort at national laboratories needs to complement industrial efforts and this can be hard because industry is secretive. The reviewer thought that this project suffers from not being able to find this balance. The techniques used (cross section scanning electron microscope, bend test, etc.) seem rather routine, which is not to say they are not very useful. However, one wonders if this is repeating what industry already knows. The reviewer suggested that a deeper use of the amazing resources at the national laboratories to address the questions the PI proposed to answer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

During the past year, the reviewer noted that the effects of calendaring on porosities at various temperature were studied. The mechanical properties of the electrode were evaluated again the polymer fraction and addition of carbon nanotubes. The electrode made under various conditions were made into half coin cells and tested. The performance of the electrode of various properties was tested.

The reviewer opined that the PI ought to extend the area of evaluation beyond calendaring, e.g., mixing process, viscosity of slurry, drying temperature, particle size of powder etc.

Reviewer 2:

The reviewer said that the work was good, but not particularly innovative or insightful.

Reviewer 3:

The reviewer referenced prior comments and described technical accomplishments and progress as okay, but not of particular interest or value to developers.

Reviewer 4:

The reviewer commented that the PI seemed to have not looked at his slides before the presentation. Thus, the reviewer found it hard to tell how much was the presentation versus how much was the accomplishments, but there seemed to be less detailed understanding and more reporting of what the project team found.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that number of collaborators was excellent, both within the BMR program and with outside firms like Daikin, Umicore, and Arkema.

Reviewer 2:

The reviewer noted that the PI has extensive collaborations. It is not clear why the PI is getting materials from secondary sources (e.g., separators from Brigham Young University [BYU]).

Reviewer 3:

The reviewer observed that the PI established adequate collaboration with researchers in academic institutions and material manufacturers and encourages the PI to collaborate with cell manufacturers.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that it is clear that the PI intends to address a number of issues resulting from the present effort.

Reviewer 2:
The reviewer noted that it looks as though the team has planned future research to improve their own electrode making ability and proposed that they focus on the "why" and aim to help industry more.

Reviewer 3:
The reviewer stated that the proposed future research covers the critical area of electrode process.

Reviewer 4:

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer asserted that the project is directly related to Li-ion cell production technologies. Cost effective and quality consistent production are key.

Reviewer 2:
The reviewer said the work is relevant.

Reviewer 3:
With the caveat that the project may be repeating what industry already knows, the reviewer thought that the premise of the project is good.

Reviewer 4:
The reviewer found the project to be extremely relevant as the ability to make high quality electrodes, especially high energy density electrodes, is critical to both laboratory and university PIs and to industry. Extreme high loading is critical for EVs, and it is good that the PI is working on this. But watch, the reviewer cautioned, as there are at least two very promising approaches: variable frequency microwaves and EB.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the PI has adequate resources to conduct the proposed tasks.

Reviewer 2:
The reviewer stated that the resources are sufficient to examine the problem as the PI has planned.

Reviewer 3:
The reviewer found the resources to be quite high compared to other projects.

Presentation Number: es235
Presentation Title: Characterization Studies of High-Capacity Composite Electrode Structures
Principal Investigator: Michael Thackeray (Argonne National Laboratory) -

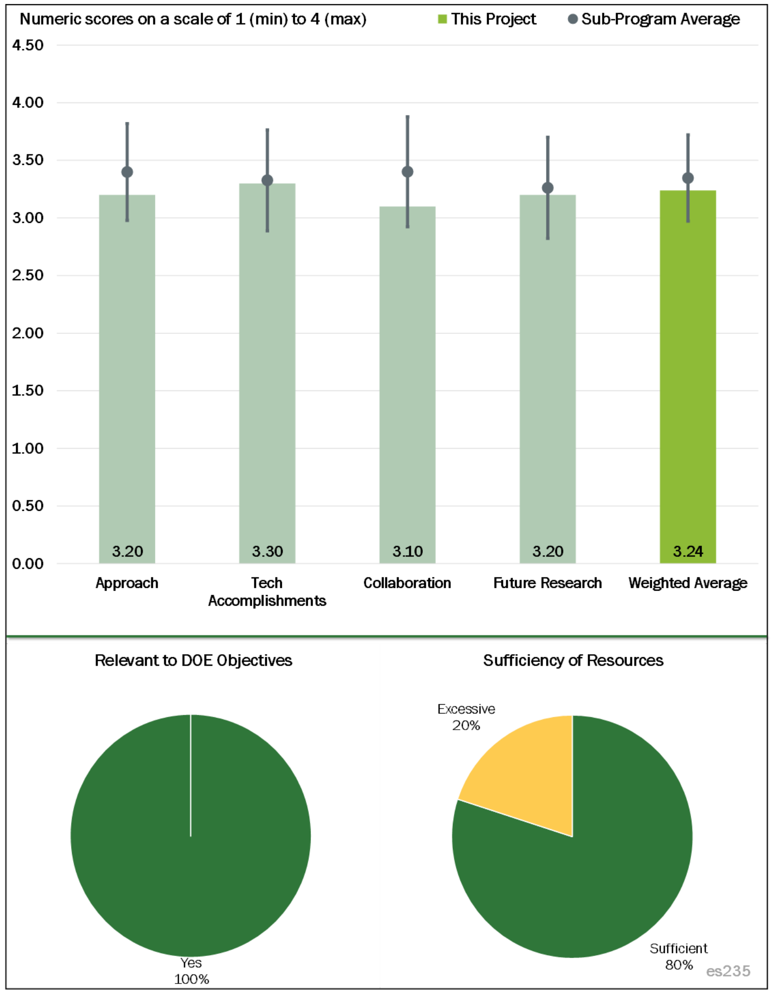

Figure 3-26 - Presentation Number: es235 Presentation Title: Characterization Studies of High-Capacity Composite Electrode Structures Principal Investigator: Michael Thackeray (Argonne National Laboratory)

Presenter
Jason Croy, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer praised the approach taken as excellent. It proceeds in a logical manner. A wide array of characterization techniques, including XRD and neutron diffraction, X-ray absorption, emission and scattering, HRTEM, and Raman spectroscopy, will be used to gain a better understanding of the challenges confronting the next generation of electrode materials. Once issues are identified, modeling will be undertaken to investigate the structure-property relationships so that improved materials can be designed.

Reviewer 2:
The reviewer said that there is an excellent selection of characterization techniques and modeling in this project that should also be used to benchmark commercially available materials from ANL licensees, for example. It is also important to demonstrate reproducibility on the scale-up samples.

Reviewer 3:
The reviewer commented that what is critical here is not “challenging experimental problems” but “understanding material problems.”

Reviewer 4:
The reviewer said nice work, and liked that the work is focusing on more than just voltage fade, but other problems that need to be addressed as well. There is good work on scale up, but lots of work. It is an ambitious effort that seems to be going well.

Reviewer 5:

The reviewer described the objective here as gaining a fundamental understanding through modeling and detailed characterization of the next-generation, structurally-integrated, Li- and Mn-rich compositions that can provide high specific capacities at higher voltages compared to the conventional 4V cathode. Specific objectives are to improve the performance (including cyclic stability) of these composite structures by designing and synthesizing “stable” surfaces and three-component, LLS electrodes through characterization and modeling. A wide variety of characterization techniques, including XRD and neutron diffraction, X-ray absorption, HRTEM, and NMR spectroscopy, are being used in the characterization of these complex structures and complemented with modeling.

This project is addressing the technical barriers of energy density, cost, and abuse tolerance of the current cathode materials. Lithium-rich and Mn-rich LL oxides, Ni-rich NMC oxides, and LLS composites are the three classes of compounds for the next- generation cathodes and it is crucial that one gains a good understanding of these materials at the fundamental level, which the present project is addressing.

There is another project (ES049) with the same PI that overlaps significantly with this project *sans* modeling, which made the reviewer wonder why these two projects could not be combined into a single project. Overall, this project is well designed with new cathode structures, feasible, and adequately integrated with the other DOE efforts on the high capacity cathodes.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that good progress has been made in designing and synthesizing LL cathodes with embedded spinel component of several new compositions (over 40) that are being evaluated for elemental-structural-electrochemical properties. LLS cathodes have been shown to provide approximately 215 mAh/g between 4.5-2.5V versus Li/Li^+. The reviewer remarked that early results on surface treatments (Al_2O_3, Li_3PO4, $Li_{2.9}Ni_{0.05}PO_4$, etc.) are promising, and the rate and energy are comparable to Ni-rich, NMC532 cathodes. These studies complement the synthesis efforts pursued in a parallel project (ES049) in order to understand the possibilities and electrochemical effects of incorporating Co-rich spinel, $Li_{2-x}[Co_{2-2y}Ni_y]O_4$ components. The reviewer explained that LT-$LiCo_{1-x}Ni_xO_2$ (approximately 400°C) consists primarily of lithiated-spinel, structurally integrated with a “defect” layered phase in which the cation distribution is intermediate between layered and spinel and the Ni substitution is limited, but, importantly, promotes the formation of spinel and suppresses the spinel-to-layered transition at elevated annealing temperatures.

This reviewer reported that simulations show that bulk oxygen lattice is stable up to about 50% Li removal from Li layers of Li_2MnO_3 component and Mn migration is correlated with O-O pairing. Surface stability is essentially zero, and any Li extraction leads to more instabilities, implying the need for surface stabilization.

The reviewer indicated that surface characterization studies are underway on these LLS structures coated with different coatings. A variety of materials seems to be beneficial, and $Li_{2.9}Ni_{0.05}PO_4$ shows the best high-rate performance. The reviewer noted that these LLS structures show promise for high capacities and good cyclic stabilities especially with surface coatings. They offer advantages in cost and abuse tolerance (but less so in the specific capacity) compared to the Ni-rich layered oxides. However, the incorporation of Co and Ni-based spinel may offset some of these advantages.

Overall, this reviewer opined that the technical accomplishments are significant and demonstrate the progress toward DOE goals.

Reviewer 2:
The reviewer observed that considerable progress was made last year. The team showed that particle processing is important to electrochemical performance. Various Mn-rich, LLS cathode materials were shown to yield high capacity and the rate is promising. Calculations and simulations show that surface protection is essential for Li- and Mn-rich cathodes.

Reviewer 3:
The reviewer commented that the goals of this project are not quantitative, but more focused on learning. To that end, the reviewer thought that there has been good progress. Other comments from the reviewer were that it would have been nice to see some full cell results and the characterization work was excellent.

Reviewer 4:
The reviewer remarked that very high quality data are presented but most of those are not immediately clear. Some small plots are not really visible. For example, in Slide 12, the reviewer wanted to know what those color indices are, whether only numbers are specified, and what the voltages are.

In the Li(oct) and Li(tet) argument, the reviewer posited that if Li(oct) is in an amorphous phase more favorably compared to Li(tet), then XRD peak ratio analysis becomes invalid. The reviewer wondered how such a possibility could be excluded. Extreme local information (e.g., HRTEM and XRD, although those are in very high qualities and good references), should not be directly correlated to the electrochemical performance data because performance data reflect the ensemble of the material in the electrode including amorphous phases and even impurities.

Coated materials show not only improved stability but also enhanced rate capability. The reviewer asked if there is any explanation so one can identify the material design direction.

Reviewer 5:
The reviewer had questions about the specific challenges of Li- and Mn-rich compositions and whether this system has a better chance for the commercial success versus Li-rich NMC materials.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer opined that excellent collaborations exist. These include various scientists from ANL, ORNL, Northwestern University, and PNNL. Each of the scientist bring unique expertise (e.g., NMR, XAS, and TEM) that will help the program tremendously.

Reviewer 2:
The reviewer remarked that collaboration looks good.

Reviewer 3:
The reviewer noted that there are good collaborations with several researchers from ANL and also with external DOE researchers in understanding these materials at the fundamental level and with the university researchers on modeling. It would be more appropriate and timely to collaborate closely with industry to establish the merit and relevance of these materials compared to NCA-based cathodes or Ni-rich cathodes, as is being planned.

Reviewer 4:
The reviewer asserted that there could have been broader collaborations; the project seems heavily ANL focused.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found the proposed future efforts to be rational. Characterization of the materials stemming from project ES049 will continue in order to assess their value.

Reviewer 2:
The proposed future research is to continue the development of these LLS cathodes with new surface coatings to optimize specific capacity, operating voltage, rate, and cyclic stability. Future studies involve completing the characterization of 40+ new compositions that have been synthesized for specific elemental-structural-electrochemical properties and working to understand the possibilities and electrochemical effects of incorporating Co-rich spinel ($Li_{2-x}[Co_{2-2y}Ni_y]O_4$) components in the LLS composites.

Characterization of the robust surface structures with various surface coatings will be augmented with theory and simulation along with characterization of LLS electrodes harvested from full cells (versus graphite anodes) for ascertaining the efficacy of surface coatings on cyclic stability. It is also important to demonstrate the benefits of these LLS cathode materials with surface coatings in an industrial environment in comparison with the surface-treated NCA-based cathode to properly address the technical barriers in the VTO program.

Reviewer 3:
The reviewer expressed anticipation about the results for all 40 compositions and hoped this can be completed in the time remaining. The reviewer also wanted to see more detail about how much characterization and testing were being planned for the other compositions.

Reviewer 4:
The reviewer stated that it appears the effort does not go beyond that in ES049. The only difference is pursuing Mn-rich instead of Ni-rich material.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that furthering the understanding of the structure-electrochemical property relationships and degradation mechanisms of promising cathode materials will contribute significantly to meeting the DOE near- to long-term goals of EV battery technologies.

Reviewer 2:
The reviewer observed that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High specific energy cathode materials (at high discharge rates) with reduced cost and improved safety are required to address these shortcomings. The LLS composite cathodes with suitable surface coatings are promising to provide stable structures, with high capacities at high rates and as being addressed in this project. This project is thus highly relevant to the DOE goals.

Reviewer 3:
The reviewer commented that high energy density materials are required to achieve the overall DOE goals and this material is an important part of the DOE portfolio. Do not give up on it.

Reviewer 4:
The reviewer said likely.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer asserted that resources appear more than sufficient.

Reviewer 2:
The reviewer stated that resources are consistent with the scope of the project.

Reviewer 3:
The reviewer affirmed that resources are sufficient in order to successfully complete the effort in a timely manner.

Reviewer 4:
The reviewer did not know what is planned for the remaining compositions but assumed it is streamlined from the detailed characterization work shown in this presentation. Otherwise, more resources might be required.

Presentation Number: es240
Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries
Principal Investigator: Cary Hayner (Sinode Systems)

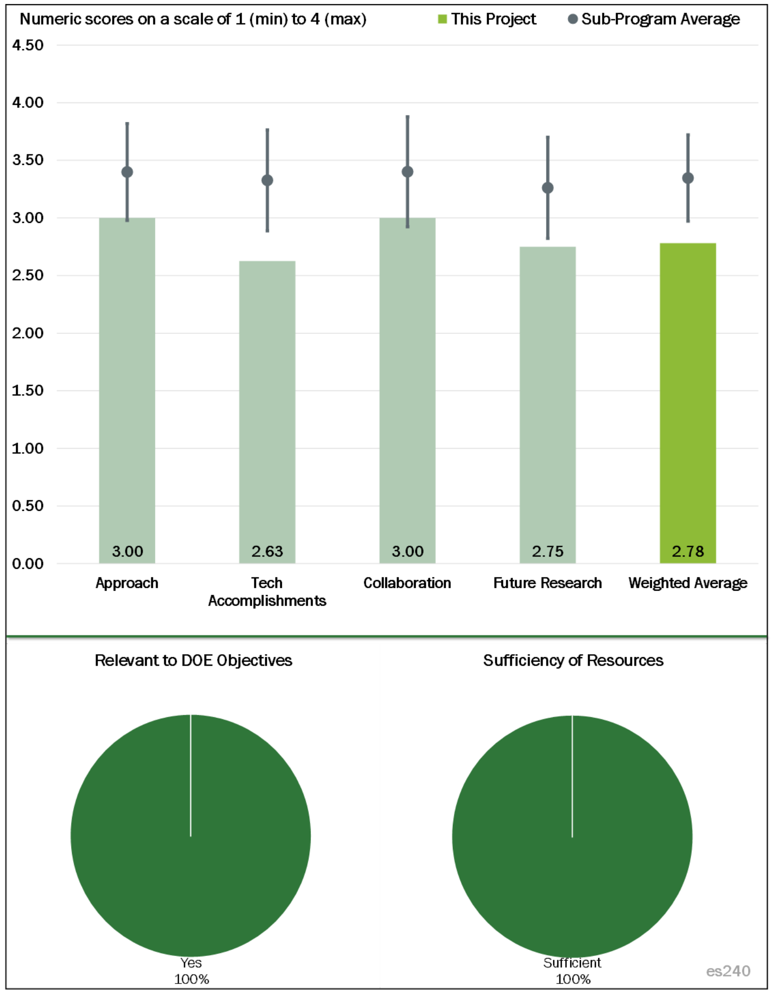

Figure 3-27 - Presentation Number: es240 Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries Principal Investigator: Cary Hayner (Sinode Systems)

Presenter

Cary Hayner, Sinode Systems

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the project is well designed and feasible.

Reviewer 2:

The reviewer described the objective of the project as developing high specific energy Li-ion cells utilizing a high-capacity SiC-based anode that can exceed DOE performance targets. The goals for this project are 200 Wh/kg for 1,000 cycles at the cell level when paired with commercial cathode materials and 750-1,500 mAh/g for 1,000 cycles for the anode. Another objective is to further optimize its manufacturability to meet commercially viable production protocols.

The corresponding deliverables were to demonstrate cycling performance of a 1 Ah SiNode anode coupled with a high energy cathode and submit a comprehensive report on current failure modes and a roadmap to reduce costs to meet DOE target.

The approach is to use SiNode's material, which is Si particles wrapped in a flexible, conductive graphene shell wherein the engineered void space accommodates Si expansion during lithiation. The micron-sized particles are customizable, and the company expects this design to be a drop-in replacement for existing anode materials. The projected anode capacity is 2,000 mAh/g, which has never been achieved experimentally before with any Si anode.

Interestingly, there is no mention of the reversible and irreversible capacities of this anode material. Also, the usual technical barriers for the Si-based anodes are poor cycle life due to volume expansion and also low coulombic efficiency in the first couple of cycles.

Surface coatings were used here to improve the cyclic stability. The use of Si anodes can result in some gains in specific energy and energy density, but only after proper pre-lithiation, which is not explicitly mentioned or addressed here.

Overall, the project is well designed, integrated with other efforts, and consistent with the project and DOE goals.

Reviewer 3:

The reviewer noted that the PI presents a plan to get to a Si-graphene composite material drop-in replacement for graphite in transportation Li-ion cells. This is obviously not the first company developing a Si-graphene composite material. The plan is rather general with not a lot of details. The reviewer found it interesting that the company does not plan to scale up the material past a certain level; rather, they will license the technology if successful.

Reviewer 4:

The reviewer stated that the team is using graphene encapsulation, which is a fine idea. However, there are other technologies that are much farther along, and it is not clear that this technique has a strong chance of doing better than those technologies.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that reasonably good progress has been made in scaling the SiNode synthesis several orders of magnitude without performance degradation. Optimized material formulations and scalable surface treatment (additives) have resulted in improvements in cycle life (both columbic efficiency and specific capacity are claimed to be improved) and suitable external suppliers were identified for reducing material costs by more than 10 times to meet the DOE cost target. Further, an improved thermal processing procedure has been shown to increase cycle life by more than 67% and improve irreversible capacity and coulombic efficiency. Thus, the modified graphene material with surface stabilization offers attractive performance and inexpensive cost compared to the control material.

In situ TEM observations confirmed that the graphene shell successfully wraps Si particles during lithiation while the void spaces accommodate Si expansion during lithiation and buffered overall particle expansion. Details are not presented here about the specific capacities and columbic efficiency (irreversible capacity) that would allow an assessment of the capability of these materials.

Even with all these improvements, the performance is well short of the DOE goals of 750-1,500 mAh/g for 1,000 cycles, underlining the challenges with the Si-based anodes. Overall, the progress is fair and is consistent with the scheduled milestones and DOE goals.

Reviewer 2:

It was clear to the reviewer that the end performance target of 750-1,500 mAh/g for the anode has not been reached. In the presentation, cycling performance data up to only 140 cycles were presented and no capacity data were reported.

The 10,000X scale-up of production process seems to have been achieved without performance degradation.

The reviewer gave a 2.5 rating because SiNode's efforts (adding additives and coating) improved to a certain degree the performance of SiC anode.

Reviewer 3:

The PI has made progress, but it is also clear the material needs quite a bit more development. As far as the reviewer can tell, all the data pertain to half-cells and are plotted as capacity retention, rather than specific capacity, with no current efficiency data. This tends to show the material in the best light, but it is not very informative.

Reviewer 4:

The reviewer found the present status to be not very good: fewer than 200 cycles and SEI issues not being addressed. A maximum production rate of 180 g/day is still very low. All of these accomplishments are far behind other companies, such as Amprius and Sila Nano.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer pointed out that SiNode collaborated with Northwestern University and the University of Illinois at Chicago (UIC)

Reviewer 2:

The reviewer stated that there were collaborations with university partners (Northwestern and UIC) in the characterization of materials and with Merck for the material supply.

Reviewer 3:

The reviewer noted that there are a few collaborations.

Reviewer 4:

The reviewer stated that they are funded by USABC, which implies connection to the auto companies.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the project ended at the end of July 2016.

Reviewer 2:

The reviewer asserted that the project ended in July 2016, but there are still a few challenges remaining. SiNode needs to continue development to demonstrate longer cycle life (greater than 500 cycles) prototype cells and high energy required for commercialization. The supply chain, active material formulation, and scale-up manufacturing to achieve long-term cost targets need to be explored, and comprehensive safety testing on prototype cells required to determine characteristics has to be performed.

Reviewer 3:

The reviewer noted that there is no future work because the project is over.

Reviewer 4:

The reviewer commented that the team knows what needs to be done, but did not see how the team plans to accomplish those goals.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer observed that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High capacity anode materials are required to improve the specific energy of Li-ion cells. Si anodes have the potential to offer twice the capacity of graphitic anodes, and SiNode has developed a fairly robust Si anode based on graphene. These high-capacity anodes are to be paired with high-capacity commercial cathodes to provide high specific energies and energy densities for Li-ion cells with lower costs.

Reviewer 2:

The reviewer stated that the project aimed at developing SiC anodes for LIBs with extended cyclability, which is important for EVs.

Reviewer 3:

The reviewer pronounced the work to be relevant.

Reviewer 4:

The reviewer said okay.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found the resources to be adequate.

Reviewer 2:

The reviewer stated that the funding is sufficient.

Reviewer 3:

The reviewer said resources are okay.

Reviewer 4:

The reviewer had no comments.

Presentation Number: es241
Presentation Title: Advanced High-Performance Batteries for Electric Vehicle (EV) Applications
Principal Investigator: Ionel Stefan (Amprius)

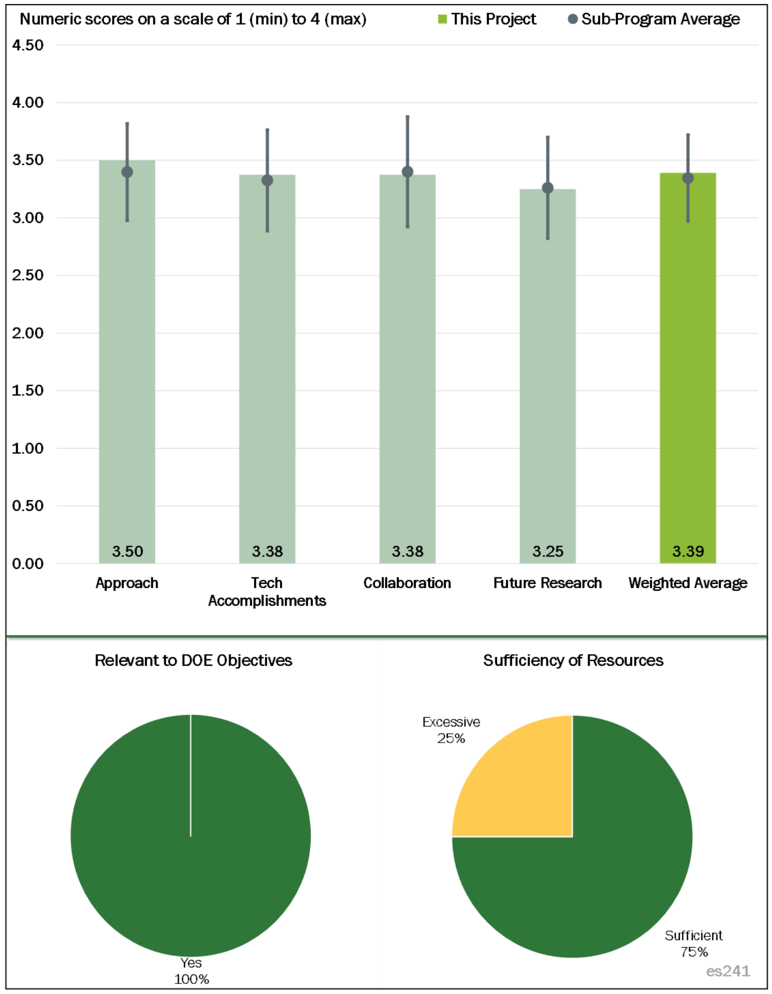

Figure 3-28 - Presentation Number: es241 Presentation Title: Advanced High-Performance Batteries for Electric Vehicle (EV) Applications Principal Investigator: Ionel Stefan (Amprius)

Presenter

Ionel Stefan, Amprius

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer pronounced the project as being well designed and feasible. The Si nanowire anode is a promising approach to develop high-performance batteries.

Reviewer 2:

The reviewer pointed out that the project has highly original approaches to providing full cells with high energy density.

Reviewer 3:

The reviewer observed that the objective of the project is to develop high specific energy Li-ion cells utilizing Amprius Si nanowire anodes for EV batteries. Specific objectives are to design and fabricate Si nanowire anodes matched with advanced (high capacity and high energy density) cathodes and state-of-the-art cell components. Additional work covers design, fabrication, testing, and delivery of 2 Ah, 10 Ah, and 40 Ah Li-ion cells with Si nanowire anodes that meet the USABC 2020 goals of 350 Wh/kg and 750Wh/l at end of life (EOL), 2:1 power-to-energy ratio, and 1,000 dynamic stress test (DST) cycle life.

The technical barriers that will be addressed are to reduce the mass and volume of the anode for higher energy density and specific energy, reduce cost, and improve the cycle life by optimizing the nanowire structure. The use of a Si anode can result in some gains in specific energy and energy density, especially after proper pre-lithiation. However, with the Si anode, even with nanowires, the cycle life would be a considerable challenge especially for EV applications, though some decent cycle life has been reported here.

The specific approach involves matching Si nanowire anodes with advanced (high capacity and high energy density) cathodes and state-of-the-art cell components, developing anode and other cell components in a 2 Ah cell form factor and later scale it up to an intermediate 10 Ah cell and modify to 40 Ah cells for performance demonstration.

Overall, the project is well designed and integrated with other efforts and consistent with the project and DOE goals.

Reviewer 4:

The reviewer has followed this project from the beginning with great interest. The unique anode design combined with industrial connections makes for a very real world test of the technology. Amprius does not seem to be able to calculate the percentage of completion accurately, but they have done a lot of other, more important things well. They are focusing on technology development, but should have a better plan to convince the reviewer and others that this technology can be made affordably.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that Amprius has already achieved the milestone of 800 Wh/l, 380 Wh/kg, and 850 cycles in 2 Ah cell and 10 Ah cells with similar performance. It is very likely that they will reach their remaining goals at the end of the project, which are to develop, test, and deliver 2 Ah, 10 Ah, and 40 Ah Li-ion cells with Si nanowire anodes that meet the USABC 2020 goals.

Reviewer 2:

The reviewer mentioned that good progress has been made in developing the first-of-its-kind pilot line tool for roll-to-roll production of double-sided, rooted Si nanowire anodes with high Si content (100%), high loading (2-3 mg/cm^2), and matching the Si nanowire anode with high-capacity NMC cathodes. High capacity cathodes of high loadings, high specific energy, and densities have been demonstrated in 2-3 Ah cells, with the performance exceeding the DOE targets of 350 Wh/kg and 750 Wh/l. Further, the cycle is reasonable with more than 500 cycles for the NMC cathode and 300 cycles with LCO cathodes operating at high charge voltages of 4.35V. Operating at these charge voltages may aggravate the safety issues with the LCO cathode, however. With the NMC cathode, the voltage profile will be more sloping to add to the relatively sloping voltage profile of Si.

About 30 Si nanowire-NMC cells have been delivered to INL and SNL for performance and safety evaluation. It would more appropriate to show the data generated at INL and SNL as part of this review. Finally, a design was developed for larger (10 Ah) Si nanowire and NCM cells with specific energy of 340 Wh/kg and 850 Wh/l. High cathode loadings contribute to higher specific energy, no doubt, but only at the cost of cycle life. It is important to understand the interplay among cathode loadings, energy densities, and cycle life.

Overall, the progress is good and is consistent with the scheduled milestones and DOE goals.

Reviewer 3:

The reviewer remarked that they seem to be making steady progress on more than one front. It is good to see they are focusing more on NMC systems. Last year they touted 500 cycles, but it is not clear that they have increased on that value very much.

Reviewer 4:

The reviewer stated that they have overcome challenges in designing tabs for a 10 Ah cell. They have recently improved the energy density by about 10%, both volumetric and gravimetric and are getting 337 Wh/kg now. They are up to about 550 cycles with NMC550. A big challenge is the poor calendar life.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that Amprius has a long list of collaborators including universities and industrial companies.

Reviewer 2:
The reviewer said that Amprius has collaborations with other companies where necessary.

Reviewer 3:
The reviewer observed that they have had to develop a number of collaborations to push the technology forward.

Reviewer 4:
The reviewer pointed out that Amprius is the only project team member. However, there are multiple industrial and university partners for the development of cathode and electrolyte to go with the Si nanowire anodes.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer discussed what future studies will involve: the continuation of cell optimization to increase specific energy, cycle life, and calendar life using the design of the experiment methodology for electrolyte studies, completion of testing the 10 Ah cells with INL and SNL to map out the performance gap table, and the development of the design for 40 Ah cells by iterating the cell assembly, evaluating performance, and fabrication and delivery of the cells. The future work planned is logical with appropriate decision points in the materials selection and cell fabrication processes. These future studies are consistent with the DOE goals

Reviewer 2:
The reviewer asserted that Amprius has well-defined plans for future works, such as further cycle life and high-temperature stability improvements by optimization of electrolyte formulation.

Reviewer 3:
The reviewer commented that they seem to have an excellent plan for their performance metrics. Again, it would also be interesting to see some consideration of cost.

Reviewer 4:
The reviewer expressed a lot of confidence that they will be able to fabricate 40 Ah cells, but did not see how they will solve their calendar life problem.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High capacity anode materials are required to improve the specific energy of Li-ion cells. Si anodes have the potential to offer twice the capacity of graphitic anodes, and Amprius has developed a fairly robust Si anode based on Si nanowires. These high-capacity anodes are to be paired up with high-capacity cathodes in suitable electrolytes so that prototype cells (10-40 Ah) can be fabricated to validate the benefits of the Si nanowire and NMC cells. High gravimetric and volumetric demonstrated in these cells will make the EV batteries lighter, more compact, and may be even lower cost.

Reviewer 2:
The reviewer observed that the more than 1,000 cycle life of LIBs is one of the central problems to be solved for their application in EVs. The project also works on improvements in energy density, high temperature stability, and calendar life of LIBs.

Reviewer 3:
The reviewer stated that the project is relevant.

Reviewer 4:
The reviewer said okay.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based on the demonstrated works and the wide collaborations, the reviewer believes that Amprius has sufficient resource to achieve the stated milestones on time.

Reviewer 2:
The reviewer stated that resources are sufficient.

Reviewer 3:
The reviewer said resources are okay.

Reviewer 4:
The reviewer commented that the resources seem to be excessive compared to FY 2016 though the scope is similar (except the size of the cell deliverables).

Presentation Number: es247
Presentation Title: High-Energy Lithium Batteries for Electric Vehicles
Principal Investigator: Herman Lopez (Envia Systems)

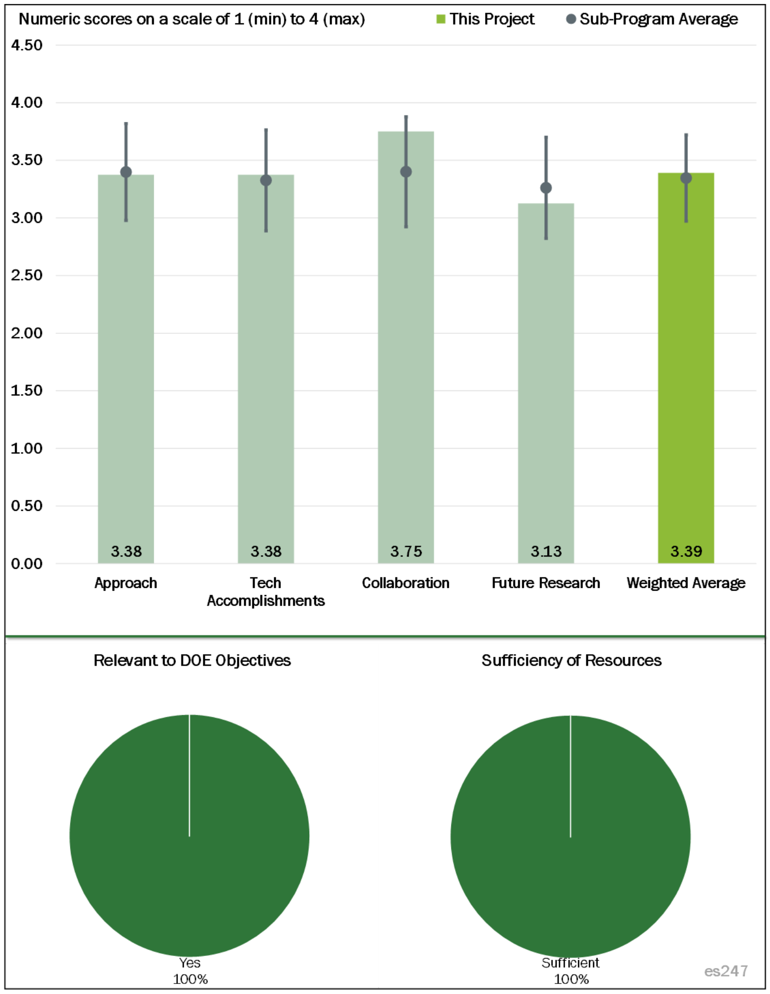

Figure 3-29 - Presentation Number: es247 Presentation Title: High Energy Lithium Batteries for Electric Vehicles Principal Investigator: Herman Lopez (Envia Systems)

Presenter

Herman Lopez, Envia Systems

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer stated that Envia's project, centered in the optimization of the pre-lithiation process of silicon oxide (SiO_x) anode, is well-designed and feasible, and a promising approach to develop high-performance batteries.

Reviewer 2:

The reviewer confirmed the objective here is to develop high-capacity cathode and anode materials, screen commercial electrolytes and separators, optimize pre-lithiation process and integrate the materials and processes into high-capacity pouch cells that meet the USABC EV battery goals, i.e., 300 Watt-hour per kg (Wh/kg), 750 Watt-hour per liter (Wh/l) and cycle life 1,000 DST cycles. The challenges here are related to the poor cycle life of (n-rich or Ni-rich cathodes and S) anodes and to identify a viable pre-lithiation process and to develop cell designs that meet the safety and cost targets. To achieve these performance characteristics, the reviewer stated the approach adopted was to collaborate with multiple partners, especially on the Si anodes, separators and electrolytes. Based on these materials, the reviewer commented proprietary electrode processes and cell designs are being developed to demonstrate the performance targets in 1 to 20 Ah cells. Eventually, these cells will be sent to the DOE national laboratories (INL, SNL, and NREL) for an independent performance verification and validation. Overall this reviewer summarized that the project is well designed, integrated with other efforts and consistent with the DOE's goals.

Reviewer 3:

This reviewer confirmed there was a clear division of labor among many companies for what needs to be done.

Reviewer 4:

The reviewer noted this project is certainly challenging with many problems to overcome. The PI seems to understand the problems and has a plan to attack them. This reviewer found the blending strategy for the cathode interesting, hoping to get the best of both materials. Although in the end, the reviewer opined the anode may present the greatest challenge.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer acknowledged Envia has achieved more than 700 cycles with 80% retention from 20 Ah cells using high SiO_x containing anodes, and stated that this meets the USABC 2020 goals. This reviewer expects that the project team will improve the performance of their cells to meet the USABC EV specs by the end of the project.

Reviewer 2:

The reviewer noted the project seems the have made steady progress. The 700-plus cycle life is particularly impressive. The use of SiO_x in the anode forces one to consider pre-lithiation, which this reviewer stated continues to be a challenge.

Reviewer 3:

This reviewer confirmed 700 cycles at 300 Wh/kg is very good. Pre-lithiation of SiO_x could be a serious problem in terms of cost; however, the reviewer noted that the project is collaborating with a company to address this.

Reviewer 4:

The reviewer said good progress had been made with various cell components and cell designs: A cycle life of 800 cycles was realized in 21 Ah, (270 Wh/kg) pouch cells with nickel-rich nickel manganese cobalt oxide (NMC) cathode and Si anode (less than 50%) with suitable pre-lithiation. Proprietary Si-based anodes were developed by using commercially available SiO_x materials and applying proprietary electrode formulation, processing, and coating methodology. This reviewer noted both Mn-rich and Ni-rich cathodes will provide the high energy densities (350 Wh/kg and 750 Wh/L when combined with the Si anode, and also meet the safety and cost requirements. Large-scale roll-to-roll pre-lithiation pilot line was completed the reviewer remarked and is currently being used to pre-lithiate promising anode formulations for 20 Ah cells. The reviewer pointed out there are no data here (on the anode irreversible capacity or coulombic efficiency during formation) to quantify the benefit of this pre-lithiation. Prototype cells were fabricated (11-20 Ah) that showed consistent cell performance (260-280 Wh/kg) and physical specifications, and also meet the EOL USABC EV peak specific Regeneration and Discharge power requirements after reference performance test (RPT) 1 (post 30°C DST cycling). This reviewer mentioned the next generation of the cells are expected to provide higher specific energy of 300 Wh/kg and 1,000 cycles. As impressive as these performance numbers are, the reviewer observed the results are not much more impressive than the recent high-energy commercial 18650 cells that provide 265 Wh/kg and 800 Wh/l with graphitic anodes at the cell level. Proper cost analysis needs to be made to assess from the pre-lithiation and the associated electrode handling needs versus its benefits. Overall progress is good the reviewer summarized and is consistent with the DOE's goals.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer said the project team is doing an excellent job collaborating with the right people.

Reviewer 2:

This reviewer commented there are excellent collaborations with several researchers from different organizations, specialized in different components and manufacturing processes.

Reviewer 3:
The reviewer stated Slide 5 shows a well-organized collaboration among industrial and national laboratory partners.

Reviewer 4:
The reviewer asserted the project has extensive collaboration in many areas.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted the project is nearing completion this year. The remaining activities are: to complete Cell Build #2 and deliver cells to the national laboratories for their assessment; downselect best pre-lithiation process to be used in final cell build; and complete Cell Build #3 development and freeze cell design for final program cell deliverable. This reviewer stated the future work planned is consistent with the project objectives and deliverables.

Reviewer 2:
This reviewer noted Envia listed detailed steps for future works.

Reviewer 3:
This reviewer concluded directions are clear, but pathway to success is unclear.

Reviewer 4:
The reviewer warned as this project is nearing completion, the future plans are somewhat limited. The reviewer thought the PI will be able to look back and feel good about the progress. It will be interesting for this reviewer to see the independent testing of the technology.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High capacity cathode and anode materials are required to improve the specific energy of Li-ion cells. This reviewer noted blends of Ni/Mn-rich cathodes and Si composite anodes with proprietary pre-lithiation strategy are promising both from an energy and cost perspective. These high-performance and low-cost materials and processes are being addressed in this project the reviewer concluded.

Reviewer 2:
The reviewer affirmed the project is good.

Reviewer 3:
This reviewer stated the project is relevant.

Reviewer 4:
This reviewer commented the major objective of Envia's project is to develop high-energy Li batteries to meet the USABC EV specs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based on the demonstrated work and the wide collaboration, the reviewer believes that Envia Systems has sufficient resource to achieve the stated milestones in time.

Reviewer 2:
The reviewer acknowledged the resources are adequate based on the scope of the effort that ranges from material and process development to the fabrication of high-capacity prototype cells for performance demonstration.

Reviewer 3:
The reviewer asserted the resources are sufficient.

Reviewer 4:
The reviewer stated the resources for the project were okay.

Presentation Number: es252
Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Electrolytes and Additives
Principal Investigator: Dennis Dees (Argonne National Laboratory)

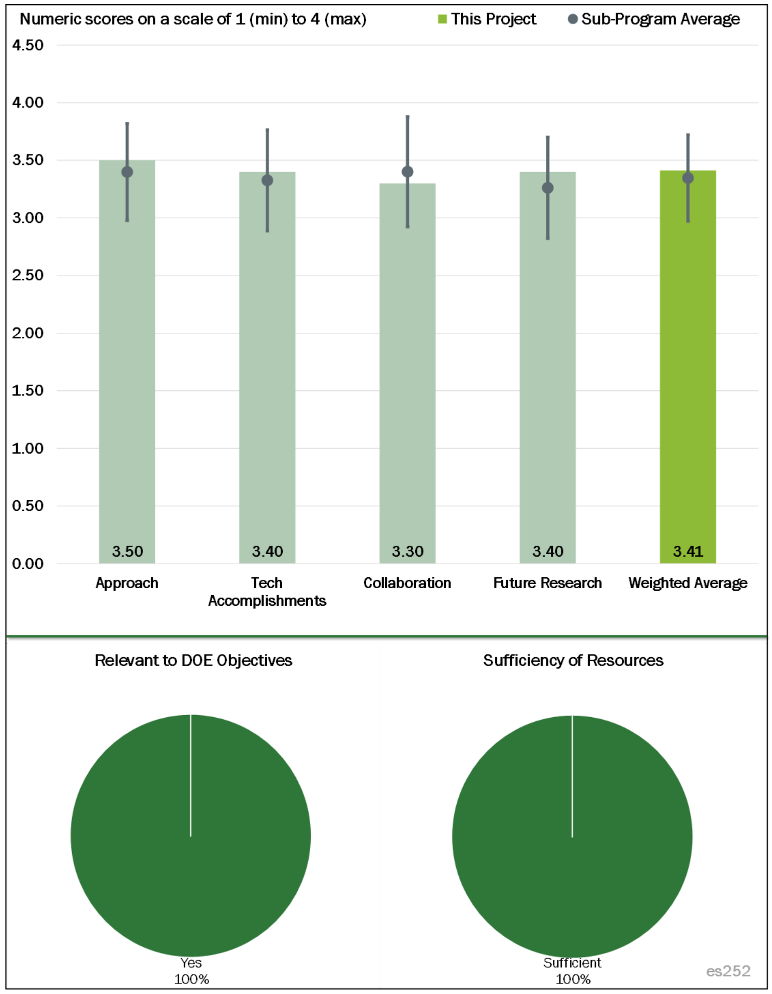

Figure 3-30 – Presentation Number: es252 Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Electrolytes and Additives Principal Investigator: Dennis Dees (Argonne National Laboratory)

Presenter
Daniel Abraham, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer asserted the combined computational and experimental approach is very well designed and very effect to study electrolyte stability and additives.

Reviewer 2:
This reviewer observed this project's goal is to develop electrolytes and additives for high-energy/voltage Li-ion cells. It has well-designed and feasible experimental plan in the proposed work and been integrated well with the other teams' efforts. The reviewer affirmed the project took good advantage of ANL's CAMP facility to prepare standard electrodes for various tests. The capacity degradation mechanism is studied from full cell point of view and well correlated to the experimental results. The reviewer commented standard protocols are used to evaluate the effect of electrolytes/additives.

Reviewer 3:
The reviewer stated the effect of electrolyte additives has been studied using a mini combinatorial approach. The studies have used energy figure of merit and power figure of merit as two criteria to compare the effect of additives, and electrolyte with no additives are reasonably used as baseline. In addition to the electrochemical tests, the reviewer noted nuclear magnetic resonance (NMR) and XPS studies are used to explain the mechanism of interactions between electrode surface and electrolyte with difference additives. Electrochemical impedance tests have also provided important insights regarding the reactions on the surface of positive and negative electrodes.

Reviewer 4:
The reviewer recounted the project approach identifies the issue that will be addressed; outlines what will be done to try to mitigate the causes of the issue; and highlights the need to be able to model what happens and report the results. The need for support by a number of other agencies was also noted.

Reviewer 5:

The reviewer concluded the approach is feasible to understand the degradation mechanism of NMC532/graphite electrode. However, the industry is now using NMC622 and exploring NMC811, thus the baseline material could be out of date. The reviewer stated the goal of this project is to explore new electrolyte and electrolyte additives using EC:EMC and baseline electrolyte to understand the interaction between EC and different electrolyte additives. In the future plan, EC free will be used. The question this reviewer had is how much learning from baseline can be applied to total new electrolyte system with new electrolyte additives.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer remarked progress showed significant improvement over the baseline performance. The presentation clearly spelled out the reasons for the improvement by reviewing the strengths/weaknesses of electrolyte additives with respect to electrodes and power and energy figure of merit. The reviewer noted the project also developed tests for specific electrolyte evaluation.

Reviewer 2:

The reviewer expressed the outcome of the project will help design liquid electrolyte compounds that will enhance the calendar- and cycle- life of high-energy LIBs. The accomplishments of the project are within the mainstream of electrolyte studies, and the part of the work that tries to propose possible mechanisms for surface reactions is more novel in the opinion of this reviewer.

Reviewer 3:

This reviewer affirmed this work made great progress in understanding the effects of electrolyte additives on cell impedance. It can be improved by using surface techniques to better understand the role of these additives.

Reviewer 4:

This reviewer asserted good progress toward overall project and DOE goals was made. Performance, especially the power performance, improvement has been demonstrated after screening various additives and their combinations. The reviewer pointed out the fundamental mechanism underneath the additives is also explored with some new insights provided to the community. The PI has discovered that the content of transition metal at the negative electrode increases with increasing upper cutoff voltage, which traps Li^+ ions. To this reviewer it is not clear why the cell variation is still large when using the standard protocols in NMC532/graphite (Gr) coin cell (3-4.4 V) testing. At high voltages, aluminum (Al)-clad is suggested to be used to passivate the cell pans at high voltages. The electrochemical window of each additive needs to be considered which this reviewer noted is missing in the table. If a switch is made from coin cells to pouch cells, this reviewer wondered whether the same optimized recipe will work the best or whether a new round of screening will be necessary. The function of trivinylcyclotriboroxane (tVCBO) is not clear to the reviewer but it could provide some guidance in the further development of additives. When evaluating electrolyte/additives, the reviewer noted Coulumbic efficiency is an important indicator that needs to be reported which is missing in this project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer praised the excellent collaboration with multiple individual and facility contributors. The strengths of each was maximized for best possible results.

Reviewer 2:

The reviewer affirmed the work is done mainly at ANL, and there is a reasonable degree of collaboration between various divisions/groups within the lab.

Reviewer 3:

This reviewer commented he PI has collaboration with CAMP and post-test facilities at ANL.

Reviewer 4:

The reviewer observed this project works closely with CAMP at ANL. It is not very clear to this reviewer what the other national laboratories' contributions were to this project.

Reviewer 5:

This reviewer asserted the baseline electrolyte has been widely studied. Some of the collaborators are developing high-voltage electrolytes. The reviewer stated the project team can have more interaction with those experts and test the high voltage electrolytes.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

This reviewer commented the results show that Li-ion cells with certain combinations of electrolyte additives exhibit improved performance. Future plans of the project are mainly focused on obtaining more insights into the mechanism and function of the reactions in these promising systems, and the reviewer noted a list of activities in line with this goal are proposed.

Reviewer 2:

This reviewer confirmed the project team identified potential areas for electrolyte improvements and what needs to be understood to make those improvements. One area missing as observed by this reviewer is comparing the cost associated with these electrolyte additives and their effects. The reviewer also, would like to have seen effects of varying the percentage of additives in the matrix.

Reviewer 3:

This reviewer stated that in order to better understand the effects of electrolyte additives on cell impedance, the PIs can leverage great resources of surface science expertise and instruments at national laboratories to better understand the role of these additives.

Reviewer 4:

The reviewer said the proposed future work has a detailed plan which is in the right direction. This reviewer suggested that Coulombic efficiency, especially for the full cells, needs to be included for evaluating various electrolytes and additives. The storage life of the cells in the presence of the additives at room and high temperature effects need to be considered. If the conclusion on the TM content at high cutoff voltage is correct, the reviewer pointed out corresponding strategies need to be proposed to mitigate the dissolution of TM from electrolyte or additive point of view. This reviewer pondered whether the EC-free system in the future work is consistent with the finding on TM dissolution. Electrochemical modeling that can quickly screen different electrolytes and additives is needed remarked the reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated this project supports the overall DOE objectives with respect to petroleum displacement. The project is seeking to significantly reduce a key failure mechanism for the LIB system—energy fade. The reviewer observed the project team is doing this via better understanding of what electrolyte additives impact that characteristic and which ones decrease that fade. Reducing that fade improves the chances of consumers adopting this technology for vehicle use.

Reviewer 2:
The goal of the project is to enhance the cycling performance of high-energy batteries which the reviewer noted thereby facilitates the transition from a fossil fuel based economy to one that may be driven by a mixture of fuels.

Reviewer 3:
This reviewer asserted this project supports the overall DOE objectives. Electrolytes and additives are the main roadblocks for developing high-energy/voltage battery systems.

Reviewer 4:
This reviewer mentioned electrolyte additives are used to improve the battery performance. A better understanding of the role of electrolyte additives, can significantly advance battery electrolyte development and help accelerate the EV adoption.

Reviewer 5:
The reviewer pointed out understanding the failure of the electrode and electrolyte is critical to further optimize the future battery system.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer expressed this work needs funding at this level to address this issue.

Reviewer 2:
This reviewer concluded the resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 3:
This reviewer asserted ANL has all the required facilities to conduct the proposed research.

Reviewer 4:
This reviewer observed the team of the project has access to sufficient resources including Advanced Photon Source (APS) user facilities. The project is in the middle of its third year and 65% of the project is completed.

Presentation Number: es253
Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Theory and Modeling
Principal Investigator: Dennis Dees (Argonne National Laboratory)

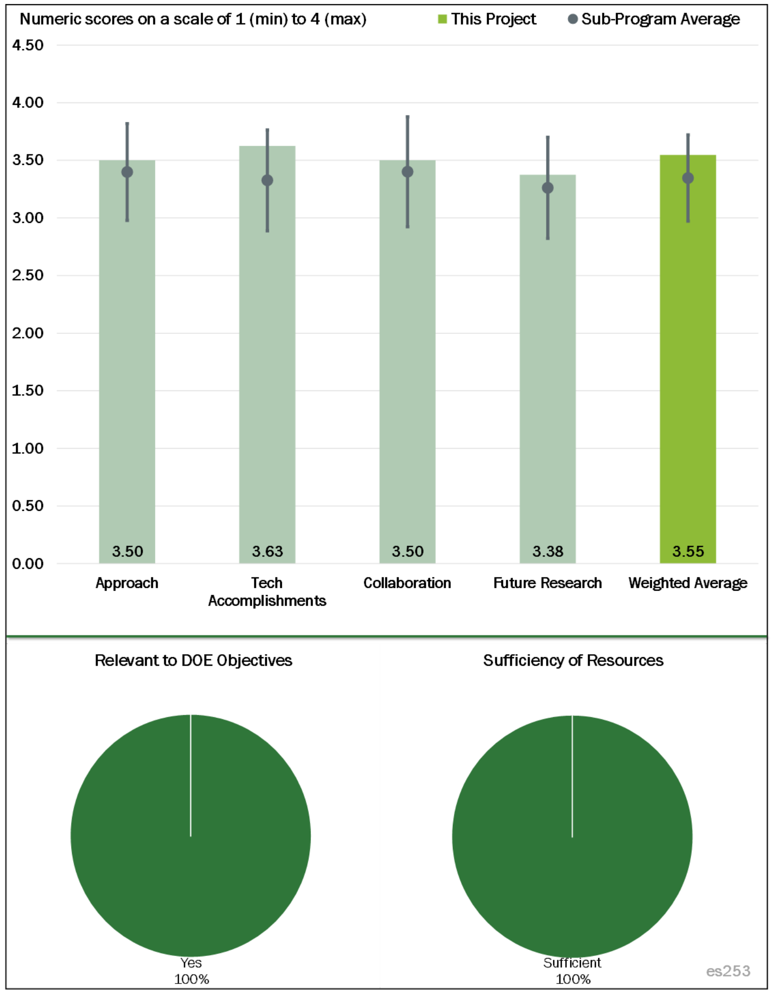

Figure 3-31 - Presentation Number: es253 Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Theory and Modeling Principal Investigator: Dennis Dees (Argonne National Laboratory)

Presenter

Hakim Iddir, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated the approach to perform first-principles DFT at the GGA+U and the hybrid functional levels is very helpful to understand bulk and surface structures, processes at surfaces and interfaces, and electrolyte-surface interactions.

Reviewer 2:

This reviewer praised the approach as excellent. Layered NMC are promising cathode materials that are intrinsically capable of meeting DOE goals. Unfortunately, surface degradation occurs that reduces the battery lifetime this reviewer acknowledged. The reviewer affirmed that this effort will use DFT to gain a better understanding on the atomic-scale processes governing battery degradation.

Reviewer 3:

This reviewer noted the project uses atomistic modeling to provide detailed understanding of NMC cathode both in bulk (lattice) and on the surface. The project uses both GGA-U and hybrid functional levels. The reviewer pointed out the modeling efforts are combined with experimental studies. There is a good agreement between the calculated surface energy of facets and the experimental findings regarding growth of NMC single crystals. The reviewer asserted valuable information on the formation of vacancies and transition metal cation segregation on the surface are presented. The obtained models are used to understand the interactions between cathode surface and electrolyte/additives and the reviewer concluded the results are consistent with the experimental findings and surface analysis.

Reviewer 4:

The reviewer observed that the approach identifies the issue that is being considered and how this project supports a broader project. This project objective is to handle the modeling portion of a larger project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised this work for achieving very impressive milestones.

Reviewer 2:
This reviewer confirmed that significant progress was made this past year. One major contribution was the development of a model that can predict the surface structure, relative stability and particle shapes for NMC based cathode materials.

Reviewer 3:
This reviewer asserted the computational work in this project has provided valuable insights into the interaction of cathode surface with electrolyte and electrolyte additives, and that the outcome and predictions are consistent with the experimental findings. The project has had a significant progress in one year the reviewer observed, and the findings can be used as a predictive tool to improve high-energy LIBs.

Reviewer 4:
This reviewer concluded significant progress was made relative to stated objectives. An appropriate model for the Li-ion NMC cathode surface material was built as well as a model of the interaction of the electrolyte with the cathode. Other surface interactions were also modelled the reviewer noted. Bulk modelling was not clearly addressed this reviewer said, but was highlighted as an objective.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer said excellent collaboration with other teams was evident and needed. The strength(s) of each collaborator was maximized.

Reviewer 2:
The reviewer expressed this is a strong collaborative effort between four national laboratories (ORNL, NREL, LBNL, and ANL).

Reviewer 3:
The reviewer observed there were collaborations between various DOE national laboratories (samples obtained from LBNL) and modeling and experimental groups within ANL.

Reviewer 4:
The reviewer pointed out this work can be improved by providing more experimental support for the computational results.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer pointed out that the effort is scheduled to end next year. The concluding tasks to continue the modeling efforts and to investigate the electrolyte-additive/NMC surface interactions are good. This reviewer noted the results are expected to continue to give important insights into design criteria of high-performing cathode materials.

Reviewer 2:

The reviewer pointed out that the future work is presented relatively generally, and mainly as a continuation of the tasks performed so far. In most presentations the reviewer observed, the presenters had the concern of future funding and were skeptical about detailing their future work.

Reviewer 3:

This reviewer commented that the proposed future work supports the overall project as it provides modelling to help direct the work and then allows for modelling refinement based on test results. The reviewer stated that ideally, a clear Bulk Modelling effort should be called out in the future plans.

Reviewer 4:

This reviewer noted that the future plan should include more interaction with experiment team to confirm the computational results.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said this portion of the larger project supports the overall DOE objectives with respect to petroleum displacement. This specific project handles the modelling that is needed to make the improvements to the energy component of the battery system.

Reviewer 2:

The reviewer affirmed the project's effort is aligned with the objective of petroleum displacement.

Reviewer 3:

The reviewer expressed the project provides knowledge on the cathode surface reactions that is believed to be the main origin for the degradation of LIBs, and thus will contribute to the enhancement of energy storage.

Reviewer 4:

The reviewer acknowledged that the project is very helpful in order to understand electrode bulk and surface structures, processes at surfaces and interfaces, and electrolyte-surface interactions to address the problems associated with "enabling" high-energy Li-ion cells.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer concluded the funding level of this project meets the need of the overall project.

Reviewer 2:

This reviewer asserted the resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 3:

The reviewer affirmed the project team has access to sufficient resources and collaborations in order to perform the proposed tasks.

Reviewer 4:

This person said the project team has made significant progress with the resources they have received to date and there is no reason to assume that this will change in the future.

Presentation Number: es254
Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Materials Characterization
Principal Investigator: Dennis Dees (Argonne National Laboratory)

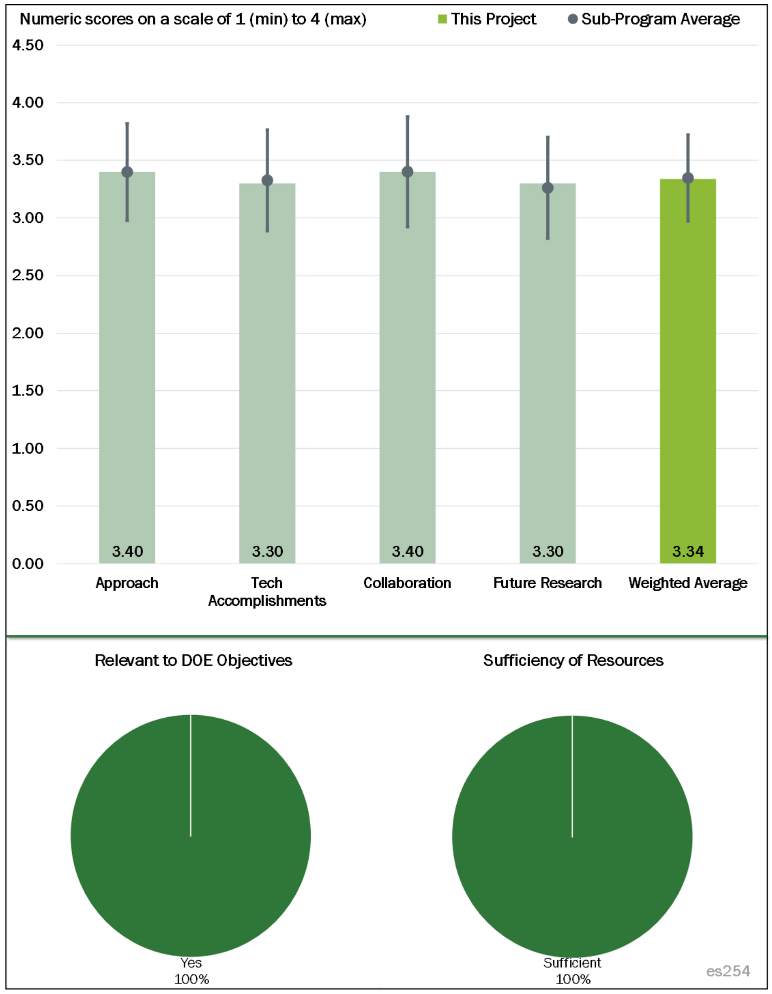

Figure 3-32 - Presentation Number: es254 Presentation Title: Enabling High-Energy/Voltage Lithium-Ion Cells: Materials Characterization Principal Investigator: Dennis Dees (Argonne National Laboratory)

Presenter
John Vaughey, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer commented that understanding and improving performance of cells at high potential is both extremely important and very challenging. The person further stated that this more fundamental approach is badly needed because Edisonian approaches have not and are not likely to work.

Reviewer 2:
The reviewer noted the approach states the intent and identifies three strategies that that will be employed. Two baseline high-energy/voltage cathode materials were considered for this evaluation.

Reviewer 3:
The reviewer said this work introduces magic angle spinning NMR as a tool to study Al coating and substitution which advances the understanding of Al role in the electrochemical performance of NMC and LCO electrodes.

Reviewer 4:
The reviewer mentioned that Ni-rich cathodes are very important for the development of advanced LIBs. The investigation and modification on these cathodes are urgently needed and timely. This person praised The PI for having made great progress on this project providing new insights and contributions to the field. The PI also developed surface sensitive characterization tools to probe and understand the interfacial compounds of Ni-rich materials. This reviewer noted that single crystal approach has been employed for a while from spinel to LMR and now Ni-rich. The only concern is how much knowledge gathered from single crystal can be used to address the challenges of the polycrystalline cathode materials. For this reviewer, the correlation is not quite clear.

Reviewer 5:

This reviewer noted that development of surface sensitive characterization tools, understanding the role of ceramic coatings, and studying single crystals are proposed in order to understand the interfacial reactions that lead to instability of Ni-rich electrodes.

Most of the ceramic coating studies were reported in 2016. The reviewer pointed out the outcome is not new and the approach of the project is similar to the ones previously reported in articles. For example, it has already been shown that thicker alumina coatings (more ALD cycles) result in poor performance. This person also stated wet methods to apply the coating have been previously reported, and warned there is not much uniqueness in the approach of the project.

Regarding the single crystal work, the reviewer commented that the particles are synthesized, but characterization of these particles seems to be very challenging.

Though the project has emphasis on the details of the mechanism of interfacial reactions, this person said the report lacks solid discussions on the possible mechanisms.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer praised the excellent progress on understanding and tuning the properties of Ni-rich materials. The challenge was tackled from different aspects to obtain a whole map of accurate understanding. The person said the different coating effects of Al_2O_3 on NMC and LCO are discovered which is interesting and may be helpful for other materials modifications. Electrolyte decomposition has been studied and quantified which is critical to understand the interfaces. The reviewer pointed out the stoichiometry control of thin film NMC cathode by sputtering method may need to be addressed before any further modifications on as-prepared cathodes.

Reviewer 2:

The reviewer acknowledged this work made great progress on understanding effects of surface structure, Al coating and process history on the performance of electrode materials at high voltage.

Reviewer 3:

This person said the progress was mostly in the growth of the single crystal and for comparison to the model. The project results demonstrated an understanding of the parameters needed to effect crystal growth and then related the effect of crystal size, surface chemical composition and the particle surface facet.

Reviewer 4:

This reviewer commented it would be helpful to compare cycle life results of the materials synthesized in this program to commercially available materials. This person remarked more statistical rigor would also be useful.

Reviewer 5:

The reviewer noted the spectroscopy techniques used in surface studies are not necessarily novel, and it is not clear if any new feature in the existing techniques were developed with the exception that thin film samples providing more accurate and well-controlled data are used.

This person said the effect of ceramic coatings is already known, and the project should place more emphasize on understating the function of these coatings.

The reviewer commented that the single crystal work could provide valuable information, however, the feasibility of future experiments is not clear.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The person noted this project required excellent collaboration with the many teams involved in this project.

Reviewer 2:
This reviewer asserted the PI has collaborations with LBNL and NREL and that good team effort has been demonstrated.

Reviewer 3:
This reviewer said this work shows good collaboration and coordination with computational team and LBNL to understand facet effects on surface chemical composition and stability.

Reviewer 4:
The reviewer observed the project team is collaborating with different groups. More communication and exchange of results in regard to the ALD coating could be helpful.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer mentioned the proposed future work is well planned covering coating, cathodes, single crystal development and modeling as well as the electrolytes. It is suggested to integrate all the modifications on cathode materials into pouch cell design for further validation. This person pointed out the electrolyte work by another team needs to be accelerated to combine with coated Ni-rich cathode materials.

Reviewer 2:
This reviewer remarked that when studying the evolution of a coating (either Al- or T)-based), it would be great to determine the bulk solubility limit for Al or Ti substitution in NMC materials. This will help separate coating and doping effects when certain amount of Al or Ti is used to synthesize the targeted composition.

Reviewer 3:
This reviewer commented the future plans involve a lot of work with the other teams. The reviewer stated the statement was made by the PI that the target is titania-based coatings, but there was no clear explanation made on why the direction change. This person pondered whether the direction change meant that the Al coatings are being abandoned. That was not made clear to the reviewer.

Reviewer 4:
The reviewer observed that future plans are mainly focused on understanding the evolution of ceramic coatings, optimization of NMC thin films as a model system, and the completion of single crystal studies.

The use of titania-based coatings is suggested, but this should be given less priority compared to understanding the mechanism of alumina coating remarked this reviewer. It should also be noted that Ti unlike Al is a transition metal cation and might interfere with the performance of cell, and creates even more complications.

As mentioned by a reviewer, experimental methods necessary to study the single crystals should be planned according to the resolution needed to see the differences between different facets.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

This reviewer said this project is one of the key aspects of a larger project that will allow for improved battery performance.

Reviewer 1:
The reviewer mentioned that understanding electrolyte-surface interaction at high voltage is critical for battery materials development and help accelerate the EV adoption.

Reviewer 2:
This reviewer asserted that the project provides knowledge on the cathode surface reactions that lead to the degradation of LIBs, tries to find solutions to stabilize cathode surface/particles, and thus will accelerate the utilization of high-energy LIBs in automotive industry.

Reviewer 3:
This person commented this project supports the overall DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer noted this project is part of a larger project and the funding is shared.

Reviewer 2:
The reviewer said the resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 3:
This person asserted the project team has access to sufficient resources and collaborations in order to perform the proposed tasks.

Reviewer 4:
The reviewer concluded that ANL and other collaborating laboratories have all the required equipment and facilities to perform the project.

Presentation Number: es261
Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Overview
Principal Investigator: Dennis Dees (Argonne National Laboratory)

Presenter

Dennis Dees, Argonne National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

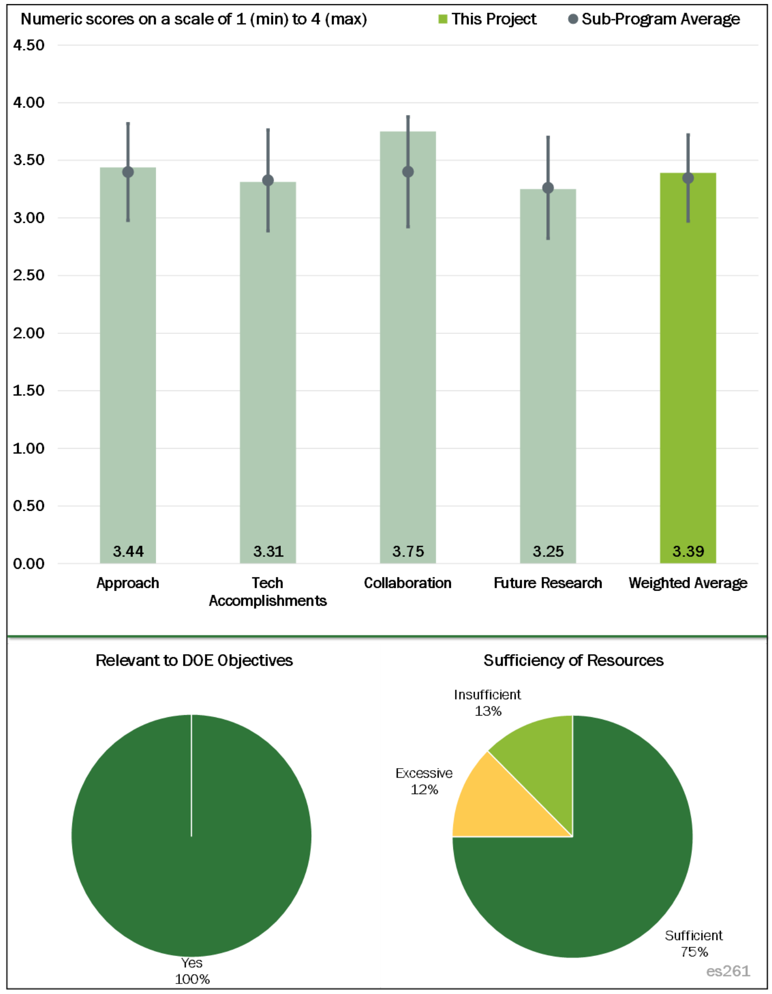

Figure 3-33 - Presentation Number: es261 Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Overview Principal Investigator: Dennis Dees (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked the project is an outstanding, comprehensive study on understanding Si in Li-ion systems.

Reviewer 2:

The reviewer expressed this is a very ambitious program to assess advantages, disadvantages and solutions for Si anode materials. It systematically investigates various aspects of materials, electrodes and use case scenarios.

Reviewer 3:

This reviewer observed the large multi-lab effort focused on overcoming cycling issues of high-capacity Si anodes, including silicon carbide (Si-C), particle size and Si SEI layer affects.

Reviewer 4:

This person praised the approach to performing the work as excellent. Detailed electrochemical and analytical diagnostic study plan are conducted. The anode advancements are verified based on full cell results which are rare in the community remarked this reviewer. The reviewer offered a few following suggestions. Firstly, because pack level benefits reach diminishing returns after 1,000 milli-Ampere hours (mAh)/cubic centimeter (cm^3) (Si with less than 75wt% graphite), the baseline may consider choosing Si (25%)/graphite (75%) in addition to 15% Si in the mixed anode. Secondly, the detachment of high Si content electrode from the substrate after cycling needs to be considered. Thirdly, because Si undergoes large volume change (i.e., increase of surface area after cycling), the impedance measured on the anode side always decreases, although SEI incured impedance increase accumulates with cycling. Therefore, this reviewer observed it is early to conclude that impedance rise on cycling is mainly at the positive electrode. More cross validation is needed to confirm this point. Fourthly, some of the team members used NMC while this poster uses NCM for Ni Mn Co. This has to be consistent within the team. Lastly, the reviewer questioned the ratio of electrode/electrolyte has been controlled when performing ARC testing and if that would be the possible reason for the large variation among different cells.

Reviewer 5:

The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

This reviewer commented that most aspects of the overall approach are very good. The scope of the project is wide ranging and comprehensive. This person noted the project attempts to address most major issues including particle size, choice of binder, methods of processing, nature of the SEI, important side reactions, etc.

The reviewer pointed out one weakness in the approach is that the commitment to doing publishable (i.e., public) work means that the project does not have full access to proprietary materials being developed by industry. It is possible that the first Si-containing materials to be incorporated into production cells will have been developed by industry and never evaluated in this “deep dive” effort. Given the tension between the goals of open publication and protection of proprietary information, this reviewer cannot suggest a solution to the problem, but the issue should be noted as a limitation on the scope of the work being done in this effort.

Reviewer 6:

This reviewer stated the multi-lab approach is quite comprehensive, addressing critical issues hindering the advancement of Si-C electrodes. One of the Remaining Challenges and Barriers” noted, “Particle cracking, particle isolation, and electrode delamination”, would require additional effort to measure the mechanical properties of the Si-based electrodes and adhesion between Si particles and polymer binders. This person mentioned the project may benefit from collaborating with researchers in the mechanics of materials community.

Reviewer 7:

This reviewer expressed the approach lacks focus to some extent. The binder is varied, but the fundamental stability of the Si is suspect in all cases as witnessed by impedance, gassing, cycling, and thermal studies.

The reviewer concluded the project would benefit from a study of the patent literature which shows a number of methods of stabilizing the Si in the presence of graphite or carbons. Perhaps one of these methods would be a better starting point than simply ball milling the mixtures.

Reviewer 8:

Although the study of Si-based materials is intrinsically of interest, this person commented the materials studied are not competitive with the most advanced Si anodes, such as those being produced by Amprius and Sila Nano. These companies are now producing at significant volumes and will be commercialized shortly. Instead, this person observed the sort of materials being studied seem unlikely to be commercialized.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer acknowledged the excellent progress on this challenging topic. The team evaluated different commercial sources of Si as well as their lab made Si model system to understand the fundamental mechanisms underneath. This person remarked there was a clear path to compare the results using standard protocols and the key issues that the team should focus on, while different tasks are assigned. There were many publications and presentations last year to disseminate the knowledge gathered. The reviewer observed more solutions need to be proposed in addition to the diagnosis approaches considering the large amount of published knowledge.

Reviewer 2:
The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

Based on the information in this poster, the reviewer concluded good progress is being made; and all critical milestones are being met. It is very clear that the benefits of Si-containing materials are balanced by the challenges of getting these materials to function in cells that meet the DOE's goals for cycle and calendar life.

This reviewer further commented that the large amount of work being done on many aspects of the materials by multiple labs, makes it challenging to absorb a full understanding of all of the results that are being obtained. Multiple, focused papers in the open literature serve to document specific areas of the total project. This reviewer hopes that an overall, coherent, review of all of the work and results will be prepared before the project ends.

Reviewer 3:
This reviewer asserted the project was on path to address its milestones/goals in a number of areas, showing good progress on understanding Si on graphite (Gr), SEI layer and particle size impacts, but noted it appears ORNL milestones have been delayed. The reviewer noted there were interesting results on Si-Gr cycling and Raman mapping of inactive Si.

Reviewer 4:
This reviewer acknowledged a great deal of very high-quality work has been done. Binder development is very important. This person was not sure how much the surface coating program is adding to the very large literature.

Reviewer 5:
This person observed this is an extremely large project. Certain areas are advancing more quickly than others. The presentation materials do not provide sufficient details on the “twenty-five milestones” for this reviewer to have a more complete understanding of the accomplishments and progress.

Reviewer 6:
The reviewer noted many interesting results were presented. However, the results seem to be mostly an initial evaluation and do not show progress along the multiple directions of investigation. This reviewer stated the work should be more iterative.

Reviewer 7:
This reviewer remarked that while there are some good results, they are overshadowed by the lack of stability of the Si in the experiments.

Reviewer 8:
The reviewer pointed out many, many issues both known previously and discovered have been presented. This person questioned whether there are actually solutions to these problems. Some perspective from the authors would be useful. The reviewer pondered how much more effort is needed to make high Si content electrodes feasible, whether it is worth the effort or if there are other (solid state with li-metal) more viable approaches.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer praised the terrific set of collaborators.

Reviewer 2:
This person remarked the whole team is collaborating very well with each other. Frequent communications and focused effort on the key challenges are demonstrated.

Reviewer 3:
This reviewer observed this was a multi-lab effort with numerous collaborative interactions.

Reviewer 4:
This reviewer noted that there are many collaborations that are excellent and pondered whether there are meetings of all of these collaborators to try to set directions of the program.

Reviewer 5:
The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

The person stated this poster and supporting information clearly shows the roles of the several national laboratories working on this effort. This poster also references other posters that are reporting aspects of the overall project.

The reviewer observed that while the poster does not document exactly how coordination is being done (such as meetings, teleconferences, or cross-lab staff), the implication is that the process is going smoothly.

Reviewer 6:
The reviewer said this program is a great example synergistic collaboration of national laboratories, and good use of their resources. However, it would be wise to include a commercial battery manufacturer, even if only for the feedback related to the practical use of Si materials. This person pointed out that effects such as gas generation during slurry mixing, cell swelling between charged/discharged states, calendar life etc. are very relevant in manufacturing and use of cells, but may be overlooked in early material development.

Reviewer 7:
The reviewer stated the project can be further enhanced by collaborating with experts outside the national laboratories, especially in the area of mechanical measurements, including coupled electrochemical-mechanical properties and interface adhesion.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

The reviewer noted this is a large, complex effort; but the proposed future work is reasonable to address the challenges of the material.

Reviewer 2:
This reviewer stated there was an appropriate continuation of effort, albeit with limited description.

Reviewer 3:
This reviewer praised the outstanding suite of diagnostics, but noted concern that state-of-the-art Si compounds are not on the horizon.

Reviewer 4:
The reviewer expressed that the future work is planned in detail with many milestones in each institution. While the direction is correct, this reviewer had a few comments on the proposed research. The reviewer suggested that whether or not polypyrrole (PPy) can be used for Si/graphite with significant improvement needs to be determined. Otherwise, PPA or LiPPA will be worth more effort. ALD or MLD coating has been explored for many years. Considering the cost and the effects of coating, will this technique be eventually adaptable by industry needs to be answered. The reviewer stated that probably a few communications with industry can help determine the go/no-go on this coating approach, or whether alternative coating methods should be planned. The reviewer also recommends 25% Si be included in the map because 15% Si still cannot meet the goal according to the PI's simulation results.

Reviewer 5:
The reviewer observed that one of the Remaining Challenges and Barriers namely “Particle cracking, particle isolation, and electrode delamination” is not addressed under “Future Work.”

Reviewer 6:
This reviewer recommended more iterative than exploratory research.

Reviewer 7:
The reviewer would like to see a real effort to review the literature (including patent literature) to find a better starting point for the project, particularly with respect to protecting and stabilizing the Si surface from the processing steps.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer noted improved battery performance will advance vehicle electrification and thus displace petroleum consumption.

Reviewer 2:
This person stated this project supports the overall DOE objectives.

Reviewer 3:
The reviewer expressed that a high-energy anode is very much in support of DOE objectives.

Reviewer 4:
The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

This reviewer noted it is generally agreed that to meet the DOE's goals of reduced cost and improved energy density and specific energy, cells incorporating new materials and fabricated using new manufacturing techniques will be required. Current Li-ion technology has maximized the performance of “standard” graphite electrodes. Further improvement in the negative electrode's performance will require new materials such as Si or Li metal remarked the reviewer. This project addresses this need for new materials.

Reviewer 5:
This reviewer stated the project was highly relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said the national laboratories have more than sufficient resources to conduce the project.

Reviewer 2:
This reviewer noted the large lab effort results in large overall budget, albeit split among the labs.

Reviewer 3:
The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

This reviewer said the large number of cooperating laboratories means that this project has access to an extensive set of facilities and a large group of knowledgeable scientists and engineers. The budget, of $3.6 million for FY 2017 reflects the large scope of the project.

This reviewer stated there is no question that facilities and staff should be adequate. No financial details are provided, but the reviewer inferred that the funding is adequate to support the facilities and staff.

Reviewer 4:
The reviewer observed the team has accomplished a very large amount.

Reviewer 5:
This person said the resources were okay.

Reviewer 6:
This reviewer mentioned mechanical property measurements may be added.

Presentation Number: es262
Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Fundamental Studies of Si-C Model Systems
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

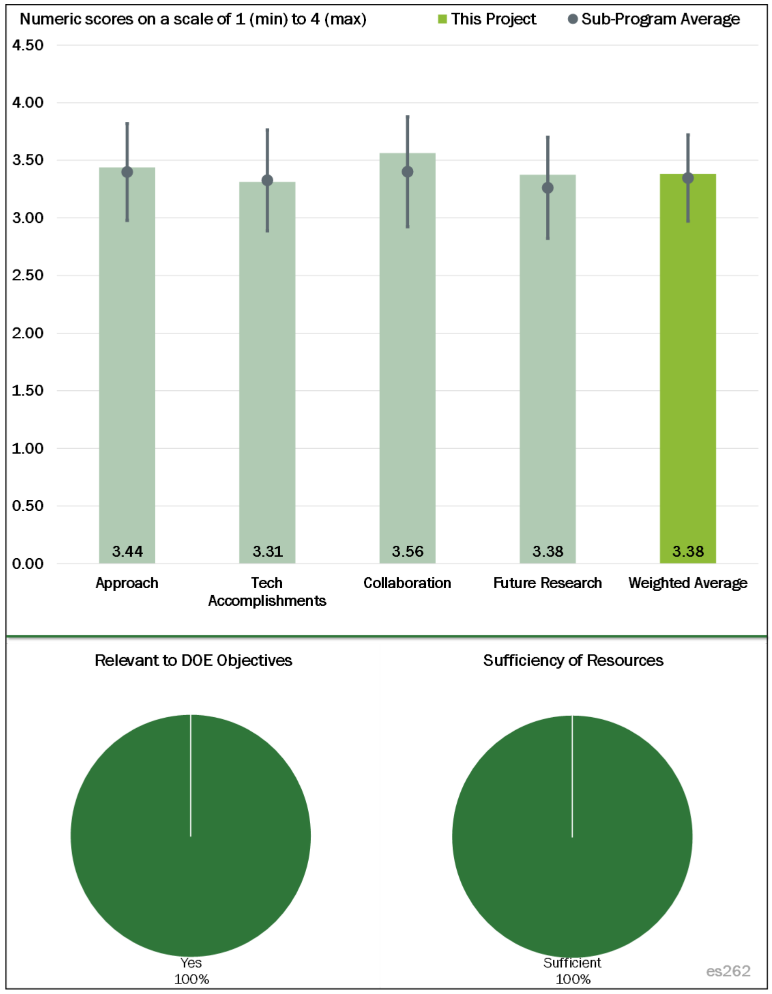

Figure 3-34 - Presentation Number: es262 Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Fundamental Studies of Si-C Model Systems Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter

Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer stated the mechanical properties of the binders in electrochemical environment are known to be important and should be measured.

Reviewer 2:

The reviewer noted this project as an interesting fundamental approach to the real, practical issue of binder selection for Si based systems.

Reviewer 3:

This person concluded the project was a very thorough effort to understand and mitigate the problems of Si-C anodes. It is very well-integrated with other advanced anode projects.

Reviewer 4:

The reviewer said Si anodes are a critical enabler to achieve DOE goals for energy storage. The approach, systematic and in collaboration with other national laboratories, seeks to address many of the technical barriers that Si anodes still have to pass to become a practical anode material.

Reviewer 5:

This person observed the project team was working on addressing issues of high-capacity Si anodes while focused on model Si electrodes and the effect of binders, including *in situ* and *ex situ* characterization.

Reviewer 6:

The reviewer noted that this poster covers only a part of the work being done in the overall project on the development of Si materials for use in Li-ion cells. It is possible that concerns mentioned in this review are adequately addressed in other presentations which were not reviewed by this reviewer.

The reviewer affirmed the overall approach is systematic and reasonable. Results provide a basic understanding of issues associated with Si electrodes and binders. This person pointed out that because most of the reported research was done on model systems, the results may not always reflect what happens in production cells. This fact should be recognized, but it does not invalidate the work reported. The reviewer further acknowledged it might be or would be difficult to impossible to make the basic measurements reported in this poster on production cells.

Reviewer 7:

This reviewer asserted the PI is using a model of the Si/PPy electrode to understand the binder effects for a Si anode. Binder is known to be very critical for Si anode. The person commented the project provides very good understanding on the interactions among Si, binder and electrolyte. The adhesion ability of polyacrylic acid (PAA), PPy and as polyvinylidene fluoride (PVDF) binders to Si wafer are compared systematically. The reviewer observed processing conditions are revealed to largely affect the binder adhesion. This person suggests the project team investigate the binder adhesion to Si after cycling. The reviewer pondered whether PPy will still provide good adhesion of Si and Cu after repeated cycling. For the purpose of evaluation of PPy stability under electrochemical reactions, this person suggests the project team to use PPy mixed with carbon.

Reviewer 8:

The reviewer remarked the approach using a Si wafer is a good one to obtain fundamental information regarding the Si/binder interface because a number of experimental methods are now possible that would not be useful for particulate Si such as attenuated total reflectance geometry Fourier transform infrared (ATR-FTIR) spectroscopy and atomic force microscopy (AFM). This person would have been happier to see a conventional binder such PVDF used rather than the PPy, which has not been characterized for such properties as molecular weight, degree of polymerization (such as is this a copolymer with PAA), etc. This reviewer also noted it is important to establish the absorption of electrolyte into the polymer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This person said the project team prepared model Si electrodes and evaluated interfacial phenomena with binders, from *in situ* spectroscopic and electrochemical analysis to mechanical properties. The reviewer concluded the results were on track with regard to milestones.

Reviewer 2:

The reviewer said the data presented in the report are clearly presented and analyzed, including results that may not be considered positive toward a practical solution. However, they are relevant to understanding the mechanisms and interactions between Si materials, binders and electrolyte. This person pointed out this study not only determines the mechanism of PPy interactions in composite Si electrodes but also offers insights into rational design principles of advanced multifunctional binders for intermetallic Li-ion anodes.

Reviewer 3:

This reviewer asserted that all deadlines seem to have been met in a timely fashion. Progress is appropriate.

This person remarked that this part of the larger project is clearly designed to focus on “Fundamental Studies.” These studies will produce data that will improve the understanding of Si-C systems. Because the studies are “fundamental” in their scope and design, the reviewer pointed out additional work will be required to transition these results from “model systems” to production cells. To the extent that DOE goals are focused on production cells, this project is one (or more) step(s) removed from having direct applicability to meeting these goals.

However, the reviewer stated it is reasonable to assume that other efforts within the larger project will help with this transition.

Reviewer 4:
This reviewer concluded the results themselves are really excellent for this project. This person was especially impressed with the studies on conducting binders.

However, the Si anodes closest to commercialization (and they are very close) are not mentioned. These are the anodes produced by Sila Nano and by Amprius, both of which should be available in electronic devices within about a year. The reviewer concluded ignoring these products is an important shortcoming of this project.

Reviewer 5:
The reviewer observed results were presented at many conferences, though there were few peer-reviewed publications. The PI should publish the results in peer-reviewed journals to disseminate the results the reviewer commented.

Reviewer 6:
This reviewer noted that some new findings on the binders are uncovered, providing new insights on the effects of binders on Si anode performances. This project concluded that the intake of diethyl carbonate (DEC) solvent by PPy causes the formation of instable SEI on Si. Because the amount of PPy to be used in practical electrode will be much less than in the model electrode, this person pondered whether the DEC intake effects will still be a big concern. The AFM imaging may help extract the thickness information of SEI layers at different potentials. For this reviewer, it was hard to tell the difference in Si/PPy electrode below 2.25V simply from a morphology point of view.

Reviewer 7:
As in the approach, this person was concerned about the use of PPy as the test material rather than a more well studied binder such as PVDF. The reviewer agreed that an aqueous based binder can give problems of oxidation of the Si surface, particularly for nanoparticle Si, which will lead to a very high level of irreversible capacity.

Reviewer 8:
The model system (Si wafer) is interesting but this person wondered whether it is a practical representation for actual electrodes. The reviewer pondered if the binder coating on Si-particles is conformal and questioned if the results would be substantially different if the coating was patchy.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer observed this program is interfaced with a number of other efforts to make Si work to give something like 1,000 Ah/kg activity in a carbon Si electrode, so the project features excellent collaboration with other institutions.

Reviewer 2:
This person noted that this project involves multiple laboratories and many scientists and engineers and this poster indicates how this particular project fits into the collaborative effort.

Reviewer 3:
The reviewer said there was good collaboration with other team members. The binder was supplied by Gao Liu at LBNL.

Reviewer 4:
This reviewer acknowledged the project was collaborating with a number of national laboratory groups/PIs.

Reviewer 5:
This reviewer commented there is a huge list of contributors, but there is no indication of the extent of their involvement in the project. Extensive interactions with other national laboratories were noted by this person.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer praised the excellent well described future research in three thrusts.

Reviewer 2:
This person stated the three areas of research planned address well the directions of work toward project goals.

Reviewer 3:
The reviewer stated this is an ambitious, but worthwhile proposal for future work.

Reviewer 4:
This person observed the proposed future research is described well in multiple slides.

Discussion of future work does not provide details on how these fundamental studies will be used to help guide the development of production-type cells.

Reviewer 5:
This reviewer concluded these were well thought-out plans, but there is no mention of the most likely winners in the race to produce commercial Si anodes.

Reviewer 6:
This person remarked the PI provides very detailed future work plan which is also well integrated within the whole focus team. The binder effects in the X-Y directions of the electrode (currently it is focusing on Z-plane i.e., perpendicular to the Cu substrate) also needs to be considered, which is very critical for thick Si-C electrodes. The reviewer said the project team needs to determine if PPy will be eventually employed in the final deliverables or if PPA will be adopted. Alternatively, electrolyte recipes may need to be altered to best match PPy binder.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This person pointed out improved battery performance will advance vehicle electrification and thus displace petroleum consumption.

Reviewer 2:
The reviewer noted this project systematically investigates the binder effects for Si anodes. Model systems help much towards the accurate understanding of the system. This person concluded the project supports the overall DOE objectives.

Reviewer 3:
This reviewer commented it is generally agreed that to meet the DOE's goals of reduced cost and improved energy density and specific energy, cells incorporating new materials and fabricated using new manufacturing

techniques will be required. Current Li-ion technology has maximized the performance of “standard” graphite electrodes. The reviewer said further improvement in the negative electrode's performance will require new materials such as Si or Li-metal. This project addresses this need for new materials by investigating fundamental processes in Si-C model systems.

Reviewer 4:
This person asserted the project was clearly relevant.

Reviewer 5:
This reviewer said yes, Si anodes can enable high energy density and specific energy batteries that will increase the adoption of electric vehicles.

Reviewer 6:
This reviewer expressed the project was okay to the extent that these sorts of electrode materials are not made irrelevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer concluded the staff and facilities at LBNL in collaboration with the other laboratories and scientists working on this project are clearly adequate to do the proposed work.

Although detailed financial data are not included in the poster, this reviewer assumed from the progress that is being made that the funding is adequate.

Reviewer 2:
This person mentioned that LBNL has sufficient facilities to carry out the proposed work including synthesis and characterizations. In addition, the PI has collaborations with other institutions and thus access to the equipment that may not be immediately available at LBNL.

Reviewer 3:
The reviewer stated the resources were appropriate given budget limitations.

Reviewer 4:
This person said the resources were okay.

Presentation Number: es263
Presentation Title: Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing
Principal Investigator: Stuart Hellring (PPG)

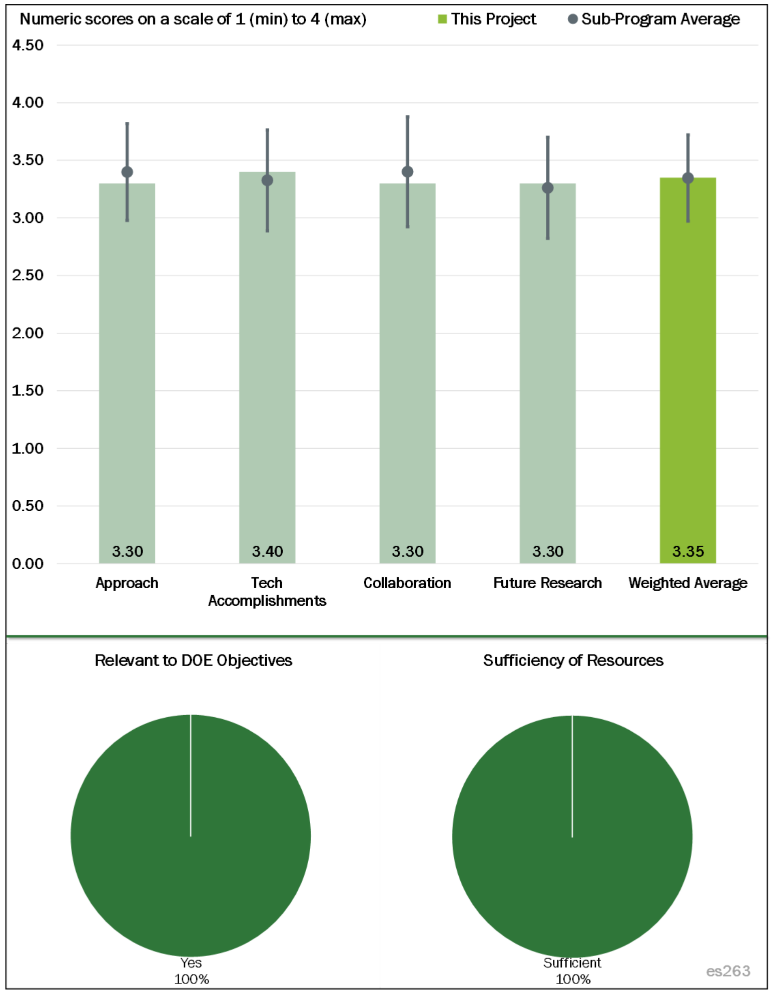

Figure 3-35 - Presentation Number: es263 Presentation Title: Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing Principal Investigator: Stuart Hellring (PPG)

Presenter

Stuart Hellring, PPG

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said the approach for deposition of Li-ion electrodes from water is very unique. Many of the previously recognized barriers and problems can be effectively overcome with the proposed steps.

Reviewer 2:

This reviewer stated that the project “Gant-Chart” included in 2016 poster slide-deck and reference in 2017 editions reveals a well-considered program, with logical time-lines assigned for each established milestone event/task. Initial experimental work demonstrates the adequacy of this planning process, although this person remarked it would be useful to include task assignments for all participants in this effort.

Reviewer 3:

The reviewer asserted the water based electrodeposition is very attractive approach. It would help if practical challenges (which are significant) to achieving this are better outlined.

Reviewer 4:

The reviewer observed that battery performance is limited to only 50 cycles. Even at C/3 rates this would only be a 10-day test. This person would like to see more electrochemical testing. The reviewer does not think 50 cycles are far enough to determine there is no loss in cyclability long term (especially for automotive long term). This reviewer said the project seemed to demonstrate a good approach to improving coating performance, but having only one material show good discharge capacity after 1-15 cycles even though materials should be similar from different vendors is not encouraging. It was difficult for this reviewer to determine if the project team understands the underlying mechanism for the one good result. The project talked about additional active material coatings to avoid Li leaching, but this person’s preference is for the manufacturing process to adjust to suit the material that performs well electrochemically, rather than have a material that needs to be modified (and possibly affect electrochemical performance) in order to be processed. It is still unclear if production rate even with double sided coating will be fast enough to overcome the slow nature of the electrocoat process. This reviewer understands that it is “tunable” but there has to be an upper bound for coating speed, and this person cannot judge if that is acceptably fast or not.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked that the work is progressing in reasonable agreement with the initial work schedule. Besides selection of a material set, the process has demonstrated feasibility of the electrodeposition process in coating battery substrate materials. This reviewer noted that many process hurdles and challenges remain to be addressed (e.g., coating homogeneity, dual-side coating, etc.) and significant challenges are expected as the process is scaled to a “larger size-scale”.

Reviewer 2:
The reviewer would appreciate more focus on demonstrating good cycling and rate capability for extended time. While the reviewer understands that this is still part of the work plan so may be a non-issue, this person stated it would be nice to know if it's an issue as soon as possible.

Reviewer 3:
This reviewer considered if there is a way to more fundamentally understand the differences observed between different NMC supplies.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer asserted that the project team reports considerable interaction between PIs at ORNL, ANL and private industry (PPG and Navitas) as well with SMEs from other sectors.

Reviewer 2:
This person noted that collaboration exists and is described in the poster, but, if possible, the developer and supplier of active material should be more deeply involved in the solving of some questions, such as why only one active material from the variety of similar types can be used effectively.

Reviewer 3:
This person mentioned that collaboration with battery makers may strengthen this project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted the original schedule contains relevant metrics for years 2 and 3. However, review of FY 2016 presentation poster “slide-deck” does not indicate any edit to original milestone events. Instead, the reviewer commented this document, which is a “living” document, should be routinely updated to address envisioned new knowledge, as the project progresses. Presentation of “future” effort is presented, but it seems overly broad and high level. The reviewer said additional details would have been very useful.

Reviewer 2:
The reviewer recognized this question should have been asked during the review, but now wonder if PPG is doing any work towards electrocoating anodes as well. If there is a truly compelling reason to replace the traditional coating equipment with electrocoat maybe there is a future application for this technology, but if the end goal is to only replace cathode coating the traditional coating equipment would still be required for anode, then the full (proposed) cost and factory floor space savings would not be realized, needing two coating systems in one factory. If anode electrocoating is planned, this person pondered whether this would be easier than cathode considering no Li leaching, or whether there is a reason a materials anode electrocoat process would not work. (The reviewer apologized for not thinking of this during the discussion).

Reviewer 3:
The steps are correct but this reviewer was concerned that without more and deeper understanding of the fundamentals (difference in performance between commercial materials, effect of residual moisture, uniformity of deposited layers, etc.) scale-up will be difficult.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer remarked that assuming cost projections are accurate, any cost reductions will help. This project seems like it has a long way to go in development compared to the highly optimized methods currently used for coating at speed. Also, the reviewer pointed out a need to understand the failure mechanisms the project team is seeing, because if it only works with a small number of active materials the investment will not be appealing compared to a more flexible process.

Reviewer 2:
The reviewer stated that the introduction of LIBs within the transportation sector will result light-weighting of designed vehicles which serves to conserve energy, whether it be petroleum or other based energy source. However, this project is one which is focused on energy storage, regardless of generating source. Further, the reviewer noted this project is more focused on enabling a more cost-competitive process route which can be used to manufacture batteries. Thus, this person concluded this project is more focused on process cost than petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This person concluded the project seems fully supported.

Reviewer 2:
The reviewer said the project team represents a collaborative effort between national laboratory and private industry. As such, researchers have access to a wide variety of tools and resources to support conduct of this effort.

Presentation Number: es264
Presentation Title: Li-Ion Battery Anodes from Electrospun Nanoparticle/Conducting Polymer Nanofibers
Principal Investigator: Peter Pintauro (Vanderbilt University)

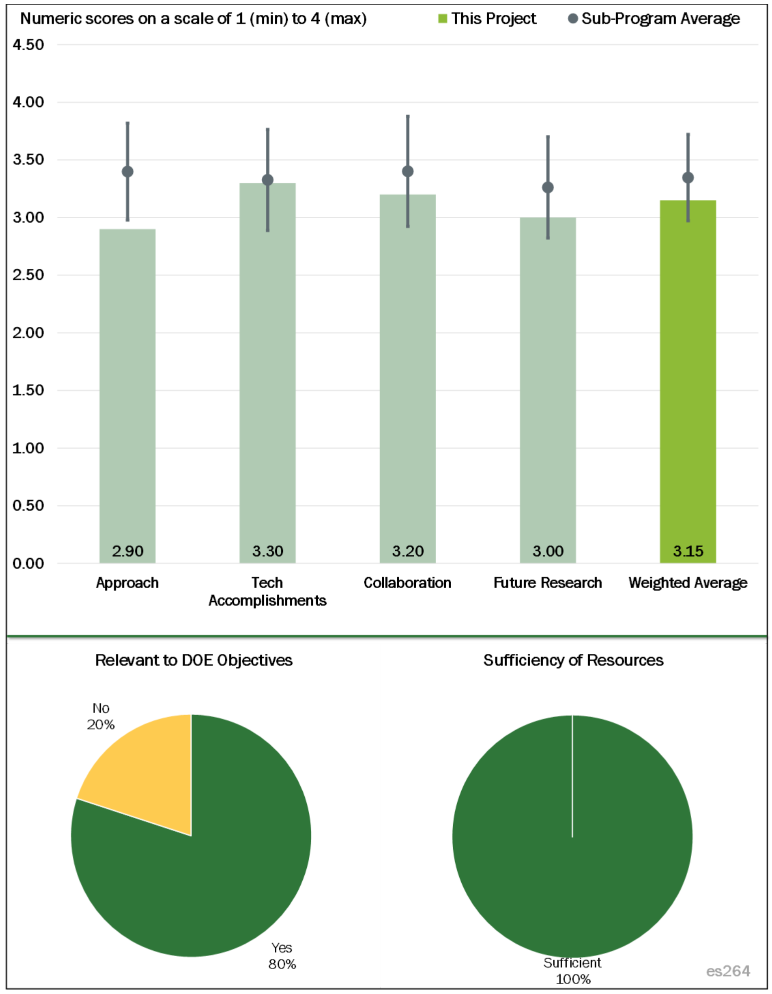

Figure 3-36 - Presentation Number: es264 Presentation Title: Li-Ion Battery Anodes from Electrospun Nanoparticle/Conducting Polymer Nanofibers Principal Investigator: Peter Pintauro (Vanderbilt University)

Presenter

Peter Pintauro, Vanderbilt University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer commented collaborative laboratory and private industry team is addressing well defined issues germane to battery technology. Among the issues are performance impact due to binder system, density, thickness, Si content, conductivity etc. The reviewer affirmed the project has been designed to address all in logical fashion, gaining valuable knowledge with each milestone event.

Reviewer 2:

This reviewer asserted that it seemed like a highly promising approach. The reviewer inquired about the long-term cycling result (e.g., 1,000 cycles) and the degradation mechanisms.

Reviewer 3:

The reviewer mentioned the project currently has achieved 750 mAh/cm^3 volumetric capacity with a final target of 800 mAh/cc for the anode only. This person would not expect full cell volumetric energy density to meet goals. For example, USABC goals for anode active materials is 1,800 mAh/cm^3. While it may be acceptable on a gravimetric basis, many automotive engineers would argue that having enough space for the battery is more difficult than enough volume. This reviewer said there are ways to make a more traditional Si anode more porous than is currently designed that could use the same equipment and processes that are already place, but are not pursued by cell manufactures because the resulting impact on energy density is untenable. This seems to be a further extension of that potential design, but to an extreme and using new equipment. The reviewer observed that current densities for most tests is also very low, and this person has questions about manufacturing this at a scale that would support vehicle production volumes at a reasonable price. There is very high content of inactive materials (conductive additive, binder).

Reviewer 4:

This reviewer pointed out the main failure mechanism of Si based electrode is the intrinsic mechanical fracture from Si. Nanofiber mats will not provide an effective mechanical protection, or otherwise, the team did not state clearly how the nanofiber mats can improve the cycle stability.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This person said solving issues with Si anode would greatly enhance commercial viability of electric vehicles.

Reviewer 2:

The reviewer commented that the project team has made significant discovery regarding most all variables laid out in the project planning stage. Relationships have been established between density, capacity, anode/cathode mat type (slurry versus fiber), etc. This person acknowledged that significant information has been gained regarding alternative polymer systems being used and process approaches to yield a range of fiber physical characteristics. It does seem that electro-spinning to create fine-dense fiber mats offers a unique approach to fabricate functional anode/cathode systems for an LIB. The reviewer would suggest that in addition to work current within the project that scale-up approaches, such as roll to roll be considered. Overall, the project team is meeting milestone events, on-schedule and finding positive results which justifies the effort done and envisioned for this project.

Reviewer 3:

This reviewer mentioned the program seems to meet goals laid out at beginning of project, but this person is not sure those goals are good enough to meet ultimate DOE goals.

Reviewer 4:

This reviewer warned that the testing results did not show the cycle efficiency, which could be most important in order to see the improvement.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer noted the project team reports considerable interaction between PIs at Vanderbilt University, ORNL, LBNL and private industry i.e. e-Spin Technologies, Inc., as well with SMEs from other sectors.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the project team describes a sound set of endeavors to investigate over the next time-period. Each will add to the knowledge base for this technology application, which will prove very positive. However, this person stated a review of all work to-date should be conducted and then compared to work accomplished by other researchers. It seems that the wealth of knowledge resulting from this effort will allow for establishment of new priorities and paths to follow. The reviewer asserted that this revised roadmap should then be integrated into the work plan, accordingly.

Reviewer 2:

This reviewer stated volumetric energy density should be considered, or the porosity of the nanofiber mats should be controlled in order to meet DOE's required volumetric energy density.

Reviewer 3:

This reviewer observed that it seems difficult to build actual cells with any power capability, no current collector. Highly porous nature of electrode means more intimate contact with electrolyte. This person mentioned that SEI growth is already a big problem for Si anodes, and it would seem a great deal of effort will need to be focused on forming a highly stable SEI layer or electrolyte-Si compatible pair that will not lead to high impedance growth and loss of capacity. Even if there is room for Si to grow, the reviewer pointed out the SEI will still crack and be in very intimate contact with electrolyte for further degradation. Longer cycling tests needed to demonstrate automotive capability.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer asserted that the introduction of LIBs within the transportation sector will result light weighting of designed vehicles which serves to conserve energy, whether it be petroleum or other based energy source. However, this project is one which is focused on energy storage, regardless of generating source.

Reviewer 2:

This reviewer said improvement in anode remains one of the key challenges for widespread adoption of battery powered vehicles.

Reviewer 3:

This reviewer pointed out the cost advantage is not demonstrated, energy density advantage negated on a volumetric basis. The use of Si does not guarantee a high-energy density electrode if the design is highly porous and has high percentages of inactive components.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed that the collaborative laboratory team has access to a wide variety of tools and resources to support conduct of this effort.

Presentation Number: es265
Presentation Title: UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of Lithium-Ion Battery Electrodes
Principal Investigator: John Arnold (Miltec UV International)

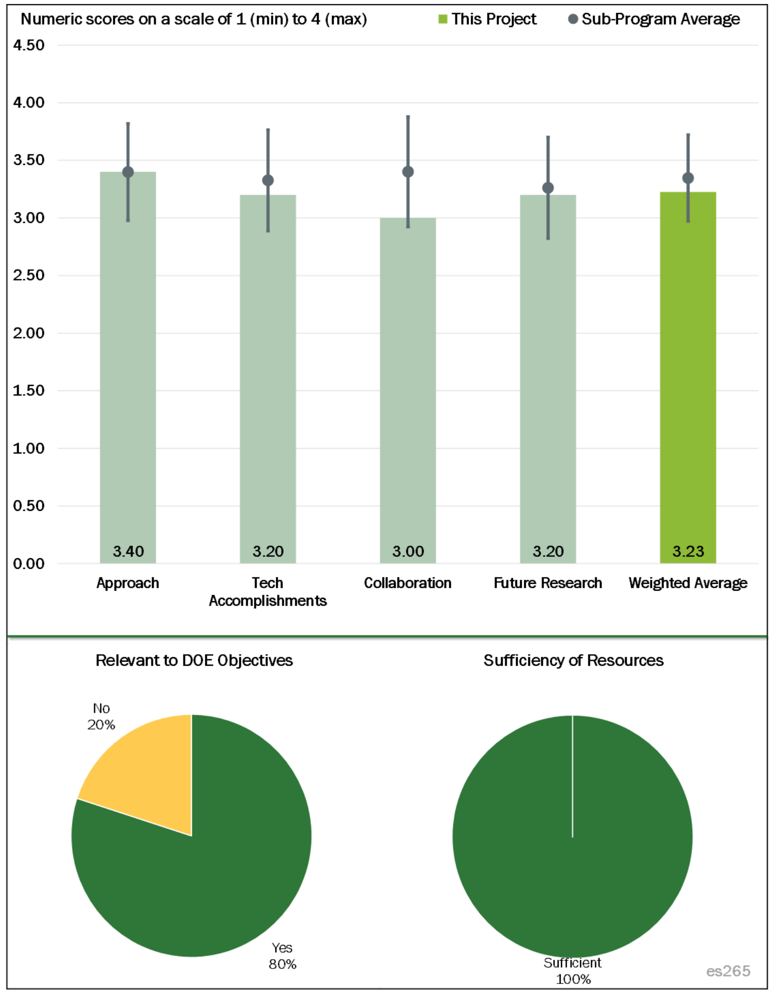

Figure 3-37 - Presentation Number: es265 Presentation Title: UV Curable Binder Technology to Reduce Manufacturing Cost and Improve Performance of Lithium-Ion Battery Electrodes Principal Investigator: John Arnold (Miltec UV International)

Presenter

John Arnold, Miltec UV International

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer loved the approach of using printing technology and ultraviolet (UV) curing to decrease cost of manufacturing and possibly increase performance of electrodes. The use of multiple layers to enable thicker electrodes is good, and has a secondary benefit of allowing for the possibility of gradient-type electrodes in which the formulation of different layers is changed.

Reviewer 2:

This reviewer praised the interesting work to reduce the cost of battery.

Reviewer 3:

This reviewer expressed that UV curing is attractive approach if it can be made practical.

Reviewer 4:

The reviewer asserted that UV curable binder technology could be significant advantage over conventional drying process in size and cost of capital equipment as long as there is minimal additional cost of precursors. Approach is to demonstrate efficacy of this.

Reviewer 5:

This reviewer commented that the initial project design incorporated a path to investigate potential means to discover polymer system which would outperform current generation materials at a lower overall manufacturing cost. As such, schema was developed to investigate alternative UV cure materials at same and lessor polymer content using processes which could offer greater throughput capacity at lessor cost. This person said the basic project outline was well-considered, providing a path to investigate representative state-of-the-art UV polymer system in such manner as to enable valid comparison to current state-of-the-art processing. Work plan was established so as to limit degree of equipment modification needed to perform experiment work, allowing experimental effort to be performed using existing facility and equipment. The reviewer concluded that work plan and milestones were established which were reasonable and per DOE Office of Energy Efficiency and Renewable Energy (EERE) APM, go/no-go events were established.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
This reviewer observed that this work determined that UV polymer systems can be used to substitute for existing materials, whether processed using a single side or dual side coating approach, when applied at 1 micron (μ) thicknesses. Although discussion regarding extent of polymerization, variation of coating thickness and compositional homogeneity, deposition process rate, etc. is presented, this reviewer commented that only very limited detail is presented. Details presented do not show any distinct advantage to using the process approach under investigation, other than a brief discussion regarding "cost". However, the reviewer noted that not presented is comparable cost involved to enable dual-side traditional polymer coating system or the capital expenditure cost for UV cure processing systems. Thus, this reviewer concluded although the project appears on-track in accomplishing established milestones, there is no go/no-go event requiring a decision whether or not to continue this endeavor, based on a Technology-Economic Analysis (TEA) of the proposed process approach.

Reviewer 2:
This reviewer pointed out that initial results indicate this approach is comparable or possibly better than conventional, however, additional data are necessary (two points to make a line e.g., Slide 11 is not sufficient).

Reviewer 3:
This reviewer has a concern about the need to calender these electrodes so highly in order to get adequate electronic contact. The project team might consider some kind of carbon-rich coating of the current collector. Another concern the reviewer brought forth is that testing of the films produced so far seems sparse (repeated testing would allow error bars on the data so there is indication that results are not just for the single "best case"). This person would like to see the project team get samples in the hands of other researchers so the products of the manufacturing process can be more rigorously tested and publicized at conferences.

Reviewer 4:
This reviewer concluded there was good technical accomplishment for NMC cathode with UV binder, stable capacity with cycle.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated the project team reports considerable interaction between PIs at ANL, ORNL and private industry i.e. Miltec UV International, as well with SMEs from other sectors.

Reviewer 2:
The reviewer said it looks like good collaboration with ANL and ORNL to validate results.

Reviewer 3:
This person noted it appears to be two individuals at national laboratories who tested films. There should be more testing done.

Reviewer 4:
This person concluded additional collaboration with battery makers would strengthen this project.

Reviewer 5:
This reviewer said the project needs more collaboration.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer affirmed the project team presents some very "high-level" next steps and challenges which to investigate during the next funding period. Greater detail needs be provided to allow for better understanding of how and the rationale behind the proposed effort. The reviewer commented this should be provided to assure reviewers that work is being performed for a justifiable reason.

Reviewer 2:
This reviewer said the future work is appropriate, especially the need to demonstrate with thicker coatings, but this person would like to see more validation of results as well efficacy with different electrode materials.

Reviewer 3:
This reviewer liked the idea of using letterpress as well as slot die technologies, as well as attempts to decrease additive load. Plans to do long-term cycling are essential remarked the reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer asserted that improved batteries will advance vehicle electrification and thus help displace petroleum.

Reviewer 2:
This person confirmed reducing battery manufacturing cost would significantly benefit adoption of battery powered vehicles.

Reviewer 3:
This reviewer concluded the project is relevant because batteries are used for EVs and PHEVs.

Reviewer 4:
The reviewer said this work improves U.S. technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 5:
This reviewer cautioned that on the surface, the effort comes across as one which is more focused on manufacturing cost and not an approach which increases manufacturing sector capacity.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted the collaborative laboratory team has access to a wide variety of tools and resources to support conduct of this effort.

Reviewer 2:
This reviewer concluded the resources were appropriate given budget limitations.

Reviewer 3:

The reviewer remarked this is a fairly expensive project, compared to others.

Presentation Number: es266
Presentation Title: Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing
Principal Investigator: Ranjeet Rao (PARC)

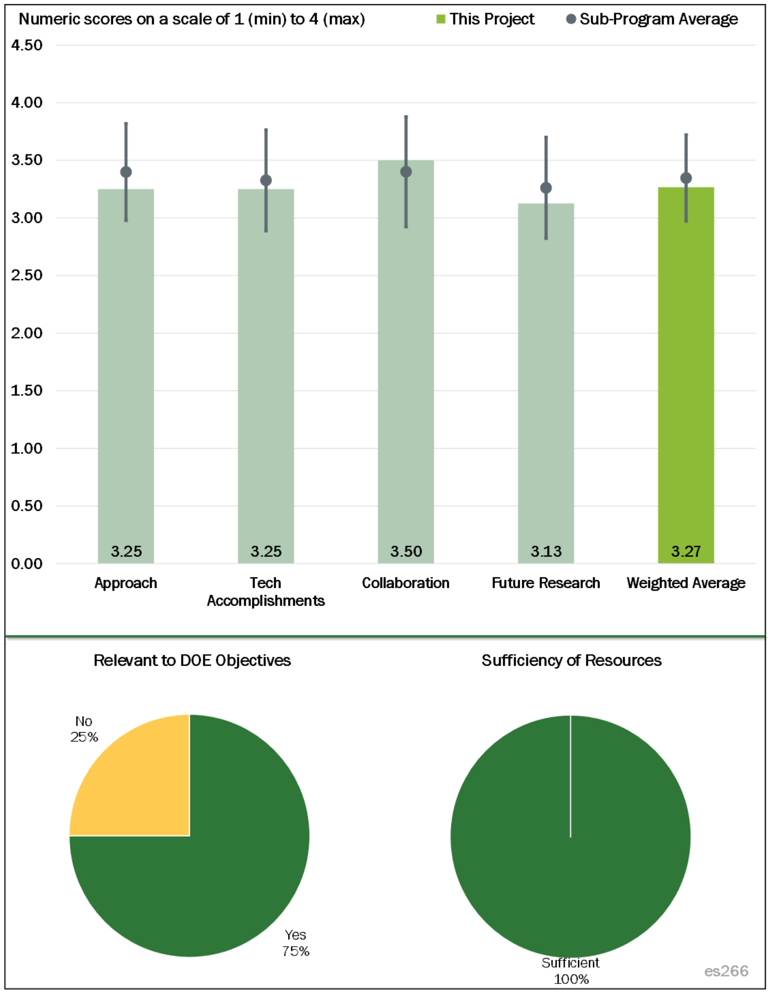

Figure 3-38 - Presentation Number: es266 Presentation Title: Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy-and-Power Battery Electrode Manufacturing Principal Investigator: Ranjeet Rao (PARC)

Presenter
Ranjeet Rao, PARC

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer was surprised to see calendered electrode still showed performance advantages of peaked electrode. The person was glad to see matching anode has been determined and that option 3 takes into account concerns for volumetric energy density penalties. The program seems to be making good progress.

Reviewer 2:
This reviewer acknowledged the approach of the project was to focus on a way to implement a concept that allows for the use of thick anodes and cathodes via a co-extrusion method. The process required work on binders and conductive additives. The reviewer commented that the technical goal of a thick crack free anode was clearly spelled out as well as the performance targets.

Reviewer 3:
This person said the approach to make a high-energy and high-power electrode via interdigitated design to increase surface area and thick electrode to increase energy density is very reasonable. The reviewer warned that regions of high porosity mixed with regions of low porosity in the interdigitated electrode will result in uneven current density and possibly lead to Li plating on the anode.

Reviewer 4:
This reviewer stated the research team is focused on process approaches to drawing/processing thick films of PVDF composite materials. As such, this work involves use of established thick-film process technology to support drawing LIB anodes/cathodes/etc. This person recognized that LIB materials sets represent relatively new application technology area for the selected process, but it needs be noted that analogous industries have been processing like-type films for a range of electronic applications for decades. The use of a “print-head” that is pressure-fed higher solids-loaded slurries to process thick-films is a logical casting, a reasonable

approach, and should prove successful. Of course, as processing cost is a major objective for this project, the reviewer asserted cost-savings will only be had after volume manufacture and commercial scale-up. What is not presented is how this process approach creates a means to save significant process cost when compared to other continuous processing approaches, such as slot-die (single- or multiple-pass), etc. This person noted that casting thick-films of dielectrics and piezoelectrics at thickness at and greater than, for current commercial products is commonly accomplished employing similar approaches. In fact, PVDF is commonly used in large scale for piezoelectric applications. This reviewer hoped that common industry practices for these applications would have been studied in developing the overall statement of work for the project. Regardless, the reviewer concluded that there needs be a comprehensive TEA conducted to determine if this justifies federal investment.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer commented the project team co-extruded calendered electrode based on the corrugated electrode modeling design and demonstrated significant advantage over a conventional electrode with comparable thickness. The project team needs to address the internal short risks associated with loose foreign object damage particles from the co-extruded electrode. Based on the half-cell data, this reviewer mentioned the project team should provide cell level power density (W/L or W/kg) projections of their corrugated thick electrode.

Reviewer 2:

The reviewer commented the results presented relative to conventional cells show significant improvement with the process however, actual values would have been more helpful. The work on identifying a suitable anode to move forward with was excellent, and the demonstration of results in a 1 Ah full cell was good. It was not clear to this reviewer from the material presented however, if either or both the cathode and anode had been through the co-extrusion (CoEx) process for the cell, nor what the thickness was prior to calendering.

Reviewer 3:

This reviewer said materials have been successfully processed which have supported process into battery systems. Testing has demonstrated that the likelihood of success remains high and that regardless of achieving cost related objectives, the approach should enable near equivalent manufacture of assemblies with performance similar to current commercial approaches. This reviewer raised concerns regarding ultimate quality of cast films, especially as thicknesses are increased, that need to be more comprehensively addressed. In other industries, this is often an issue relating slurry solids loading, solvent selection and rheology. This person suggests that these variables be addressed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer exclaimed the team put together for this project was excellent! It included an automotive original equipment manufacturer (OEM) and a battery supplier.

Reviewer 2:

This reviewer affirmed there was good collaboration and that the roles of each collaborator were specified.

Reviewer 3:

The reviewer observed the project team reports considerable interaction between PIs at Ford, PARC, and Navitas Systems, as well as with SMEs from other sectors.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This reviewer was very pleased to see plans for 14 Ah pouch cells. This seems like a real step toward being able to demonstrate functionality in the desired application.

Reviewer 2:
This reviewer agreed with the project team's proposal to demonstrate the performance of co-extruded corrugated electrode in a full cell.

Reviewer 3:
The reviewer acknowledged that the proposed plans fit the initial goals, but appear to be behind schedule for the large format cell work. This person is not sure how the cost model estimates will be met based on model indications of a 10% improvement in energy density.

Reviewer 4:
This reviewer pointed out future efforts do need to address the topics presented in the poster "slide-deck." However, beyond the items presented, as previously referenced, at this point a TEA should be accomplished in order to justify further federal investment. This person said tooling and "printing" or casting at scale will be part of the normal scale-up as industry moves to commercialize this approach.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer mentioned that the project overall goal is to reduce the cost of this technology. This cost reduction fully supports the overall DOE objectives toward petroleum displacement.

Reviewer 2:
The reviewer remarked that assuming BatPac models are accurate, the project seems to provide some benefit without totally tearing up the existing cell manufacturing infrastructure.

Reviewer 3:
The reviewer said it is still not clear the feasibility of scaling up this technology but insights learned from corrugated electrode will guide future thick, high-energy electrode design.

Reviewer 4:
This reviewer noted that on the surface, the effort comes across as one which is more focused on manufacturing cost and not an approach which increases manufacturing sector capacity. Even if successful, this person warned this approach will likely only replace like-type manufacturing and not be cause to displace current petroleum use/needs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer stated $2.99 million for about 40 months should be sufficient to demonstrate full cell performance using their co-extruded corrugated electrodes.

Reviewer 2:
The reviewer concluded the funding is sufficient for this project.

Reviewer 3:

The reviewer observed the collaborative lab project team has access to a wide variety of tools and resources to support conduct of this effort.

Presentation Number: es267
Presentation Title: Commercially Scalable Process to Fabricate Porous Silicon
Principal Investigator: Peter Aurora (Navitas Systems)

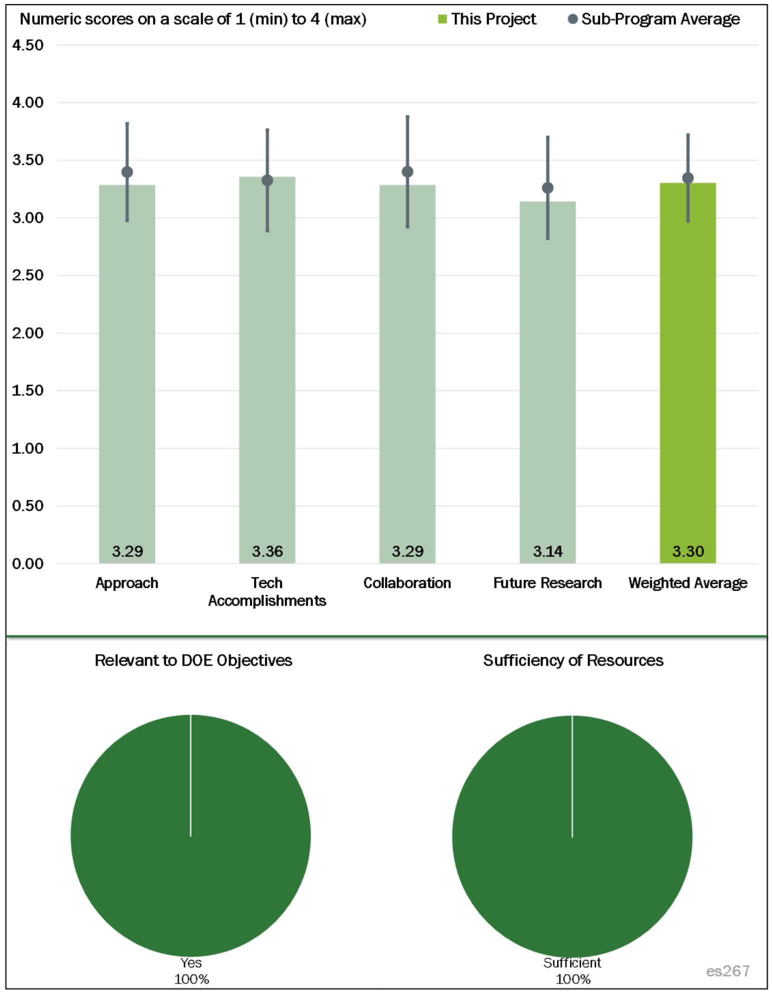

Figure 3-39 - Presentation Number: es267 Presentation Title: Commercially Scalable Process to Fabricate Porous Silicon Principal Investigator: Peter Aurora (Navitas Systems)

Presenter

Peter Aurora, Navitas Systems

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the project is well-designed to achieve low-cost and less environmental footprint.

Reviewer 2:

The reviewer said that primary program objectives appear to have been met.

Reviewer 3:

The reviewer said that the approach to technology development, and partnering for scale-up, seems sound.

Reviewer 4:

The reviewer pointed out a low-cost process to produce Si.

Reviewer 5:

The reviewer asked what the reducing metal used in Step 1 is, and what the etching agent is if hydrofluoric acid is not used.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said that scale-up of processes appears to be going well and milestones are completed. Projected cost is comparable to graphite (per unit of capacity). The reviewer said that this technology appears to be about as good as can currently be achieved with “standard Si.”

Reviewer 2:

The reviewer said that significant progress has been made on scale-up.

Reviewer 3:
The reviewer commented improvement of the Si to be test at full cell and also the evaluation of volumic expansion.

Reviewer 4:
This reviewer indicated an inability to evaluate the cost analysis without knowing the types of reducing metals and the etching agent used in the process.

Reviewer 5:
The reviewer asked if there were any issues with ultra-fine Si nanoparticles that are likely created in this process. The reviewer inquired if the Si particle size can be reduced, and what the optimal size is. The reviewer indicated that cell data look okay but not spectacular.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out great collaboration with ANL.

Reviewer 2:
The reviewer said that the team might need the collaboration with battery manufactures in order to make better pouch cells and for future commercialization.

Reviewer 3:
The reviewer said none.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future plan is reasonable and practical.

Reviewer 2:
The reviewer is very curious to see a validated cost model, and would expect the cost of reducing metal to be expensive. The reviewer understood that the developer did not want to share the material, but it seems like costs could be a risk.

Reviewer 3:
The reviewer said that the project is very near completion, and the reviewer would like to see more concrete ideas for how Nexceris or another partner will commercialize the product after funding is ended.

Reviewer 4:
None were noted by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that this work improves U.S. technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 2:
The reviewer cited a low-cost and environmentally friendly process.

Reviewer 3:
None were noted by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources seem well-used on this project.

Reviewer 2:
None were noted by this reviewer.

Presentation Number: es268
Presentation Title: Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials
Principal Investigator: Aaron Feaver (Group 14 Technologies)

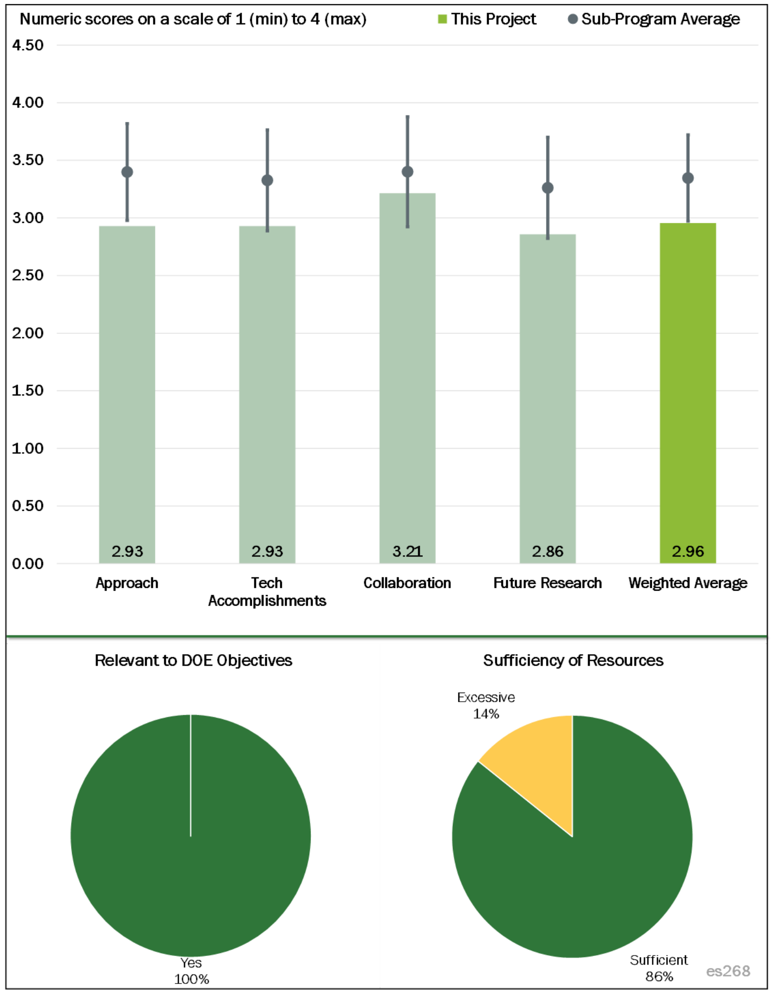

Figure 3-40 - Presentation Number: es268 Presentation Title: Low-Cost Manufacturing of Advanced Silicon-Based Anode Materials Principal Investigator: Aaron Feaver (Group 14 Technologies)

Presenter

Henry Costantino, Group 14 Technologies

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the team is currently pursuing the only sensible approach to using Si: putting it in some kind of matrix that minimizes detrimental effects of volume changes and allows for electronic contact. The team also has paid a lot of attention to how their technology can be scaled to kilogram quantities.

Reviewer 2:

The reviewer noted that the project is developing a carbon (C)-Si composite anode to increase capacity relevant to C while addressing the limited cyclability of Si. The reviewer pointed out that many groups are doing this and the approach to develop this composite was not described so it was hard to give any score on the uniqueness of approach.

Reviewer 3:

The reviewer detailed that the approach is to reduce cost by increasing energy density via SiC anode. Milestones and go/no-go decision points were specific and quantifiable.

Citing proprietary information, the project team would not disclose how the Si was supported on the C matrix, and would not disclose the synthesis process or the precursors used in the synthesis, thus it is very difficult to assess the feasibility of achieving the $125/kWh cost target.

Reviewer 4:

The reviewer said that the program claims to show cycle stability to 600 cycles, but the data appear to show that all of the Si composite anodes are at the same energy density as a standard graphite anode after 500 cycles, and the trend line continues to point downward at a more rapid rate than for graphite only. The reviewer interpreted this to mean that the Si does not appear to be stabilizing in any way and the only stabilizing component is the graphite itself. If the new technology is at parity with state-of-the-art technology halfway through the cycling target, and projected to be worse over the second half of the life target, the reviewer did not see a technological advantage to the material.

The reviewer said that the developer has also not done a very good job of explaining the distinguishing trait that leads to the novel aspect of their material other than "low two-dimensional expansion," which the reviewer does not have anything to compare their measurement to for other Si materials. The reviewer is sure 30% is still more significant than graphite, and because a physical lithiation took place instead of an electrochemical lithiation the reviewer is not sure it is showing the full expansion of the material. The reviewer thought a lot of the development of Si anodes should be focused on electrolyte-anode pairing and stable SEI formation; it seems unlikely that this material will meet end of program 1,000 cycle goals using an off-the-shelf electrolyte formulation (and the reviewer understands this is likely outside the scope of this program).

Reviewer 5:

The reviewer said none.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer remarked that the use of novel C materials seems unique.

Reviewer 2:

The reviewer commented that the project does seem to show improvement over the beginning of program performance, but the reviewer was still unclear if this actually provides a benefit if energy density at 500 cycles is equal to graphite.

Reviewer 3:

The reviewer noted that the team has made SiC composites with increased capacity relative to C, and of course less capacity than Si. TEM results indicate significantly reduced expansion issues relative to Si. However, capacity fade is still significant.

Reviewer 4:

The reviewer said that coin cell data appear quite good; however, the reviewer would like to see more than "one or two" good cells before the team proceeds with process scale-up. The reviewer said that confidence for that kind of investment requires a presentation of a lot more repeated tests. The team's use of micron-scale aggregates indicates the team has a good idea of what industry needs to make this a product that can drop into existing processes. The projected price is comparable to graphite per mAh.

Reviewer 5:

The reviewer pointed out that the project achieved a pilot scale 10g synthesis of the Si/C mix and demonstrated greater than 300 cycles in full cells with energy density greater than 700 Wh/L at C/2 rate.

The energy density was very high, close to 800 Wh/L at 4.2V 2.5V at a C/10 rate. The reviewer said that the team needs to provide enough details on the cell modeling (e.g., loading, specific capacity of the Si/C composite, porosity, first cycle irreversible loss) to show how they achieved 800 Wh/L at only 4.2V.

Reviewer 6:

The reviewer acknowledged having not seen the capacity mAh/g versus cycle, energy density Wh/k, the loading, irreversible capacity, etc. The *in situ* TEM should be with an anode (Si-binder) and no one particle.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that strong collaboration with PNNL was demonstrated.

Reviewer 2:
The reviewer commented that the PNNL analysis of materials is excellent and convincing. The reviewer would like to see more cycling and cell test data, perhaps by partnering with a group able to do that.

Reviewer 3:
The reviewer noted good collaboration with PNNL and the University of Washington, with sufficient details on the role of each team member.

Reviewer 4:
None were observed by the reviewer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
In addition to the future focus on scaling up, the team needs to include a third-party to perform independent validation of the excellent density achieved at 4.2V.

Reviewer 2:
The reviewer said that proposed future work is good, but the team needs to address capacity fade and also update cost analysis.

Reviewer 3:
The reviewer said that a kilogram scale is probably needed to confirm larger cell format cycle life performance, but the reviewer was not convinced that cell performance at this time justifies cost investment in process scale-up.

Reviewer 4:
The reviewer said that as mentioned in previous comments, the team needs to consider more than just process scale-up. However, process-scale-up plans themselves are adequate.

Reviewer 5:
None were cited by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that improved batteries will advance vehicle electrification and thus displace petroleum.

Reviewer 2:
The reviewer said that using a high-energy and inexpensive anode is relevant to achieving DOE's EV objectives.

Reviewer 3:
The reviewer commented that this work improves the U.S.'s technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 4:
The reviewer said yes, assuming program goals are met.

Reviewer 5:
The reviewer said none.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources appear adequate.

Reviewer 2:
The reviewer said that $2.8 million for 3 years is sufficient to demonstrate the performance and scalability of the SiC composite.

Reviewer 3:
The reviewer said that the budget seems high relative to other projects evaluated.

Reviewer 4:
The reviewer had no comment.

Presentation Number: es269
Presentation Title: An Integrated Flame Spray Process for Low-Cost Production of Battery Materials
Principal Investigator: Yangchuan Xing (University of Missouri)

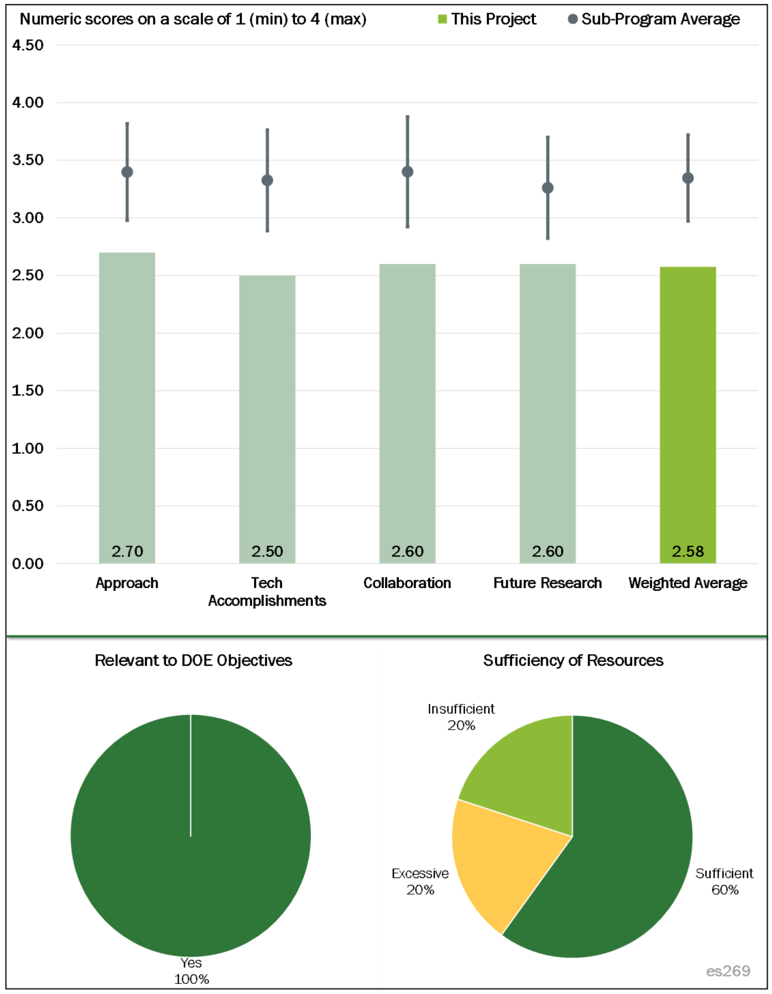

Figure 3-41 - Presentation Number: es269 Presentation Title: An Integrated Flame Spray Process for Low-Cost Production of Battery Materials Principal Investigator: Yangchuan Xing (University of Missouri)

Presenter

Yangchuan Xing, University of Missouri

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the approach taken to reduce manufacturing cost is good. Replacing water with biomass glycerol would save on water treatment cost.

Reviewer 2:

The reviewer said that the integrated flame spray process has potential to reduce cathode powder cost by process intensification. However, this aspect (process intensification and reduced cost) is not demonstrated yet. The reviewer pointed out that the figure on Slide 6 is a schematic of coated powder production, but where is the coating process described or shown. Also, current significant Li loss will impact cost.

Reviewer 3:

The reviewer said that although the process could be a sustainable material manufacturing process, how to scale-up and achieve better quality control could be issues in the future.

Reviewer 4:

The reviewer said that the process path selected seems to be a reasonable approach to fabricating powder systems for use in LIB systems. It presents a means to insure compositional homogeneity and purity in processed materials. Selected chemical precursors can be readily and fairly easily blended so as to achieve most chemistries envisioned to be of use for these systems. The reviewer noted that process tooling is near-commercially available and can be modified, as can most process condition variables to meet the unique needs to achieve high volume of spherical particles. The reviewer pointed out that what appears absent from the approach and work-plan includes: a means to fully classify finished powders to specified particle size diameters (PSD), a viable means to ALD coat as-finished powders while surfaces remain chemically active and receptive to any required coating as poster/slide-deck over-simplifies this process step, development of a roadmap and techno-economic analysis to determine if approach is commercially feasible if objectives are achieved, etc.

Reviewer 5:

The reviewer said that major weaknesses in the approach are associated with scaling up the process to produce materials at lower cost than current prices. The poster provides no information to support the idea that flame spraying technology can be scaled-up to allow the production of several hundred tonnes of material per year without loss of uniformity and electrochemical performance. (The reviewer noted that in discussion, the presenter cited the fact that flame spraying technology is currently used to produce very large quantities of simple metallic oxides. But the materials cited contain a single metal and are used in pigments—a simpler structure used in a less demanding application.)

The reviewer said that in describing the reactants, the paper identifies that the solvent is "glycerol from biomass," a byproduct of the production of biodiesel—implying that it is readily available, renewable, and inexpensive. But no data are given to support this implication. The reviewer remarked that the paper states that metal acetates are used in preparing the spray solution. One expects metal acetates to be significantly more expensive than the metal salts used in conventional production. The only Li-containing materials produced in sufficient quantities to supply the cathode industry are Li-carbonate and Li-hydroxide. Converting either of these to Li-acetate would add additional cost.

The reviewer pointed out that flame spraying would not allow the production of some of the materials now under development, such as core/shell materials. In the drawing on Slide 6, the presentation implies that flame spraying equipment would allow "coating" and "processing" of the materials in an integrated system; but there is no discussion as to what this system would be or how it would function.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer said that the effort continues to move in the right direction. This past year, a Generation 3.0 reactor was constructed and the team expects to meet the production rate goal.

Reviewer 2:

The reviewer noted that lower cost materials are certainly important in meeting DOE's cost goals. The goal of this project is "low-cost production of battery materials," but the presentation provides no specific data to support this goal or the specific cost targets mentioned on Slide 3.

The reviewer said that to be accepted by the battery industry, materials must be shown to be consistent in composition, structure, and form (shape and density) over multiple, extended production runs. There are no data in the poster to show that the current process can produce consistent material during a single run, let alone over many runs.

The focus on Ni Mn Co oxide (NMC)111 and NCA may be an acceptable starting point, but neither of these materials are currently being considered for use in "next-generation" batteries for vehicles. The poster gives no information about how many production runs have been made or any discussion as to the issues with getting good materials from multiple runs.

Reviewer 3:

The reviewer said that the team has demonstrated progress in achieving what appears to be reasonably dense, fine grained particle aggregate of fairly uniform size. Work to demonstrate the final chemistry of these materials indicates a fair level of homogeneity, although extensive loss of Li from the chemistry was observed. The team indicates that the next phase will focus on "scale-up" and adjustments to current tooling sets. However, before this effort should begin, there are a number of unanswered questions which need to be addressed. According to the reviewer, these include: what particle densities are actually achieved; what yields are seen of spherical versus other "shaped" particles, i.e., SWARF, fines, and other debris; can loss of high vapor pressure materials be compensated for in the precursor chemistries without adversely impacting the process flow or final compositional homogeneity of finished powders; is there PSD control and can the processed powders be physically classified into specified PSDs, further will use of multi-model blending achieve enhanced packing densities in use; a discussion of actual raw materials costs and current state-of-the-art process approaches are needed; the approach to ALD or other-type coating, if any appears overly simplistic; etc.

Reviewer 4:

The reviewer said that the team has demonstrated the capability to make NMC powders at large volumetric rates, but the product has significant issues: particle size is not adequate, 21% Li loss in pyrolysis, and secondary phase formation. As a result, electrochemical performance was poor. The reviewer said that adding 30% excess Li improved, but that would be a significant increase in cost. The reviewer asked how this Li loss will be addressed.

Reviewer 5:

The reviewer said that electrochemical performance is not promising at this stage. The team should also compare with the commercial materials and identify the main factors responsible to the poor performance.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said collaborating with EaglePicher.

Reviewer 2:

The reviewer stated that the team reports considerable interaction between PIs at Univ. of Missouri, EaglePicher Technologies, as well with potential subject matter experts from other sectors.

Reviewer 3:

The reviewer said that collaborative effort with EaglePicher Technologies is good. They have been a major supplier for military batteries and should be able to guide the PI on cell evaluations.

Reviewer 4:

The reviewer pointed out that except for mention of a partnership with EaglePicher for production of test cells, there does not seem to be any outside collaboration. The nature of this collaboration is not described. One might infer that it is a relatively arms-length relationship: The University delivers material to EaglePicher, which makes cells using their proprietary anode. The reviewer pointed out there is no mention of active collaboration or feedback from EaglePicher to the university.

The reviewer noted that EaglePicher is an established manufacturer of cells and batteries in multiple chemistries, but their market has traditionally be the military and related users. They do not have any significant business producing cells or batteries for production, passenger vehicles.

Reviewer 5:

The reviewer said that the team might explore some collaboration with the experts on cathode materials from national laboratories or universities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the PI appears to be aware of the challenges with developing a low-cost battery cathode production process. This coming year, the team will continue to optimize the powder morphology and the process control will be investigated. There will be focus on increasing the production rate.

Reviewer 2:
The reviewer said that the team suggests that work will now focus on scale-up, tooling and addressing chemistry concerns as a result of thermal processing. It seems that much more fundamental effort is first needed to address fully characterizing current state-of-the-projects and determining how to address chemistry issues and coating approaches. The reviewer said that the team should rethink milestone events and consider what new roadmaps, economic issues, process and property issues need first to be solved prior to moving ahead with future work.

Reviewer 3:
The reviewer commented that for the future plan, the team should focus on optimizing the process and achieve the comparable performance as the material synthesized from traditional wet chemistry.

Reviewer 4:
The reviewer noted Li loss, phase purity, and particle size/morphology are major issues and are not sufficiently addressed.

Reviewer 5:
The reviewer said that the list of proposed future work identifies tasks in very general language with little detail about what each of the tasks might involve or how they would be done.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer noted that lower-cost batteries will advance vehicle electrification and thus displace petroleum.

Reviewer 2:
The reviewer pointed out that one of the major factors in the battery cost is the cathode. Therefore, reducing the cathode materials cost should have a major effort in reducing battery cost and motivating the consumer to use EVs.

Reviewer 3:
The reviewer said that introduction of LIBs with the transportation sector will result in lightweighting of designed vehicles which serves to conserve energy, whether it be petroleum or other based energy source. However, this project is one which is focused on energy storage, regardless of generating source. However, if found to be economically viable in the commercial space, the approach would serve to enhance manufacturing capacity and thus serve to increase product availability, resulting in increased product available for EVs and other applications.

Reviewer 4:
The reviewer noted that because DOE is interested in reducing the costs of advanced batteries and because reducing the cost of component materials will help reach this goal, this project may be able to support the overall objectives.

The reviewer used the words “may support” rather than the words “will support” because little specific data are provided to support the assertion that this approach will be low-cost. Therefore, the answer of “Yes” to this question is a qualified assessment. The reviewer noted that if the options were other that “yes” or “no,” the reviewer would have chosen “maybe.”

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that it appears that there are sufficient resources for this project to achieve the proposed goals as planned.

Reviewer 2:
The reviewer noted that the collaborative Lab Team set has access to a wide variety of tools and resources to support conduct of this effort.

Reviewer 3:
The reviewer said that because the poster indicates that results have been obtained and the project is on schedule, one may infer that the resources are adequate. But the poster provides no information as to what facilities and equipment are available at the university, nor is there any discussion as to how many people are working on the project and what their backgrounds might be.

Reviewer 4:
The reviewer commented that collaboration with national laboratories and utilizing the advanced diagnostic tools might help the project and meet the milestones.

Reviewer 5:
The reviewer said that given budgets on other projects reviewed, this seems excessive for work involved.

Presentation Number: es271
Presentation Title: New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage
Principal Investigator: Peng Du (Silatronix)

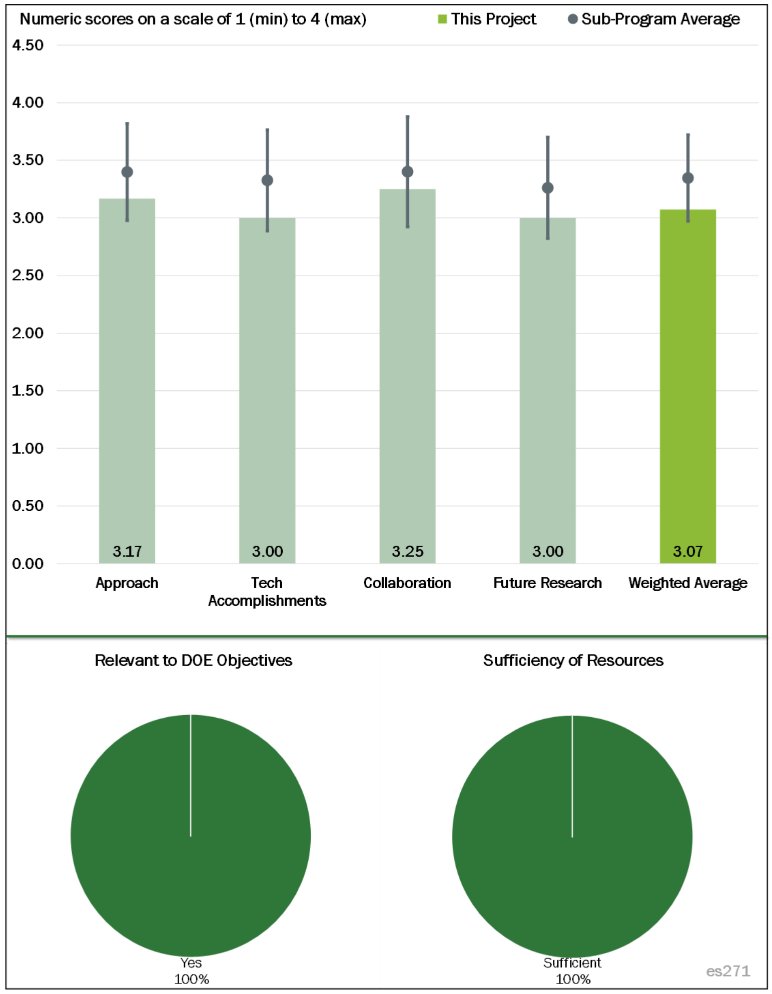

Figure 3-42 - Presentation Number: es271 Presentation Title: New Advanced Stable Electrolytes for High-Voltage Electrochemical Energy Storage Principal Investigator: Peng Du (Silatronix)

Presenter

Peng Du, Silatronix

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approaches proposed are very unique and well-designed. If it is successful, it could significantly improve the energy density.

Reviewer 2:

The reviewer commented that the project has demonstrated an ability to synthesize high-voltage liquid electrolytes. The process has resulted in series of successful compositions which could have significant impact on battery performance.

Reviewer 3:

The reviewer observed a good approach by developing organosilicon (OS) solvents to stabilize Li-ion electrolytes for high-voltage cathodes. The milestones were specific and quantifiable go/no-go decision points. The use of spectroscopy methods (e.g., NMR) to characterize Li+ solvation behavior should be beneficial in developing and optimizing OS solvents.

The reviewer said that the team did not provide risks (e.g., compatibility with $LiPF_6$ electrolyte) and risk mitigation strategies. Some rationale should be provided on the downselection of the ARL additives.

Reviewer 4:

The reviewer noted that electrolyte for high-voltage helps increase the energy density when high-voltage cathodes are used.

Reviewer 5:

The reviewer said that the approach has resulted in mixed results. The goals for the pure OS materials in terms of high-voltage stability and leakage currents have been met by several formulations. The results for electrolytes containing OS components are much less positive. The reviewer said that to function as an effective electrolyte, only a small fraction of the mixture can be an OS. Cells built with these electrolytes do not seem to perform significantly better than cells using the best available control electrolyte. Cells built with the OS electrolytes have had limited testing because of a gassing problem.

Reviewer 6:
The reviewer stated that because all pouch cells are “showing a large amount of gassing,” the project objective of developing “an electrolyte system stable at high-voltage (≥ 5V)” is unlikely achievable.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer pointed out that the demonstrated high-voltage capability is excellent, and asked but what is the conductivity. There is a table on Slide 8, but no units. The reviewer asked where the data are supporting these values. Also, gassing is an issue with safety implications that needs to be addressed.

Reviewer 2:
The reviewer noted that the team achieved impressive reduction in residual currents above 5V and voltage stability greater than 6V were demonstrated in half cells using the OS solvents in $LiPF_6$ electrolytes. The team also identified a gassing issue at greater than 4.7V.

The reviewer said that full cell results did not show the benefit of OS additives cycling at 55° C with 4.9V cut-off. Spectroscopy studies showed that OS solvents had high affinity for Li+ ions and should impact SEI formation but the impact was not evident in full cell results. The reviewer said that the ARL additives did not enhance the performance of OS3 in electrolytes.

Reviewer 3:
The reviewer said that significant progress has been made to develop a high-voltage electrolyte. The reviewer inquired can this OS3 be applied to general electrodes to improve safety as well. It looks as though high-voltage electrode materials with reliable electrochemical performance are not really available yet. The reviewer stated that the new electrolyte cannot be used even if the project is successful.

Reviewer 4:
The reviewer said that milestones are completed on schedule, though the problem of a large amount of gassing remains a challenge.

Reviewer 5:
The reviewer said that as noted in the response to question two: the performance of several “pure” OS materials (with appropriate salt) has met the goals of the project for these materials. The performance of electrolytes containing some OS does not seem to be significantly better than the best available electrolytes without OS. And the OS containing electrolytes may have problems with gassing. No data are given on low-temperature performance.

The reviewer remarked that given the performance of the OS-containing electrolytes, they do not seem to offer significant benefit in meeting DOE's goals for a high-voltage electrolyte to be used in high-voltage cells.

Reviewer 6:
The reviewer said that the PI should use Al or carbon to test the electrochemical windows at high-voltage.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that strong collaboration between the prime and ARL is demonstrated.

Reviewer 2:
The reviewer said that there seems to have been good collaboration with ANL and ARL. Each of the outside laboratories had specific tasks reflecting their specific expertise. The poster presentation clearly incorporates data from the partners as well as the prime contractor.

The reviewer noted that there was no collaboration with a battery manufacturer, but given the relatively basic technology readiness level of these materials and electrolytes, that is not a major weakness.

Reviewer 3:
The reviewer remarked that the team is very strong and has complimentary skill sets. The team can explore more collaboration with industry, which might have high-voltage electrode materials.

Reviewer 4:
The reviewer said that good collaboration with ARL and ANL, but the role of ANL was not specified.

Reviewer 5:
The reviewer said none.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer agreed with the team's focus on reducing the gassing issue, especially as a function of voltage cut-offs.

Reviewer 2:
The reviewer noted that the project is 90% complete, so future research is primarily demonstration of cell performance with developed electrolytes.

Reviewer 3:
The reviewer remarked the proposed future work is appropriate and necessary, but it seems to be quite extensive given that the project is 90% complete and will end in September. This reviewer's assessment: a good list of things that should be done, but questions as to if there are time and funding to do them all.

Reviewer 4:
The reviewer said that there is insufficient detail about what to do to solve the large amount of gassing problems aside from lowering the test voltage. The project objective of developing an electrolyte system stable at high-voltage (greater than or equal to 5V) is unlikely achievable.

Reviewer 5:
The reviewer said more coordination is needed under the DOE EERE program.

Reviewer 6:
The reviewer said none.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that improved batteries will advance vehicle electrification and thus displace petroleum.

Reviewer 2:
The reviewer remarked that a stable electrolyte for high-voltage cathode is relevant to achieving DOE high-energy density goals.

Reviewer 3:
The reviewer said that the project can meet the high-energy density requirement if it succeeds.

Reviewer 4:
The reviewer said given that DOE's goals for advanced cells and batteries may/will require the use of a "high-voltage" electrochemical couple and given that a high-voltage electrolyte will be a necessary component of these cells, the goals of this project were supportive of DOE's overall objectives.

Given that the electrolytes that have been developed and tested in this project do not seem to perform significantly better than the best electrolytes without OS components, this project may not actually provide significant support to meeting DOE's objectives.

Reviewer 5:
The reviewer said none.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that $1.7 million for 2 years should be sufficient for this effort.

Reviewer 2:
The reviewer said that funding is consistent with other projects funded.

Reviewer 3:
The reviewer said that the three partners in this project each have appropriate facilities and staff to accomplish their parts for the project.

Given that many of the milestones for the project have been met, one may infer that resources have been adequate. The reviewer said as noted in response to earlier questions, there is significant "future work" proposed given that the project is 90% complete. The remaining resources (time and funding) may not be adequate to accomplish all of this work.

Reviewer 4:
The reviewer said none.

Presentation Number: es273
Presentation Title: Composite Electrolyte to Stabilize Metallic Lithium Anodes
Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

Presenter

Nancy Dudney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

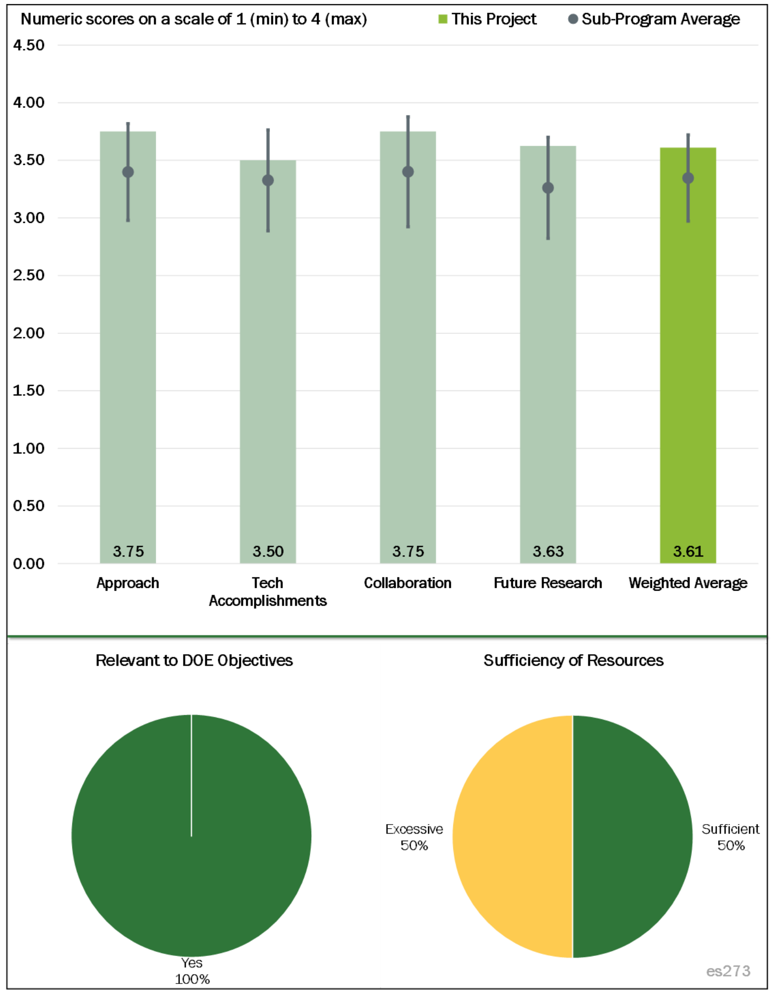

Figure 3-43 - Presentation Number: es273 Presentation Title: Composite Electrolyte to Stabilize Metallic Lithium Anodes Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

Reviewer 1:

The reviewer said, great work, the PI knows Li-metal very well and has a good approach. While the reviewer worried that composites will lead to current focusing and result in issues with dendrites, the reviewer fully supports this effort to see if this is indeed the case.

Reviewer 2:

The reviewer remarked that a composite electrolyte is one of the most promising directions to enable a Li anode. The spray-coating method is effective for the synthesis and is easy to scale up. The reviewer said the $Li_{2.88}PO_{3.86}N_{0.14}$ (LiPON) coating will be helpful to address the instability between the components and Li-metal anode.

Reviewer 3:

The reviewer observed a good approach in search for a Li dendrite blocking solid electrolyte. But, it appears as though the PI thinks the composite polymer electrolytes (CPE) will not stop dendrites, and therefore investigated a LiPON coating. This adds yet another interface with a relatively poor conducting solid, and the reviewer said it seems unlikely to work out.

Reviewer 4:

The reviewer said that a ceramic/polymer composite has many possible advantages in terms of blocking Li-dendrite growth, etc. The improvement in conductivity of such a composite, especially addressing interfacial resistance between two phases, remains a grand challenge for all the people working on this area.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer commented that the developed spray method using aqueous slurry is a great achievement. The reviewer is impressed by the mechanical strength of the LiPON layer coated on the CPE. The room temperature ionic conductivity is 10-5 S/centime (cm) only with the DMC vapor exposed CPE. The ionic conductivity without solvent still needs to be improved.

Reviewer 2:
The reviewer said good progress but very disappointing results. Poly(ethylene oxide) and Ohara glass are the two components of this composite electrolyte, both have room temperature conductivities that are too low for large format cells. The reviewer said that together, as a composite, they do worse, providing about 10^-6S/cm at room temperature, two orders of magnitude too low. This may be a consequence of the extra interfaces in this solid.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed reasonable good collaboration with academics and national laboratory groups.

Reviewer 2:
The reviewer said this project involves collaborations with both academic institution (Sakamoto at Michigan State University) and industry (Ohara).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future research is well planned: replacing Li aluminum titanium phosphate (LATP) with lithium lanthanum zironate (LLZO) may help to improve the interfacial stability and extra coating of LiPON may be not required. Using some improved polymer is the key to improve the ionic conductivity of the membrane. The reviewer said that a demonstration of a full cell from spray-coated method is encouraging.

Reviewer 2:
The reviewer noted reasonable as a research project, but this appears unlikely to yield a commercial solid electrolyte.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that if successful, this project will enable Li-metal based batteries with very high energy density.

Reviewer 2:
The reviewer said very relevant but the results are not promising.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources are sufficient to achieve the milestones, especially with the hiring of a polymer physicist and the in-house experiment with LLZO powder synthesis.

Reviewer 2:

The reviewer noted reasonable funding for the work being performed.

Presentation Number: es274
Presentation Title: Nanoscale Interfacial Engineering for Stable Lithium Metal Anodes
Principal Investigator: Yi Cui (Stanford University)

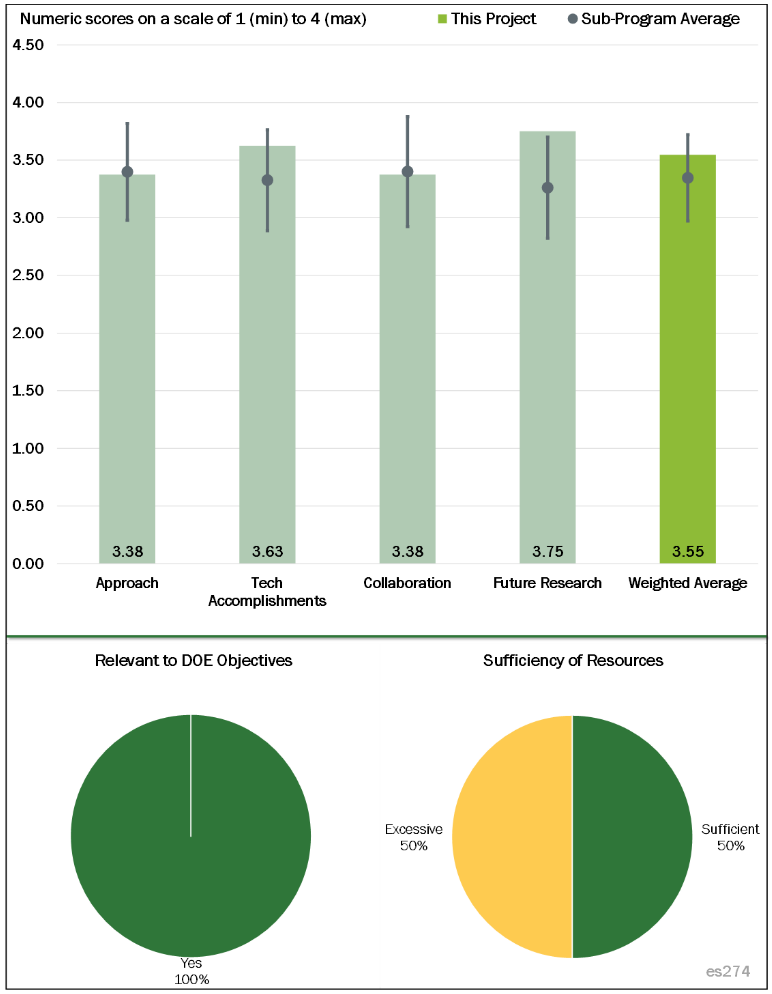

Figure 3-44 - Presentation Number: es274 Presentation Title: Nanoscale Interfacial Engineering for Stable Lithium Metal Anodes Principal Investigator: Yi Cui (Stanford University)

Presenter
Yi Cui, Stanford University

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that this work is always very inspiring. The work on changing the nucleation rates to ensure deposition in the shell was wonderful. The reviewer cited as a great example of the PI's creativity how the work on graphene seemed more hand waving in comparison. But overall, a great project.

Reviewer 2:
The reviewer remarked the project employed several very interesting and innovative approaches to address Li-dendrite growth issues.

Reviewer 3:
The reviewer commented that the PI clearly indicated the technical barriers of high-cost, low-energy density and short battery life for Li-metal batteries. The PI addressed these challenges by designing and synthesizing interfacial protecting layers and nanostructured Li-metal electrodes. The reviewer said that the advanced characterization technologies used in this research greatly enhanced the understanding of the mechanism.

Reviewer 4:
The reviewer said that reducing the volume change is a reasonable approach, but the reviewer is not convinced that electrode volume change is the major issue here. It is the instability at the electrolyte Li-metal interface and many of these methods are only partially able to reduce that interface. The reviewer pointed out that the increased wetting is critical and could reduce current focusing, which leads to dendrites.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer commented that results are outstanding. The team demonstrated significant improvement for performance and stability.

Reviewer 2:
The reviewer said that the PI improved the Li-metal cycling stability and CE by coating a composite layer/polymer on the Li-metal and greatly improved the cycling performance and CE. It should be a good progress toward the Li -metal batteries.

Reviewer 3:
The reviewer said accomplishments were mixed, and commented this approach still results in a rather low CE of 98%, meaning that the electrolyte/Li-metal interaction is still strong. As the goal is to cycle Li-metal cells with no more than 50% excess Li, these efficiencies are insufficient. This approach does appear to have reduced the likelihood of dendrite formation, which is excellent and a big step forward. The reviewer was not 100% clear how the self-healing polymer will stop dendrites if its stiffness is insufficient in the first place.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that all of the PI's coordination and collaborations are among the top, which improved the quality of the work.

Reviewer 2:
The reviewer remarked that the team has demonstrated extensive collaborations with co-PIs and industrial partners.

Reviewer 3:
The reviewer said that collaboration is relatively minor, which is appropriate for such early stage research.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that proposed future research is very well thought out, and good recognition of the criticality of CE.

Reviewer 2:
The reviewer said that all of the proposed future research topics, including the improvement of the CE, and stable cycling stability at high-current density, are the key issues remaining for the Li-metal batteries.

Reviewer 3:
The reviewer said that the future research plan is reasonable. How to incorporate the innovative technical approaches into mass production of Li-metal anodes in a cost-effective manor remain as major challenges.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked nice to see somewhat novel approaches attempted to dealing with Li deposition and dendrite issues. This is very relevant to all Beyond Li-Ion work, which is a growing portion of the VTO Energy Storage R&D budget.

Reviewer 2:

The reviewer said that the growth of the global EV market has been slower than initially predicted about 5 years ago due to the slow increase of the battery's energy density. Further increasing the energy density with long cycle life are the pivotal directions of the developments in LIBs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

No comments were received in response to this question.

Presentation Number: es275
Presentation Title: Lithium Dendrite Prevention for Lithium-Ion Batteries
Principal Investigator: Wu Xu (Pacific Northwest National Laboratory)

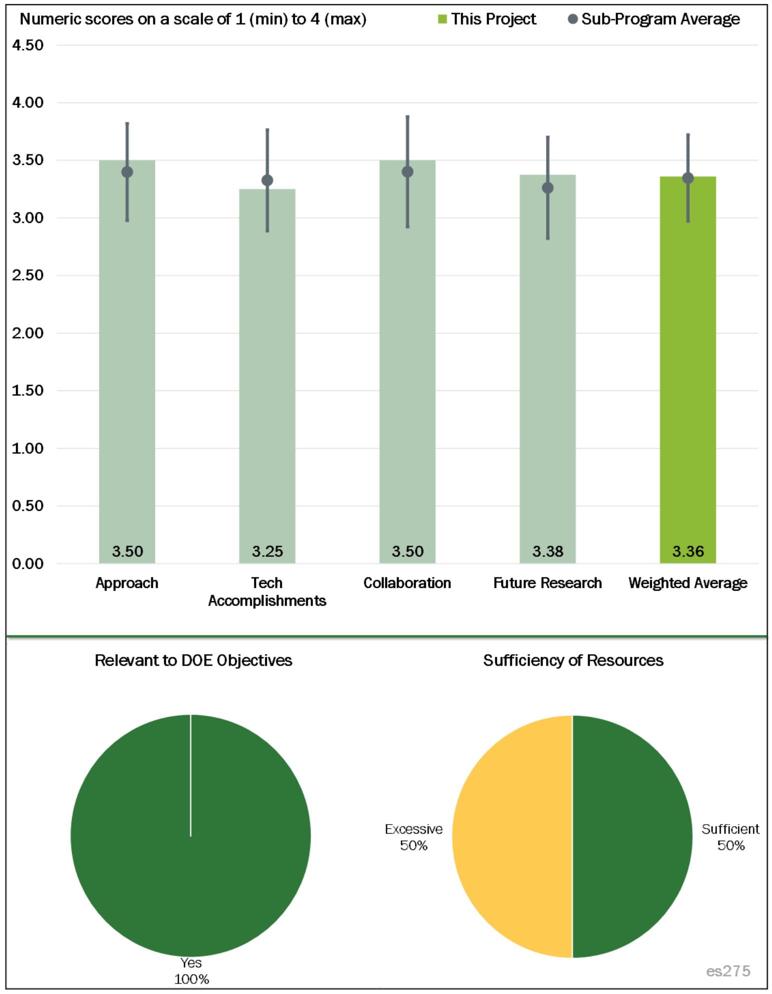

Figure 3-45 – Presentation Number: es275 Presentation Title: Lithium Dendrite Prevention for Lithium-Ion Batteries Principal Investigator: Wu Xu (Pacific Northwest National Laboratory)

Presenter

Wu Xu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the PI clearly indicated the technological barriers of Li dendrite formation on Li-metal anodes in Li-metal batteries and on carbon anodes in LIBs. The PI addressed these challenges by designing a reasonable charge-discharge protocol for Li-metal electrodes. The PI also explored various factors that affect the morphology of Li deposition. The reviewer said that the advanced characterization technologies used in this research greatly enhanced the understanding of the mechanism.

Reviewer 2:

The reviewer remarked that compared with other approaches, such as coatings, artificial SEIs, etc., electrolyte modification and additives offer great potential to address several key concerns in Li-anode, but this has not been extensively explored. This project is addressing such an issue and the approach is industrially viable.

Reviewer 3:

The reviewer said a good approach to investigate new electrolytes and electrolyte additives to stabilize the Li-metal SEI.

Reviewer 4:

The reviewer expressed worry that the project is not recognizing that with so much excess Li, one can easily fool oneself into thinking that cycle life is not an issue. The reviewer recommended using thin Li, and making sure that the cells are truly Li limited. It will be best for the community to see which ideas are working versus not, rather than fooling ourselves into thinking it is all fine.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer remarked that the results are a great improvement of Li-corrosion protection and reducing dendrite growth.

Reviewer 2:

The reviewer said that the PI developed mixed salt electrolytes to protect Al current collector and Li-metal anode, and meanwhile achieved the Li CE over 98%. These achievements are great progresses for the Li-metal batteries. Besides, the Li||Li-iron phosphate ($LiFePO_4$) cells with 300 cycles is also a great progress for the Li-metal batteries.

Reviewer 3:

The reviewer would ask the PI to not show reviewers results involving additive "X". The reviewer did not see any value in that. The $LiPF_6$ as an additive is interesting and shows promise. The reviewer would ask the PI to report how much Li is being cycled each cycle. If we are only moving 1% of the Li-metal anode on each cycle, then we already know we can cycle that thousands of times. If 50% of the Li is moved, then it has got a much, much shorter cycle life. As the PI is cycling Li-metal/NMC, the PI is technically not cycling any of the initial Li so it is really hard to say if this is significant or not. The reviewer believed the PI said the amount of Li was between 120 and 400 μ, or 24-80 mAh/cm^2. With the cathode at 1.5 mAh/cm^2, this is a massive amount of excess Li and the reviewer questioned the significance of the cycle life. The CE of 96% is low. If we start with 50% excess Li, the cell will be dead in 20 cycles.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that all of the PI's partners are the top institutions of battery research. This collaboration and coordination can substantially improve the accomplishments.

Reviewer 2:

The reviewer said that collaboration is minimal but appropriate at this point in the research.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the PI proposed three future research topics; all of these topics are the key issues which should be overcome for the future commercialization of the Li-metal batteries.

Reviewer 2:

The reviewer said that proposed future research is reasonable, and the reviewer would encourage the PI to cycle cells with the least amount of Li-metal possible.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that the growth of the global EV market has been slower than initially predicted about five years ago due to the slow increase of the battery's energy density. Further increasing the energy density with long cycle life are the pivotal directions of developments in LIBs

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

No comments were received in response to this question.

Presentation Number: es276
Presentation Title: Mechanical Properties at the Protected Lithium Interface
Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

Presenter
Nancy Dudney, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

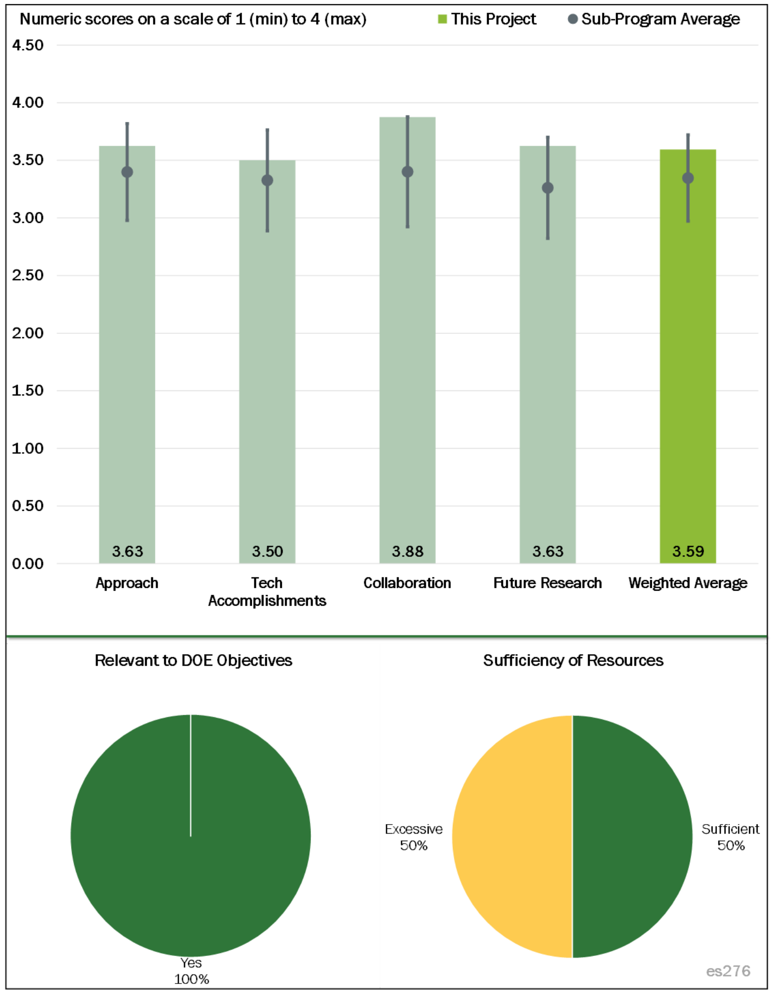

Figure 3-46 - Presentation Number: es276 Presentation Title: Mechanical Properties at the Protected Lithium Interface Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that understanding the mechanical property of the Li/SEI is important to enable high-capacity Li-metal for a high-energy battery. Nanoindentation could provide much information about this.

Reviewer 2:
The reviewer said that the use of mechanical testing to probe Li-metal and the Li-metal SEI is a good addition to our existing electrochemical testing approaches. It will be extremely challenging to learn more about the SEI this way, but it is worthwhile.

Reviewer 3:
The reviewer commented that the project, as expected from the PI, is very relevant and focused. The work is really addressing the critical questions in Li-metal focusing on the interface. The reviewer was a bit concerned that the experiments were going after a microscopic quantity, while the issue is macroscopic in nature. Relating the two is going to be an issue. But, one has to start somewhere.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer said that the mechanical properties of thick Li anode has been studied, which will help to understand the deformations during Li plating and striping. The mechanical behavior inside the grain and around the grain boundaries could help to understand the dendrite formation mechanisms.

Reviewer 2:

The reviewer liked that the team broadened their approach to characterizing Li mechanical properties after the nanoindentation technique proved more difficult than expected. The relatively recent finding that dendrites grow through LLZO grain boundaries (Sakamoto) makes this project even more daunting. It is hard to imagine that we will find mechanical signatures of such small features. Still, according to the reviewer, this is worth pursuing.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said very good collaboration with academia and industry, very complete team.

Reviewer 2:

The reviewer commented that this project involved close collaborations with academic institutions and industry.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed very solid future research, which includes further development of the technique and an attempt to detect defects in the solid electrolytes that impact Li dendrite growth.

Reviewer 2:

The reviewer said study of the mechanical behavior of Li and Li/electrolyte interface during cycling at different currents (or different strain rate) is of high interest and can provide many insights for further improvements.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that understanding the interface between Li and solid electrolyte is one of the keys to enable a high-energy battery based on a Li anode.

Reviewer 2:

The reviewer said the project is highly relevant, but it must show an ability to repeatedly detect features that impact dendrite growth in the near future.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted a very high budget, but with a good amount of work being done.

Reviewer 2:

The reviewer said that the resources are more than sufficient to achieve the stated milestones.

Presentation Number: es277
Presentation Title: Solid Electrolytes for Solid-State and Lithium-Sulfur Batteries
Principal Investigator: Jeff Sakamoto (University of Michigan)

Presenter

Jeff Sakamoto, University of Michigan

Reviewer Sample Size

A total of four reviewers evaluated this project.

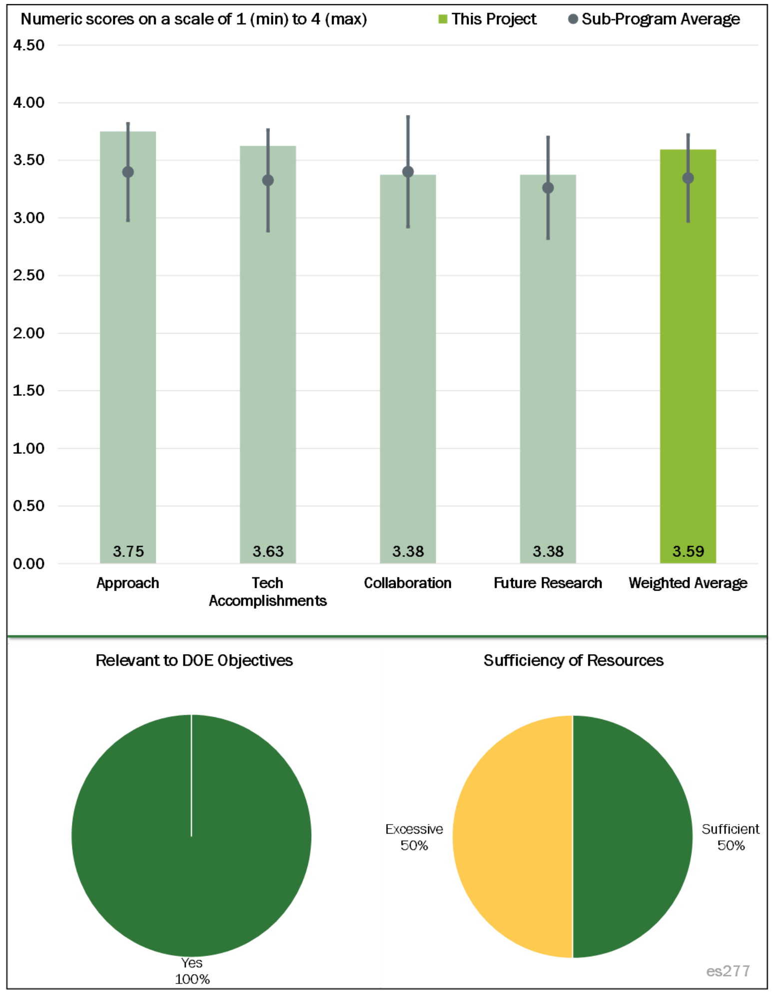

Figure 3-47 - Presentation Number: es277 Presentation Title: Solid Electrolytes for Solid-State and Lithium-Sulfur Batteries Principal Investigator: Jeff Sakamoto (University of Michigan)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented excellent project with a very good approach. The PI has shown the main failure modes for ceramics and leads the world in this area.

Reviewer 2:

The reviewer said very nice testing and diagnostics approach, and liked that the focus is on surface effects.

Reviewer 3:

The reviewer said that solid electrolytes are critical to suppress the dendrite formation and will also help to prevent the shuttle effect in Li-S batteries.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer commented that it is good that defects include the Li-LLZO interface, which is where the large impedance originates and grows during cycling. There seems to be growing consensus that poor Li wetting is the root of the high interfacial impedance.

Reviewer 2:

The reviewer remarked that the factors for the dendrite formation in LLZO has been systematically studied, from the porosity, to grain boundaries, and then to surface contaminations. The interfacial resistance has been reduced to 2 ohm/cm^2, which is much lower than that in the liquid electrolyte or LiPON-based Li cells. However, even with this low interfacial resistance, the critical current density (CCD) is still much less than 1 mA/cm^2. The reviewer said that other reasons need to be clarified.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed good collaboration, and liked that Ford is included in list of advisors/collaborators.

Reviewer 2:
The reviewer said that the project involved many collaborations from both national laboratories and industry.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer liked that the work continues to focus on the "why" of solid state battery interfacial impedance.

Reviewer 2:
The origin of Li dendrite formation in LLZO is still unclear, limiting a great improvement of CCD. The reviewer suggested more efforts towards this direction.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that if this succeeds, solid electrolytes will enable high-energy batteries with a Li-metal anode.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked good amount of work for the funding provided.

Reviewer 2:
The reviewer said that the resources are sufficient for this project.

Presentation Number: es278
Presentation Title: Overcoming Interfacial Impedance in Solid State Batteries
Principal Investigator: Eric Wachsman (University of Maryland)

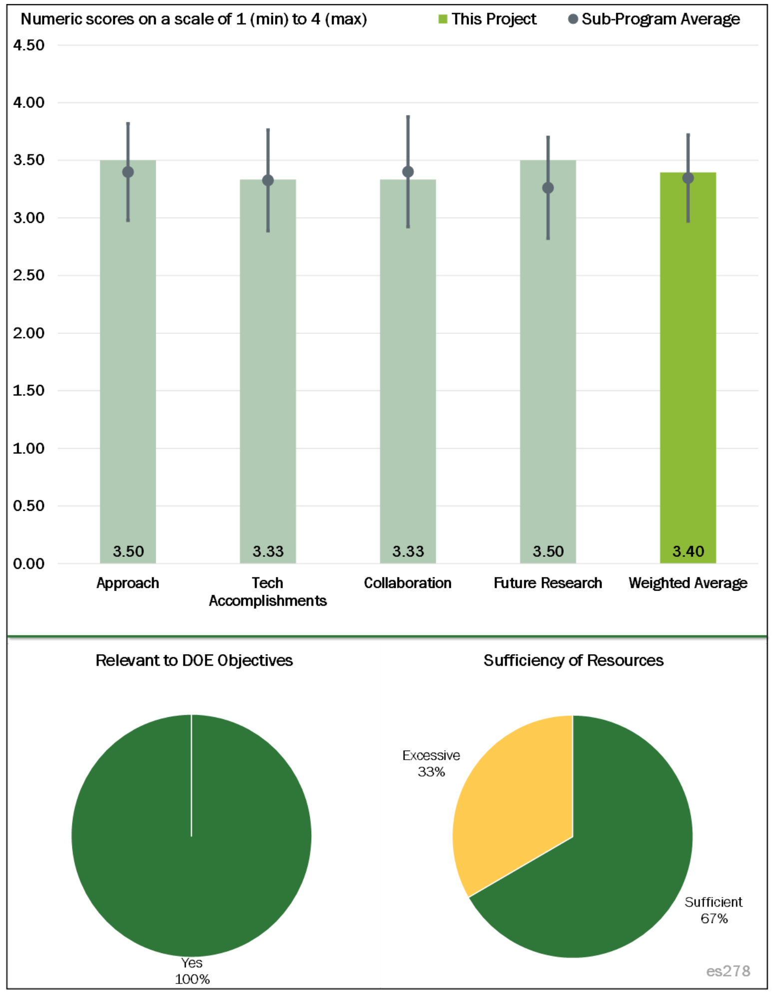

Figure 3-48 - Presentation Number: es278 Presentation Title: Overcoming Interfacial Impedance in Solid State Batteries Principal Investigator: Eric Wachsman (University of Maryland)

Presenter

Eric Wachsman, University of Maryland

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that this is one of the early demonstrations of the solid state battery after the work in Japan. The reviewer said really excellent work.

Reviewer 2:

The reviewer said that the project is focused on interfacial impedance, which is appropriate when researching solid state batteries. It seems likely that very high interfacial impedance, caused partially by poor contact between Li and the solid electrolyte, could be at least partially responsible for Li dendrite growth. But, according to this reviewer, Li dendrites also grow in cells with liquid electrolytes and with gel polymer electrolytes. So this "solution," to improve the interface, is only a partial solution.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer observed good results, and believed the conclusions of this project are similar to or identical to the Sakamoto project, which is encouraging. The result is that Li-carbonate is at least partially responsible for poor interfacial impedance. Also, the finding that increased interfacial surface area can and does reduce impedance is expected but critical to show. The reviewer was somewhat surprised that full-cell Li/NMC cycling is shown only out to 15 cycles, and Li/S out to 30 cycles, which implies that there is a major issue out there. It would be nice if the PI told reviewers what that was. The CE of the Li/NMC full cells appears to be rather low, well under 99%. The reviewer asked does the PI know what the cause of this is.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

Considering the claims being made by this PI, the reviewer would encourage him to reach to battery or material developers for collaborative efforts on validation of his findings. Enabling solid state batteries remains the holy grail of battery R&D and should be pushed to commercialization.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer expressed surprised that future work does not include collaboration and validation with cell and material developers. The reviewer is also curious about the wide variation in interfacial impedance that were measured using different ALD surface treatments.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

No comments were received in response to this question.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said this project had a reasonably high budget for a university project, but considerable work is being done as well, so appropriate.

Presentation Number: es288
Presentation Title: Construction of High-Energy Density Batteries
Principal Investigator: Christopher Lang (Physical Sciences Inc.)

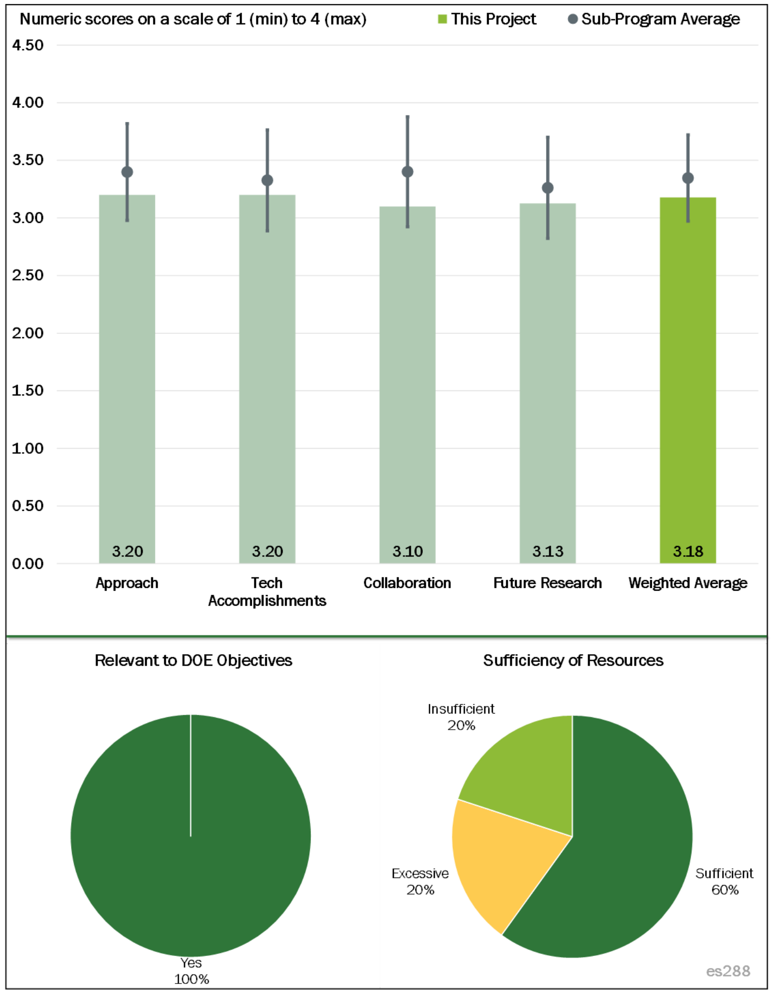

Figure 3-49 - Presentation Number: es288 Presentation Title: Construction of High-Energy Density Batteries Principal Investigator: Christopher Lang (Physical Sciences Inc.)

Presenter

Christopher Lang, Physical Sciences Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that to achieve the overall project objective of constructing a cell offering a 25% increase in cell energy density over the state-of-the-art, PSI followed a clear and well-designed path: construct cathode using their high active coating technique; increase charge voltage; increase active material loading in cathode; and fabricate lighter anode current collector. By following such a path, the energy density of the cell was gradually improved to meet the target value. The reviewer said that generally speaking, the approach to perform the work is effective and well-designed.

Reviewer 2:

The reviewer said that the scope seemed very broad and ambitious for SBIR. The reviewer said the project seemed to limit execution and follow through on the anode, which was the key contributor in the overall specific energy benefit. According to the reviewer, it would have been better to demonstrate that the cathode coating was robust to multiple suppliers, binders, and electrode loading.

Reviewer 3:

The reviewer said nice project concept on getting thicker electrodes to work, and need more effort in areas like this. The cycling results look promising. The reviewer said try to include more data using other protocols including high-temperature cycling, low-temperature power, and storage data. The reviewer would like to see more comparison on performance with state-of-the-art electrodes (lower loading), and/or standard current collectors.

Reviewer 4:
The reviewer said that results are very interesting, but there is no description of the coating material, coating process, etc., thus it is not possible to assess PSI's technology, its manufacturability/scalability.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:
The reviewer remarked that the volumetric advantage of reducing the binder content looks to be significant but is not well promoted.

Reviewer 2:
The reviewer said the project should show exact calculations for energy density. However, if they are correct, this project appears to be hitting targets.

Reviewer 3:
The reviewer commented that so far, improvement of energy density could be clearly seen. By applying the high active (HA) coating technique and light composite anode current collector, the energy density could be improved. However, whether the energy density of the cell could reach the target still needs to be verified. Besides, some information needs to be further provided by PSI. The reviewer asked, first, how the cost of anode current collector compare with Cu current collector. Second, at high active material loading of over 35mg/cm^2, the reviewer asked how the performance of cathode prepared by the HA coating technique compares with the cathode prepared following traditional coating procedure. Third, as the cycling number of provided pouch cell data with high charge voltage is lower than 1,000 cycles, the feasibility of cycling the cell under high-voltage is still questionable.

The stability of the electrolyte should be responsible for this problem. The reviewer said that no data were shown for improving the stability of electrolyte, and it seems to be difficult to solve this problem in the remaining several months. In addition, it seems that the capacity of HA coated NCM-622 cathode tends to fade faster than baseline cell under either low charge voltage (4.2V) or higher charge voltage (4.3V). But, according to the reviewer, this fading rate is acceptable. In a word, whether the final output could meet the target still needs to be verified.

Reviewer 4:
The reviewer said that the cell data looks great, but insufficient information was provided to assess PSI's technology.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent feedback from SKC.

Reviewer 2:
The reviewer said that PSI showed excellent collaboration and coordination with SKC Powertech. SKC PowerTech contributed a lot for punch cell fabrication process. However, according to the reviewer, based on the results so far, the contribution of ANL for characterization is rather too small.

Reviewer 3:
The reviewer commented that the project collaborations with a cell builder validate the approach. The reviewer asked where cost information comes from on the coating. It would be good to get a materials company involved.

Reviewer 4:

The reviewer noted that collaboration is not a SBIR requirement. PSI is working with ANL and SKC Powertech as a battery manufacturing partner, but the review is vague on what their levels of effort or contributions were.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented continue getting validation data in larger cell formats.

Reviewer 2:

The reviewer said that because the project is going to end, the future plan for demonstrating pouch cells with targeted energy density and cycle life is good. However, because no preliminary data were given for the adjustment of electrolyte to improve the stability of electrolyte at high-voltage and the cycle life of the cells cycling at high-voltage is insufficient, it is doubtable whether this work could be done in the last few months. The reviewer said that these issues should be figured out and worked on much earlier than this point.

Reviewer 3:

The reviewer noted that the project ends in six weeks from the AMR. The reviewer would like to see a finite element analysis (FEA) thermal analysis of the composite anode current collector cell design (less conductive than baseline) and the lower binder content cathode design (more conductive than baseline). Also, higher active loading slurry may enable faster throughput drying — economic benefit.

Reviewer 4:

The reviewer said that future work is only focused on a demonstrating aspect of the technology, no work proposed on improvement of the technology.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said that battery energy density/specific energy gains through improved cell design should be strongly supported. The return on investment is higher and risk is lower than material or electrolyte discovery.

Reviewer 2:

The reviewer noted that projects that improve energy density of LIBs support DOE objectives.

Reviewer 3:

The reviewer commented that this project could help improve the energy density of LIBs and in return contribute to petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that generally, the resources for this project have been sufficiently utilized and the stated milestones have been achieved on time.

Reviewer 2:

The reviewer said that the scope of the program was too broad.

Presentation Number: es289
Presentation Title: Advanced Polyolefin Separators for Lithium-Ion Batteries Used in Vehicle Applications
Principal Investigator: Weston Wood (Entek)

Presenter

Weston Wood, Entek

Reviewer Sample Size

A total of five reviewers evaluated this project.

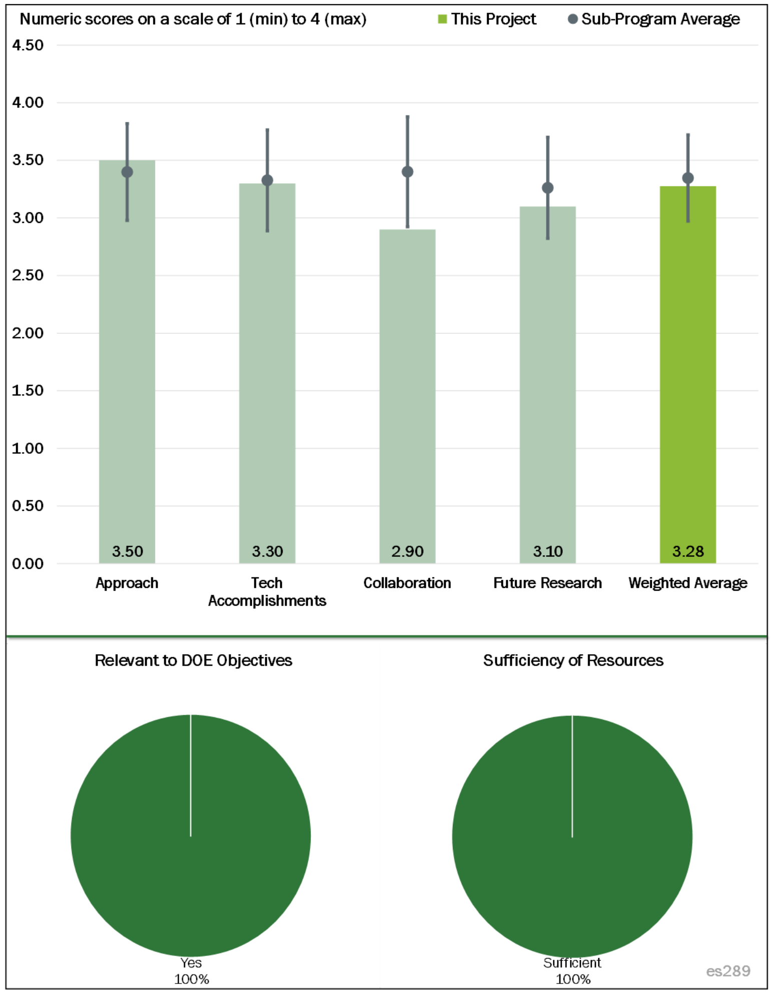

Figure 3-50 - Presentation Number: es289 Presentation Title: Advanced Polyolefin Separators for Lithium-Ion Batteries Used in Vehicle Applications Principal Investigator: Weston Wood (Entek)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted a well outlined experimental plan to address barriers and meet the objectives.

Reviewer 2:

The reviewer said it was great to see work on separators included in the DOE portfolio. The reviewer expressed concern on moisture sensitivity in a typical manufacturing environment. The reviewer said that there is not enough information about cost in the presentation.

Reviewer 3:

The reviewer commented that this work was performed well and the key points, including the wettability and safety, were investigated in a well-organized way. One concern is that the resistance/ ion mobility of the entire cell with the coated separator has not been touched, which would be an important factor for this work.

Reviewer 4:

The reviewer remarked that it appears dendrite penetration was added to scope. The reviewer was unclear if the process can be applied only to an Entek/PE separator, but Entek is not really motivated to establish this.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance

Reviewer 1:

The reviewer observed good test data for separator — penetration, etc. The reviewer said that more electrochemical testing is needed, but what the project team has looks good. The reviewer was unclear how the project will meet the electrolyte goal for 5.0V cells in the time remaining.

Reviewer 2:
The reviewer said that it is good to see the improvements on safety, Li penetration suppression, wettability, and NCM cell performance. One suggestion is to conduct the ionic conductivity and resistance test as soon as possible, which may affect the entire performance of this technique.

Reviewer 3:
The reviewer said that initial films were prepared using dip coating. The reviewer was not clear what the scalable process/integration with baseline separator production is, but Entek is well qualified to understand scalability. The reviewer would like to see large-format cell abuse testing. The reviewer remarked need more clarity on Entek benefits compared to other commercially available alumina coated separators.

Reviewer 4:
The reviewer was not clear if the data/results shown are versus a commercial separator, and if so, what are the guarantees that Entek's scale-up process produces same consistent material.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed appropriate collaborators for cell build and testing.

Reviewer 2:
The reviewer said that Farasis seemed not enrolled too much about the high-voltage cell developments at the moment.

Reviewer 3:
The reviewer pointed out that collaboration and coordination is not a requirement of the SBIR program and this may be outside what a private company is willing to share.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that a great enhancement of the separator performance has been achieved. Some key factors, including ionic conductivity, moisture removal, and high-voltage resistance, have been put forward for future study. One concern is that some of these issues are lack of investigation based on the data provided. The reviewer pointed out that it is challenging to solve them in the last phase of this project.

Reviewer 2:
The reviewer did not see a specific path to 5V shown. This is a hard problem. The reviewer also said that the moisture problem is not addressed enough.

Reviewer 3:
The reviewer would prefer to see future work address the moisture risk and in-line coating. High voltage is a complex problem to test effectively and not an immediate market. For example, electrolyte work is outside the scope of the program. In this reviewer's opinion, building a 25 Ah 5.0V cell would be premature.

Reviewer 4:
The reviewer asked what scale is planned to be used for the demonstration of the coating methods.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that this project shows good enhancements of the separator safety and possible cost reduction of separator coating. So this technology will be beneficial to the practical battery application.

Reviewer 2:

The reviewer noted that abuse-tolerant separators are in the market. Entek seems to have demonstrated that this approach has advantages over coated separators if moisture issues can be managed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the main stated milestones have been achieved timely. One thing that can be improved is progress of the high-voltage resistance and ionic conductivity tests, which can be conducted based on the achieved results.

Presentation Number: es290
Presentation Title: Hybrid Electrolytes for PHEV Applications
Principal Investigator: Surya Moganty (NOHMs Technologies)

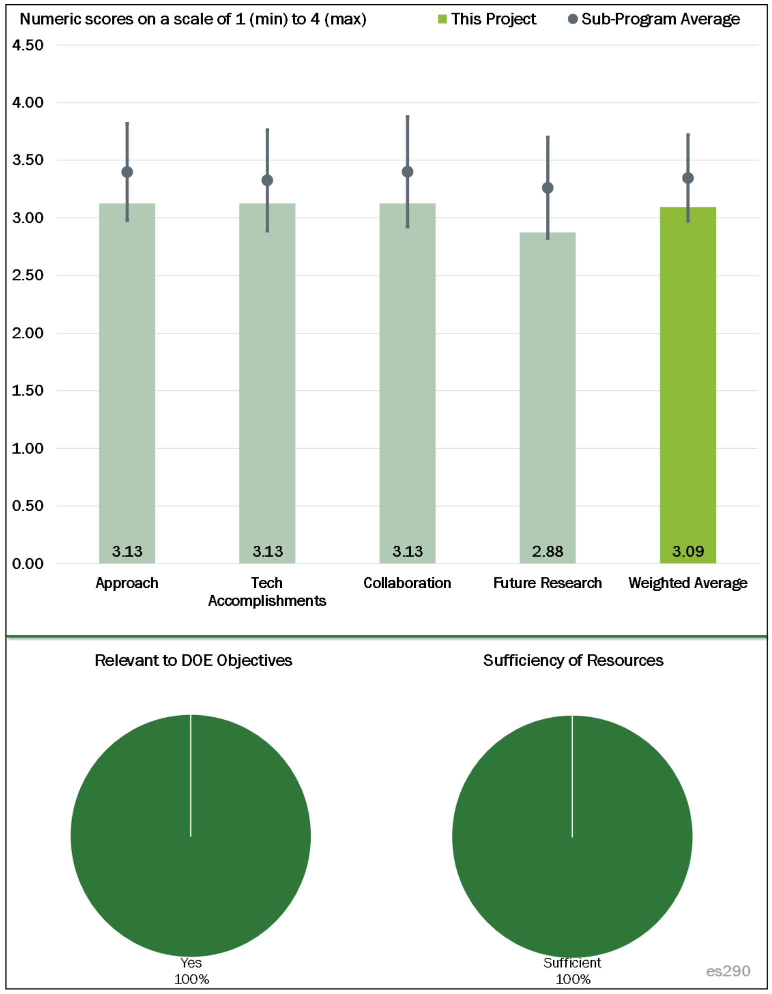

Figure 3-51 - Presentation Number: es290 Presentation Title: Hybrid Electrolytes for PHEV Applications Principal Investigator: Surya Moganty (NOHMs Technologies)

Presenter

Surya Moganty, NOHMs Technologies

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the objective here is to develop safe high-voltage electrolytes based on functionalized ionic liquid (IL)-based electrolytes that exhibit high conductivity, excellent electrode stability, and a wide operational temperature range for high-voltage (4.5 to 5V) L)-ion batteries. The reviewer explained that state-of-the-art organic electrolytes have inadequate oxidative stability at high-voltages (greater than 4.5V) and have inherently poor abuse tolerance. IL electrolytes, on the other hand, have adequate safety and high-voltage stability, but the stability at anode potentials, low-temperature performance, and cost are still issues. The reviewer elaborated that the specific objectives here are to develop the functionalized IL electrolytes, demonstrate their performance in 2 Ah pouch cells with Ni Mn oxide (NMO) and Ni Mn Co oxide (NMC) 532 cathodes, perform a design and cost study of electrolyte production, and finally, deliver 10 Ah pouch cells to DOE for further validation. The reviewer added that the approach is to design functionalized ILs based on literature data and in-house proprietary knowledge, synthesize and characterize them for transport and electrochemical properties, evaluate them in coin and in single-layer pouch cells, and later scale up to 2-10 Ah cells with the NMO and NMC high-voltage cathodes. As mentioned above, ILs have shown promise based on their oxidative stability and safety, but their stability at the anode potentials, performance at low temperature, and cost have been the issues in their implementation. The reviewer concluded that overall the approach is useful in addressing two main technical barriers of the organic electrolytes in Li-ion cells, and the project is well designed and integrated with other efforts.

Reviewer 2:

The reviewer stated that NOHMs Technologies develops IL-based electrolytes with high-voltage limits (4.5 to 5V) and better temperature stability for Li-ion, adding that this is a unique project concentrated in electrolytes for a high-voltage (greater than a 4.5V) battery.

Reviewer 3:

This reviewer understands from the discussion that the ILs component is essentially another additive to the electrolyte but added that the exact role in the overall stability is not really addressed. This reviewer thought that the effort to examine cost will be particularly useful.

Reviewer 4:

The reviewer replied that the project team is developing new molecules to add to standard electrolytes that are safe and that do not make any properties worse.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer affirmed that excellent progress has been made in designing and demonstrating new IL-based electrolytes compatible with high-voltage cathodes, elaborating that the functionalized ILs have ionic conductivities comparable to the conventional organic electrolytes but have improved stability towards high-voltage cathodes, evident from the X-ray powder diffraction (XRD) studies of the cathodes in contact with these electrolytes, even at warm temperatures. Good cyclic stability has been demonstrated in pouch cells of 2 Ah - 10 Ah at room temperature and elevated temperature (45^{o}C). The reviewer explained this is partly made possible with the electrolyte additives (some proprietary) which show similar improvement in these ILs as in organic electrolytes. Several cells of 2 Ah-10 Ah have been delivered to the USABC for its assessment, which met the USABC performance targets, including low-temperature cracking and good cyclic stability at moderately high discharge rates of C/2 at warm temperatures.

The reviewer stated, however, that it should be realized that the cathode loading is rather low (15 mg/cm^2), which may result in low specific energy and energy densities for these cells. (The reviewer suggested including those values for the large pouch cells.) The reviewer elaborated that thicker electrodes will increase the current densities, which may adversely affect the rate capability. The reviewer also observed that in some of the abuse tests performed at SNL, the cells exhibited thermal runaway, which is a bit puzzling with these IL electrolytes. The reviewer remarked that the cost analysis here shows that it would be possible to meet the DOE cost targets with the electrolytes. The reviewer concluded that overall the results are quite encouraging for the use of ILs in lieu of organic electrolytes and that the technical accomplishments are notable and the progress is good and consistent with DOE goals.

Reviewer 2:

The reviewer indicated that there seems to be good progress in the program with a fairly wide range of tests being conducted, mostly around standard cell testing.

Reviewer 3:

The reviewer explained that NOHMs Technologies has developed IL electrolytes with higher decomposition temperature (greater than 300^{0}C) and better cycle life (350 cycles with 80 retention), adding that higher loading cells (10 Ah NMC) are under evaluation. The reviewer also noted that the XRD analysis does not say much about the advantages of NOHMs Technologies' electrolytes over others in terms of maintaining of the structural stability of cathode.

Reviewer 4:

Although NOHMs Technologies' electrolytes perform better than simple electrolytes with no additives, this reviewer stated that the recipient has no evidence that its electrolytes perform any better than state-of-the-art electrolytes that have already been reported, or even commercially available (4.35V) electrolytes. Without such comparisons, this reviewer cannot evaluate whether the recipient is making any real progress.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that there are ongoing collaborations with A123 Systems for the fabrication of cathodes and small format cells construction (NMC and NMO) and small format cells for proof of concept and fabrication of 2 to 10 Ah prismatic pouch cells with NOHMs Technologies electrolyte. There was collaboration with Xerox on the cost analysis of high-volume electrolyte production and with the DOE laboratories in the performance and safety testing of cells.

Reviewer 2:
NOHMs Technologies is working with A123 Systems (electrode and pouch cell construction) and XEROX (high-volume electrolyte production). It also collaborated with SNL in battery abusing test.

Reviewer 3:
The PI has extensive collaborations with a couple of companies.

Reviewer 4:
The reviewer replied okay.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer explained that the proposed future studies are to: Complete the accumulation and analysis of USABC 2 Ah NMO test results; downselect formulation for 10 Ah NMO build; complete cost model for final electrolytes; and fabricate and deliver 30 NMO 10 Ah pouch cells with NOHMs Technologies electrolyte. The reviewer suggested it would be helpful if specific energy and energy densities realized in these cells and also get some handle on the abuse tolerance and strategize on how further improvements can be made here. The reviewer concluded that these studies are consistent with both project and DOE goals.

Reviewer 2:
The reviewer replied that NOHMs Technologies listed detailed steps for future works including delivery of 10 Ah NMO 10 pouch cells and cost modeling to complete the project.

Reviewer 3:
The reviewer noted that the project is ending in 2017 and the PI is working on the final deliverables.

Reviewer 4:
This reviewer does not see a clear path forward beyond trying a large number of molecules

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer offered that performance and safety of electrolyte at high-voltage range is critical for increasing the capacity of LIBs to be used in electric vehicles.

Reviewer 2:
The reviewer affirmed this project is highly relevant for high-energy density cells.

Reviewer 3:
The reviewer remarked that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles, elaborating that conventional cathode materials have low specific energy and energy density. In addition, the reviewer said, the use of emerging high-voltage/capacity cathodes is precluded by the organic electrolytes, which also pose safety issues. Explaining that alternate stable and safe electrolyte are needed to improve the specific energy and energy density and safety of LIBs, the reviewer concluded that these issues are being addressed by the project.

Reviewer 4:
The reviewer responded that the project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Based upon the demonstrated works and the wide collaboration, the reviewer believes that the NOHMs Technologies system has sufficient resources to achieve the stated milestones in time.

Reviewer 2:
The reviewer agreed that the resources are adequate for the scope of this work.

Reviewer 3:
The reviewer stated the resources are sufficient.

Reviewer 4:
The reviewer responded okay.

Presentation Number: es291
Presentation Title: SAFT-USABC 12V Start-Stop Phase II
Principal Investigator: Alla Ohliger (Saft)

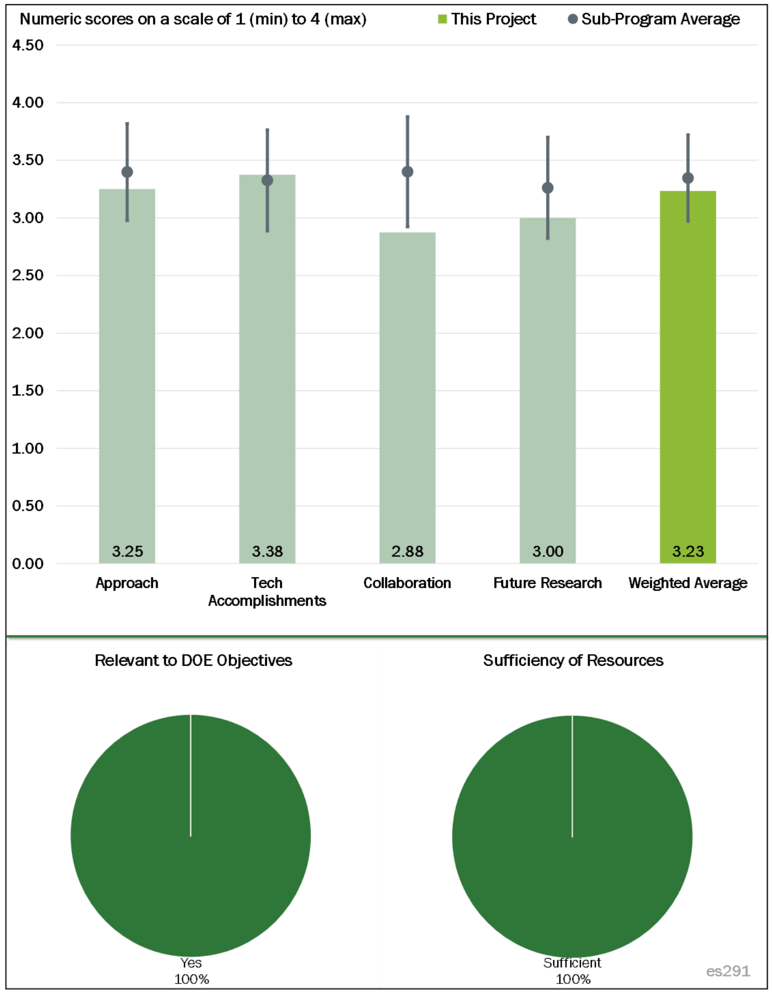

Figure 3-52 - Presentation Number: es291 Presentation Title: SAFT-USABC 12V Start-Stop Phase II Principal Investigator: Alla Ohliger (Saft)

Presenter

Joong Sun Park, Saft

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that the objective here is to develop an advanced, high-performance battery module for 12V start-stop vehicle (12VSS) applications, in compliance with the USABC performance requirements, based on SAFT's proprietary lithium titanium oxide (LTO) anode-based (with Al current collector) LIB technology. The reviewer explained that the goal is to deliver to USABC 12VSS module assemblies with pouch cells in thermoplastic module along with battery management electronics, adding that the project cost of cell module is under \$220. The reviewer elaborated that the approach involves the use of an LTO anode, which has the advantages of high-power capability, long life, and being free of Li plating, and an LMO cathode. Different electrolyte blends (binary and ternary) are being examined for improved low-temperature conductivity, improved low-temperature cranking, and high-temperature stability (gassing). In parallel, the reviewer continued, a simple battery pack design is being developed with supporting thermal modeling. The reviewer concluded that the approach addresses the technical barriers, and the project is well-designed, feasible, and integrated with other vehicle technologies projects.

Reviewer 2:

The reviewer explained that the project led by Saft Jacksonville is concentrated on temperature stability and gassing control based on the team's proprietary LTO LIB technology. The objectives are delivering high-performance 46 Ah cells and modules, and identifying a path to full commercialization. The reviewer concluded that the technical barriers are well addressed.

Reviewer 3:

The reviewer replied that while this is a valuable project, it is unclear how the team plans to address temperature and gassing problems. The reviewer, added, though, that some progress has been made.

Reviewer 4:

The reviewer commented that the PIs seem to understand the problems and have a good plan to attack the issues but that it is more than a bit disappointing that the PIs went away from the polymer monoblock case. Also, the reviewer said, their choice of going to LMO presents a lot of challenges for long life. This reviewer would have used NMC and maybe tried to work in an extra cell to attack the cold-cranking issue, but that certainly would have impacted the cost.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that because the key requirement for the USABC program is the cold cranking, much of the recent effort was focused on identifying electrolytes with good low-temperature conductivity and also high-temperature stability. The reviewer recounted that the first deliverable cells delivered to USABC for cold crank and life testing have met the energy/power requirement at RPT6 at 45ºC and the second deliverable cells Li ion Mn oxide (LMO)/LTO cells with optimized LTO anode and electrolyte formulations have passed cold crank at -30ºC after removing 360-Watt-hour (Wh) scaled energy. The reviewer continued that the modified electrolytes (maybe with a combination of ester blends and LiFSI salt and additives based on the data shown here) have provided improved low-temperature cranking, as well as reduced gassing and impedance growth during storage (at warm temperatures) and cycling.

In addition, the reviewer said, the design for the 46 Ah pouch cell has been completed and the tooling required to manufacture these cells has been identified. Thermal analysis of this module suggests survivability after exposure to at 105ºC for 15 minutes, the reviewer observed, and cost analysis indicates that the projected cost of the pouch cell module is approximately $160. Finally, the reviewer, explained, the supplier for low-cost battery management electronics were screened and downselected. The reviewer found that these accomplishments are encouraging and the progress is quite consistent with the project objectives and DOE goals.

Reviewer 2:

The reviewer remarked that while the technology needs further development, the project has clearly shown progress in a number of areas.

Reviewer 3:

The reviewer stated that the two cells delivered so far passed the energy/power requirement at RPT6 at 45^0C (first cell) and cold crank at -30^0C (second cell). The reviewer added that it is expected that the team will deliver the 12VSS prototype at the end of the project.

Reviewer 4:

The reviewer concluded that it is too early to say if the team's approach has a good chance for success. Noting that the team is trying novel electrolytes (esters) to overcome the low-temperature problems, the reviewer explained that it is unclear how it will address the high temperatures that are under the hood at reasonable cost, pointing out that the team trying to modify the LTO for better cold crank.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that there is collaboration within Saft and a few external partners and with the DOE national laboratories for the assessment of the delivered cells and modules.

Reviewer 2:

The reviewer stated that Saft tested cold crank and life performance for under the hood conditions at INL.

Reviewer 3:
The reviewer replied okay.

Reviewer 4:
The reviewer replied that collaborations are rather limited.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Noting that the project is coming to an end this year, the reviewer observed that the planned studies in the remaining few months will focus on decreasing gassing while maintaining superior cold crank performance, life, and reduced gassing. These will also include improvements in electrode formulation (e.g., porosity, binder, and carbon percolation network), surface coatings by ALD or dry-coatings, and electrolyte optimization, i.e., solvent and salt additives. In parallel, the reviewer explained, other efforts will address the module and system development to build prototype 12VSS modules. The eventual goal is to develop and manufacture over 20 fully operational batteries with an integrated electronic system. The reviewer stated that these studies are well planned and in tune with the goals of the project and needs of 12VSS LIBs.

Reviewer 2:
The reviewer remarked that sassing seems to continue to be an issue and suggested that the PIs may want to consider alternative sources of LTO from companies that "claim" to have solved the problem.

Reviewer 3:
The reviewer noted that Saft listed steps in further improving the electrode formulation to decrease gassing and improve the life of LTO at high temperatures.

Reviewer 4:
The reviewer replied that it is unclear how the project team will solve their problems

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed that replacing the conventional 12V lead-acid batteries with LIBs for start-up applications will reduce battery mass and volume (by 60%), improve the service life, and reduce maintenance. The reviewer also noted that their rapid recharge reduces the load on the alternator as they retain more power and are able to handle the charge faster than lead-acid batteries. All these characteristics will result in reduced fuel consumption and thus reduced CO_2 emissions. Noting that current active materials have low specific power to support cranking, especially at low temperatures, the reviewer stated that new active materials in conjunction with advanced electrolytes are needed to provide low-temperature cranking and high-temperature resilience. Also, the reviewer said, simpler pack designs and battery management systems are essential to make the LIBs a viable replacement. The reviewer judged that this project is aimed at addressing these challenges.

Reviewer 2:
The reviewer said this is highly important for the auto industry.

Reviewer 3:
The reviewer stated that temperature stability is critical for battery safety and must be well controlled in electric vehicles.

Reviewer 4:
The reviewer answered that the work is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that the resources are adequate for the scope of the project to meet the stated milestones in the scheduled time.

Reviewer 2:
The reviewer stated that the resources are sufficient.

Reviewer 3:
The reviewer said that Saft demonstrated that it can conduct the project with its own technologies and in collaboration with INL for some testing work.

Reviewer 4:
The reviewer replied okay.

Presentation Number: es293
Presentation Title: A Closed Loop Process for the End-of-Life Electric Vehicle Lithium-Ion Batteries
Principal Investigator: Yan Wang (WPI)

Presenter

Yan Wang, WPI

Reviewer Sample Size

A total of five reviewers evaluated this project.

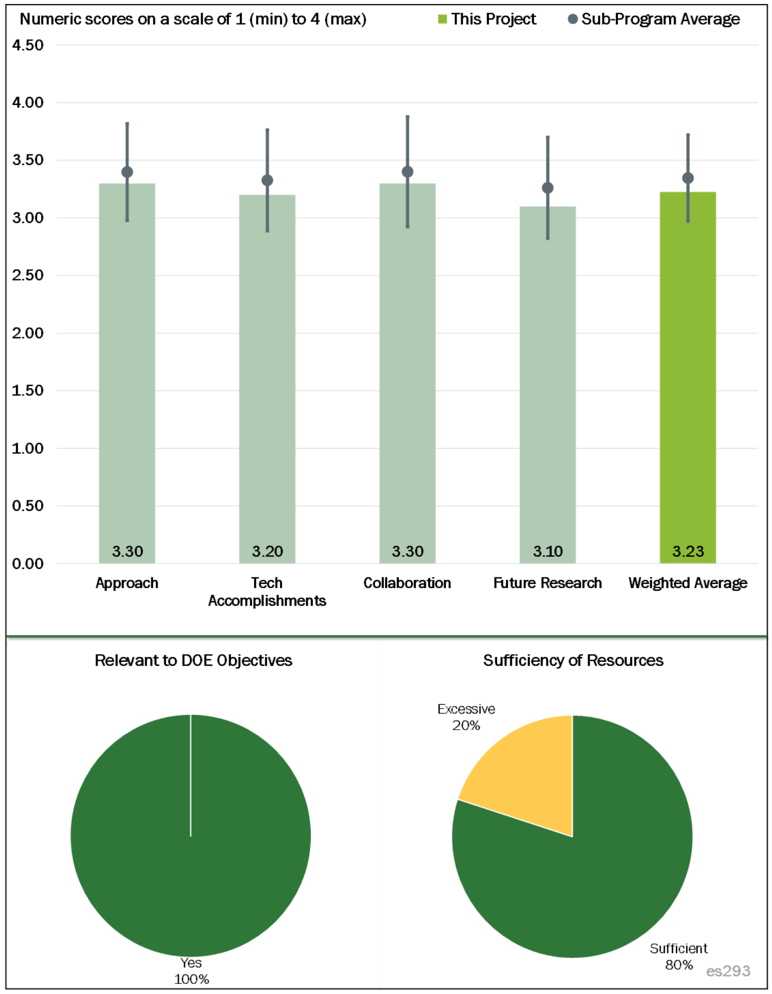

Figure 3-53 - Presentation Number: es293 Presentation Title: A Closed Loop Process for the End-of-Life Electric Vehicle Lithium-Ion Batteries Principal Investigator: Yan Wang (WPI)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer affirmed that this is the project that addresses a very critical issue of battery application, specifically, recycling. The reviewer praised the PI has having demonstrated an industrially viable process to recycle the battery and recover the most valuable elements, Ni and Co, and reuse them to make new cathode powders.

Reviewer 2:

The reviewer observed that the large amount of end-of-life battery waste causes serious environmental issues and stated that this project shows an effective and outstanding method of dealing with battery waste and recycling the metals Ni, Co, Mn, iron, and Cu via dissolving cathode material in strong acid and precipitating new cathode material. The reviewer cautioned, though, that one concern of this strategy is the cost of this approach compared with that of industry large-scale production. The reviewer recommended evaluating the cost of each approach of producing cathode material.

Reviewer 3:

The reviewer replied that this is a very practical project and approach to recycling but asked how is this recycling process different/novel/more cost-effective than Umicore's approach. The reviewer also stated that much more electrochemical testing is required to conclude that the recycled materials are of adequate quality.

Reviewer 4:

The reviewer responded that feasibility is done at meaningful 20 to 30-kilogram (kg) scale, remarking that this is an accomplishment for an academic-led program. The reviewer noted that a 0.5-ton pilot plant is planned, although it was unclear what relationship that is to the present program. The reviewer concluded there needs to be validation that large-scale shredding operations can be performed safely.

Reviewer 5:

The reviewer stated that work done on developing NMC material from the recycling stream, which is comparable to product on the market, is valid as an academic effort, but this was the main focus of the investigation. The reviewer commented that there is nothing novel in the recycling approach, elaborating that the team should have a clear path forward to demonstrate feasibility on the industrial scale and be prepared to answer questions on cost, waste disposal of contaminated liquid streams, general water usage, plant footprint sized to be profitable, etc.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked that by recycling the battery waste, this project can make large batch of new cathode material at kg scale with novel electrochemical performance.

Reviewer 2:

The reviewer stated that there is good analytical comparison, but a lack of electrochemical evaluation and asked if the team has done a cost assessment.

Reviewer 3:

This reviewer would like to see two improvements: First, inclusion of touch time/labor cost for discharging and isolating cells. The reviewer pointed out that an issue is can commingled cell chemistries or cell OEMs be accommodated or will there need to be a sorting operation. Second, accounting for the waste stream costs and management, neither of which were. With the claimed 80% yield, the reviewer observed, there is a lot of Cu and Ni unaccounted for and potentially dispersed in the operation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer affirmed that this project shows not only the recycling of battery waste to make new cathode material, but also collaborating with A123 Systems to test its battery performance to further prove the effectiveness of the proposed approach.

Reviewer 2:

The reviewer replied that A123 Systems is a good cell partner, but the project also needs a materials company involved here.

Reviewer 3:

The reviewer stated that the project would benefit from NMC material supplier such as BASF, Umicore, etc., adding that the roles of many partners was not clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that large-scale recycling of batteries may encounter some new problems and that it can further tell the effectiveness of this method of recycling battery waste. The reviewer noted that the approach mentioned the need for recovery of Ni, Co, and Mn in this research. One more thing the reviewer added about waste LIB is the recovery of Li existing in the cathode and electrolyte. Pointing out that the price of Li salts goes up quickly with increasing demand of LIB, the reviewer recommended looking for an effective strategy of recycling of Li in waste LIB.

Reviewer 2:

The reviewer replied that detailed analytical studies on the cathode materials should be helpful. For example, the reviewer noted, there is no indication that the mixed metal hydroxide precursor is being washed after co-precipitation with sodium hydroxide and asked if, in general, there is an in-process quality control to ensure chemical purity.

Reviewer 3:

The reviewer had two comments: First, the activities listed as remaining challenges are too sparse, elaborating that here is not enough electrochemistry data to jump to 2 Ah cells. The reviewer said that much more testing will be needed and that this should be done before scaling up the process. Second, a full economic model should be included to answer questions such as what do the waste streams look like now and is the cost of managing those included here.

Reviewer 4:

The reviewer found that the economic model is not convincing yet, noting that a process with 80% yield is not closed loop. The reviewer added that the model must also account for diversity in pack design, cell design, cell chemistry, state of health, etc., and must be correct on the battery pack Cu recovery, which is likely the high-value component of the pack. The reviewer pointed out that this is also an opportunity to identify design rules and best practices to enable standardized mechanical disassembly as well as recovery and chemical isolation of materials.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that the LIB plays an important role in energy storage for the renewable energy and that the project demonstrates an effective method of recycling battery waste, which may further reduce battery cost and improve the utilization of renewable energy.

Reviewer 2:

The reviewer answered that Cu, Ni, and Co recovery can improve the economics of large-scale energy storage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer responded that the project demonstrates sufficient resources of battery waste treatment, the recycled new cathode material preparation and testing.

Presentation Number: es296
Presentation Title: Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries
Principal Investigator: Chulheung Bae (Ford Motor Co.)

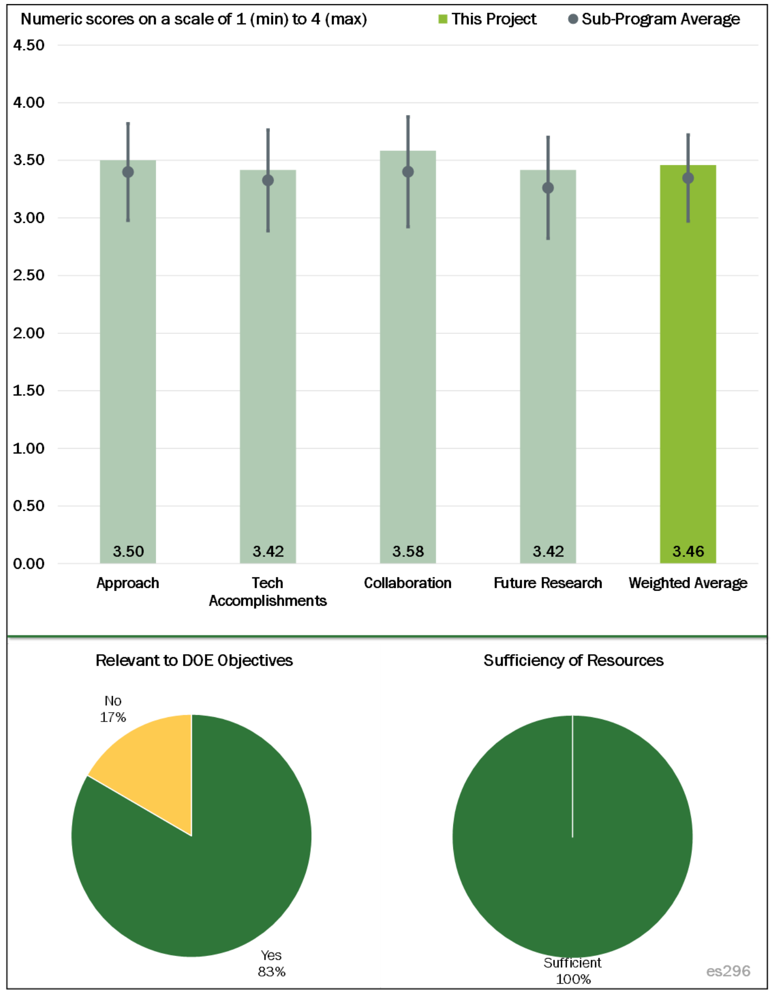

Figure 3-54 - Presentation Number: es296 Presentation Title: Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries Principal Investigator: Chulheung Bae (Ford)

Presenter

Chulheung Bae, Ford Motor Co.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised the approach as appearing to be well conceived, logical, and suitable for the associated objectives.

Reviewer 2:

The reviewer affirmed that the project is well designed and appears to leverage experiments and developments in other DOE and National Highway Traffic Safety Administration (NHTSA) projects, as well as internal resources at Ford.

Reviewer 3:

The reviewer agreed that the approach clearly identifies the gap in existing simulation capabilities and that a path to address the gap is identified and concurred that progress is made with the support of software developer.

Reviewer 4:

The reviewer stated that the vehicle and battery crush worthiness is very well defined.

Reviewer 5:

The reviewer responded that the approach seems good, but observed that when using solid elements, there needs to be at least three elements through thickness and suggested that maybe a mesh-independent study should be conducted. The reviewer would also like to see more information on heat transfer, and asked the project team how it considers advection or is it all conduction and asked the team to provide details on heat generation. This reviewer assumes the team is calculating heat release based on the Gibbs energy of reactions at electrodes.

Reviewer 6:
The reviewer stated that while the models with data comparison are always good, it is unclear that the many ways a cell can or cannot fail are well comprehended in a single fault failure model. For example, the reviewer offered, the separator could tear or just stretch or it could stretch and then tear. The reviewer said that this does not seem to be covered inherently, or it could be but only by manual intervention.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer affirmed that noticeable progress has been made with technical accomplishments with the layered solid element approach, adding that the initial accomplishments and comparative analysis to the test show promising results. The reviewer concluded overall, nicely done.

Reviewer 2:
The reviewer agreed that accomplishments seem good. Remarking that this is a necessary model to connect all aspects, the reviewer said it is good to see some code development.

Reviewer 3:
The reviewer stated that the project developed model and reduced computation time and that there is reasonable correlation of data. The reviewer further stated set up external short and module simulations.

Reviewer 4:
The reviewer replied that model development is complete.

Reviewer 5:
The reviewer responded that the work for the alpha version multi-physics solvers and material models appears to be delayed, and that the technical progress appears to be reasonable considering that the PI for this project has been changed two times recently.

Reviewer 6:
The reviewer commented that the layered solid method's performance with respect to bending moment should be evaluated.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the work as very well coordinated and collaborated with software developer and other research establishments to address the critical mission needs both from material characterization and simulation capabilities points of view.

Reviewer 2:
The reviewer agreed that the project members appear to have good collaboration among each other and the project has leveraged experiments and developments in other DOE and NHTSA projects, as well as internal resources at Ford.

Reviewer 3:
The reviewer stated there is good collaboration with LS-DYNA team and added that this is a good use of LS-DYNA if one is getting assistance with code development.

Reviewer 4:
The reviewer replied that collaboration with ORNL, (LBNL, and SNL is sufficient for the development.

Reviewer 5:
The reviewer commented that really only internal collaboration between main partners was made clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer affirmed that the proposed future research is well thought out and captures the critical needs.

Reviewer 2:
The reviewer agreed that the future research seems good but suggested focus on validation. The reviewer would also like to see a mesh study.

Reviewer 3:
The reviewer stated that the revision and fine tuning of the model will result in a better model.

Reviewer 4:
While agreeing that the proposed future research is reasonable, this reviewer expressed concern about whether this project can be kept moving slowly with PIs not replaced so often.

Reviewer 5:
While concurring that the proposed work is good, the reviewer said there is no obvious effort to look at the range of crush results that occur in duplicates of the same field tests or how to capture that with the model.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer agreed there is excellent relevance.

Reviewer 2:
The reviewer affirmed that this project supports overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (and thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 3:
The reviewer said this project addresses DOE objectives of promoting vehicle electrification by developing models and validation on automotive batteries' response to crash-induced crush and short circuit, overcharge, and thermal ramp.

Reviewer 4:
The reviewer responded that the model will accelerate battery development and system integration.

Reviewer 5:
The reviewer observed that reduction in cost and improved abuse tolerance are both needed work and goals of this project, adding that if this is achieved, batteries will be more reliable and less expensive, and this, in turn, will drive reductions in gas use by increasing electric miles driven.

Reviewer 6:
The reviewer disagreed, remarking that the project is characterizing batteries from mechanical, thermal, and electrical points of view and is therefore not relevant to petroleum displacement.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer stated that this project is a collaboration between software developer and material characterization and that all the milestones are being addressed in a timely fashion.

Reviewer 2:
The reviewer agreed that funding and resources are sufficient.

Reviewer 3:
The reviewer replied it seems fine.

Reviewer 4:
This reviewer was concerned whether the contractor can keep the PIs stable in conducting the proposed research work.

Reviewer 5:
The reviewer said that resources are on the edge. The reviewer remarked that the roughly $1.2 million is somewhat high for the work generated. While not badly overfunded, the reviewer stated that this is not as efficient as many of the other projects in the portfolio.

Presentation Number: es298
Presentation Title: Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries
Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

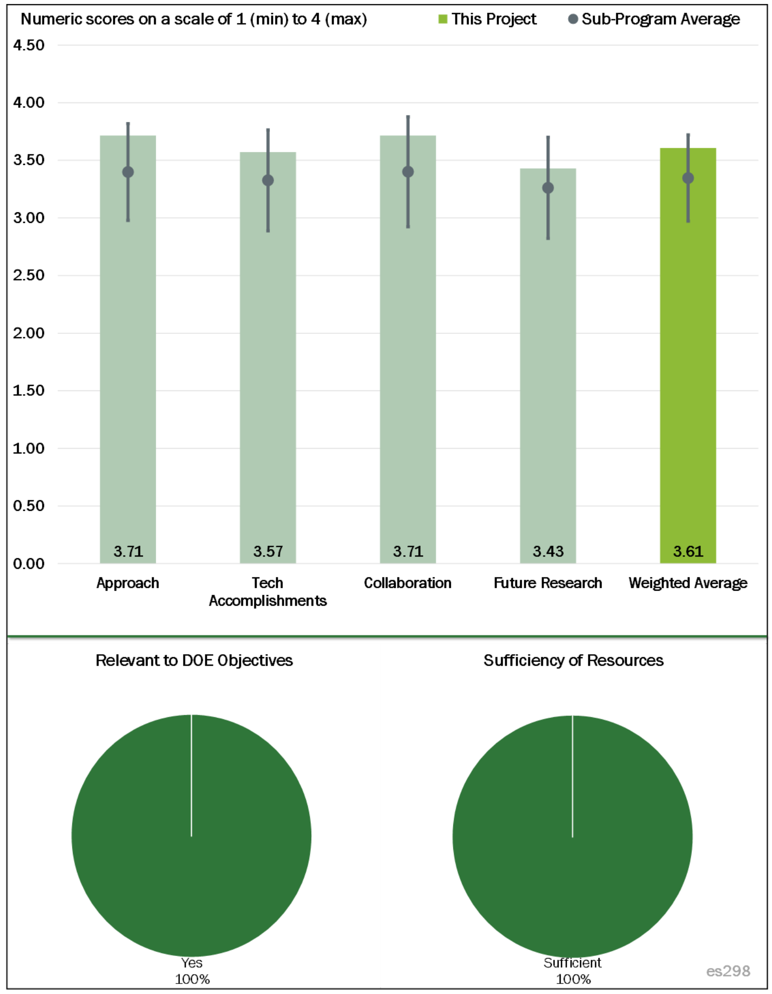

Figure 3-55 - Presentation Number: es298 Presentation Title: Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

Presenter

Shriram Santhanagopalan, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the gap between material R&D and computer-aided engineering (CAE) modelling tools addressed substantially to reduce the computational burden. The reviewer said that one of the big questions is how much of the material R&D data can be transferred to the computer-aided engineering of batteries (CAEBAT) tools, and asked if it is necessary to develop a user material model to capture the material behavior effectively.

Reviewer 2:

The reviewer said that a high-fidelity model of all aspects of a battery that works rapidly would be very helpful in design and especially safety testing of cells and that this project is well arranged to do this with a group to drive the simulations faster and two groups to increase model quality. The reviewer said that a key is validating against real data and that this is also part of the plan. The reviewer believed there is enough planned to provide high confidence and that predictions rather than posttest simulations clearly carry more gravitas. The reviewer said that the cell response is quite variable especially in abuse and so significant testing is needed to generate the scope of responses.

Reviewer 3:

The reviewer said that the time-scale separation method used as part of the reduced order modeling (and documented in the paper “Efficient and Extensible Quasi-Explicit Modular Nonlinear Multiscale Battery Model: GH-MSMD“) is an excellent approach.

Reviewer 4:

The reviewer said the project is an excellent collaboration between national laboratories, DOE, and universities.

The reviewer would prefer to on Slide 16 see a design of experiments (DOE) fractional or full factorial study with reduced set of experiments considering sample input and output. In reference to Slide 11, the reviewer hoped instability of electrolyte has been considered. In reference to Slide 20, the reviewer hoped safety by lightweighting/right-sizing is addressed, and in reference to Slide 24 the reviewer asked if that will be adequate to prevent thermal runways and capacity loss.

Reviewer 5:

The reviewer said that the approach for Task 1 seems like a good approach and that there needs to be more done to propagate uncertainty through model. The reviewer noticed error bars are on order of diffusion coefficient.

The reviewer said that the approach for Task 2 seems okay. The reviewer said that the project is using an explicit FEA model (LS-Dyna) but the strain rates that the project are experimentally testing at are static. The reviewer recommended quickly moving on to higher strain rates, this is what LS-Dyna was made to look at.

The reviewer said that it might be help to define "Abuse" as this is not a well-defined term in the materials community. The reviewer would like to know does it mean fatigue, does it mean dynamic loading, or does it mean friction.

Reviewer 6:

The reviewer said that the project appears to have addressed technical barriers properly as planned.

Reviewer 7:

The reviewer said that the gap between the modeling tools and cell design for the battery develops is addressed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that roughly hundred fold acceleration of the calculation was achieved and that some samples made tested and simulated well.

The reviewer said that the project obtained basic physical parameters of components and that the method for gathering data for parameters and deciding where emphasis will yield value in the final cell.

The reviewer said that the project subjected cells to abuse tests and that Cu foils fail before separator — noting that the foil failure was modeled on only single pairs, not full cells. The reviewer said that the project can calculate how resistance changes as crush proceeds and that the model predicted results well.

The reviewer said that the result is an area to avoid in design and then a measure of error in the good region.

Reviewer 2:

The reviewer said that, given its demonstrated huge speed-up in simulation times with minimal accuracy degradation, this breakthrough reduced order method has the potential to make LIB system modeling and simulation much more tractable. Regarding the parameter identification methodology, the reviewer did not see any indication that temperature-dependence was accounted for.

Reviewer 3:
The reviewer said that the accomplishments for Task 1 seem good and need to focus on uncertainty propagation.

The reviewer said that the accomplishments for Task 2 seem good and that they would quickly move on to realistic loading conditions.

Reviewer 4:
The reviewer said that the project is on target, and referred to a previous comment. The reviewer would also prefer that next time some more details are included on the ongoing project status PowerPoint slides.

Reviewer 5:
The reviewer said that substantial progress has been made towards achieving the target goals.

Reviewer 6:
The reviewer said that the contractor has achieved technical progress as promised.

Reviewer 7:
The reviewer said that the increased computational speed will make the model more acceptable.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the project demonstrated very good coordination among the key players and contributors to achieve the mission critical needs.

Reviewer 2:
The reviewer said that it appears the members of this project have good collaboration and the project leverages experiments and developments in other CAEBAT projects efforts.

Reviewer 3:
The reviewer said that the project is inherently collaborative with several other collaborators outside the funding circle from industry.

Reviewer 4:
The reviewer said that the collaboration is all national laboratories and that it might be useful to integrate some university materials researchers. The reviewer was not sure why the project is using LS-Dyna (commercial version of Dyna) when it could get DOE version Dyna3d or Paradyn. The reviewer asked if the automotive advisors are pushing for the team to use LS-Dyna. The reviewer said that another good software that could model the liquid electrolyte would be CTH out of SNL and that maybe collaborating with someone at Lawrence Livermore National Laboratory would provide you with the source to Dyna and more development possibility.

Reviewer 5:
They reviewer said that hopefully all famous world universities and laboratories and corporations have been explored (benchmarking).

Reviewer 6:
The reviewer said that the testing collaboration with the national labs provide more meaningful models.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future research seems fine and that the reviewer would quickly move past the static tests and move onto to dynamic testing that is more realistic of the actual loading. The reviewer said that this is also what explicit FEA schemes were designed for and that the project's current loading conditions could be simulated with transient implicit schemes.

The reviewer would also like the project to go back and get a better hold of uncertainty in Task 1as there is no way the uncertainty can be on the order of the diffusion.

Reviewer 2:
The reviewer said that the validation and publication of model information will be useful to the industry to accelerate battery development.

Reviewer 3:
The reviewer said that the future research plans are well planned.

Reviewer 4:
The reviewer said that plans are appropriate and do-able and that the timing seems about right.

Reviewer 5:
The reviewer said that it is unclear if the model can cover automotive battery working temperature range. If yes, the reviewer asked if there are validation experiments to cover that range planned.

Reviewer 6:
The reviewer said that once modelling is completed, some statistical designed experiments should be completed. The reviewer referenced prior comments.

Reviewer 7:
The reviewer said that perhaps the future parameter identification research could consider temperature dependence.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 2:
The reviewer said that this project is an integral part of efforts to develop validated modeling tools to accelerate development of batteries, in support of vehicle electrification R&D to reduce dependence on imported oil.

Reviewer 3:
The reviewer said that this could accelerate the development of safe effective cells for a low-cost electric vehicle and that helps displace petroleum.

Reviewer 4:
The reviewer said that accelerated battery development will increase the probability of an EV acceptance.

Reviewer 5:
The reviewer said that the material R&D is focused on characterizing the next gen cathode materials to improve energy efficiency of batteries and that this supports the DOE petroleum objectives.

Reviewer 6:
The reviewer said that it will help DOE to reduce time for development and make more competitive.

Reviewer 7:
The reviewer said yes, the project supports the DOE mission.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that continuing funding is important for statistically designed experiments.

Reviewer 2:
The reviewer said that the contractor appears to have sufficient resources in conducting the proposed work.

Reviewer 3:
The reviewer said that the funding seems roughly right for the task at hand and that the project is making good progress at this funding level.

Reviewer 4:
The reviewer said that resources seem adequate.

Reviewer 5:
The reviewer said that the laboratory capabilities and resources are sufficient.

Presentation Number: es299
Presentation Title: Microstructure Characterization and Modeling for Improved Electrode Design
Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

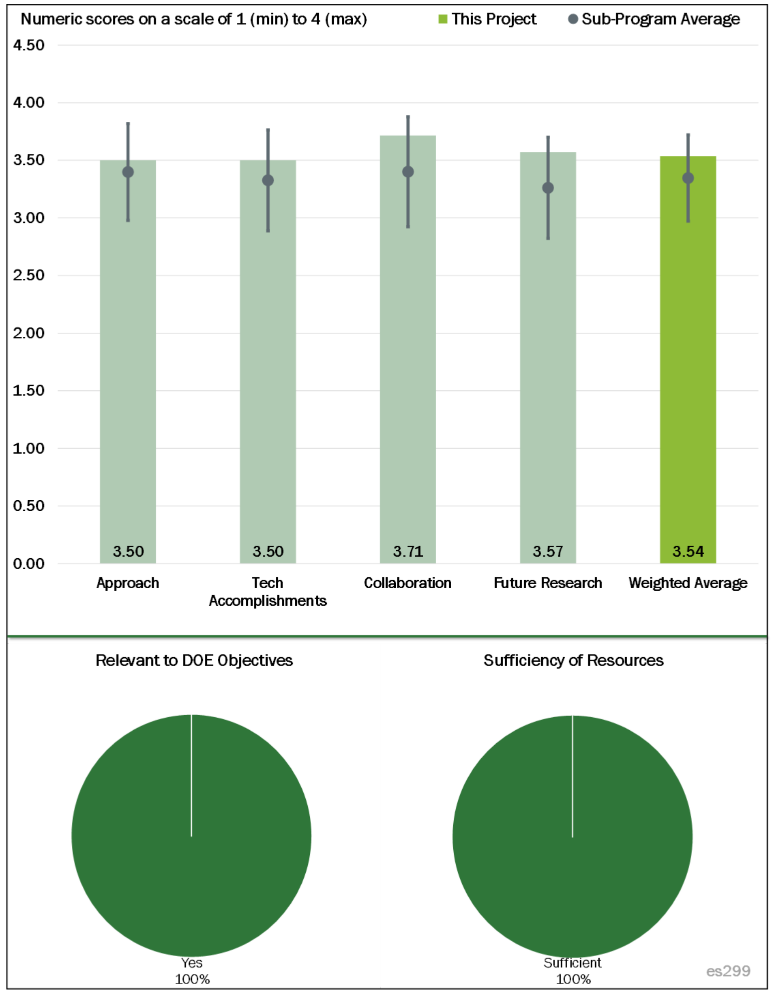

Figure 3-56 - Presentation Number: es299 Presentation Title: Microstructure Characterization and Modeling for Improved Electrode Design Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

Presenter

Kandler Smith, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the approach appears to be well conceived, logical, and suitable for the associated objectives.

Reviewer 2:

The reviewer said that the lack of predictive capability of electrode design has been addressed to some extent and that validation results shows less than 10% error between test and simulation.

Reviewer 3:

The reviewer said that all major principles are being well modeled. However, the reviewer noted that there are some ambiguities around electrodes that expand and the impact of electrolyte, how well are these modeled in their entirety.

Reviewer 4:

The reviewer said that the project appears to have addressed technical barriers properly as planned and questioned if the project started in October 2015 or 2016. The reviewer said that it claimed to be 2016 on slides and in briefing, but that 3 years' project support was started in October 2015.

Reviewer 5:

The reviewer said that the approach seems fine and that the reviewer would like to see more details on direct numerical simulation (DNS) simulation. The reviewer express uncertainty about what the justification is for a DNS simulation. The reviewer asked if the PI expects a lot of mixing. The reviewer suspected these are pretty diffuse flows and DNS might be a little over kill. However, all the physics can be captured with DNS, which is good.

Reviewer 6:
The reviewer questioned, in reference to Slide 17, how sensitive the model is to reduce variation in particle size statistically and how that will affect battery performance. The reviewer said that hopefully status of detailed tomography work will be discussed in future.

The reviewer questioned, in reference to Slide 9, how fragility will be addressed. The reviewer noted that more porosity better capacity but more fragile.

Reviewer 7:
The reviewer said that the microstructure characterization and modeling is very essential for reliable cell modeling.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that substantial progress has been made to address the project goals and that microstructure analysis helps to simulate the electrode properties effectively. The reviewer said that one of the key question is: How to characterize binder properties and their strength and failure mechanisms?

Reviewer 2:
The reviewer said that the project completed characterization of a few electrodes, developed the models, started process of applying the tools to the data, and added non-sphere models, which is clearly better.

The reviewer said that the project team is confident the microstructures are valid for other non-expanding electrodes.

Reviewer 3:
The reviewer said that the accomplishments seem good and that the reviewer would like to see some more explanation for the phenomena the project is seeing. The reviewer referenced Slide 14 and questioned why there is a maximum, but the team is fitting a straight line.

Reviewer 4:
The reviewer said that the contractor has achieved reasonable technical progress as planned.

Reviewer 5:
The reviewer said that the project is on target.

Reviewer 6:
The reviewer said that the accomplishment of microstructure modeling will help with overall model.

Reviewer 7:
The reviewer said that it does not appear that the temperature-dependence of the microstructure characterization and model parameters has been considered.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the collaboration seems good and the reviewer expressed surprise there is no one at a U.S. university doing nanoscale tomography. The reviewer said that maybe for future studies the project team should find a U.S. collaborator.

Reviewer 2:
The reviewer said that by collaborating with academia and other research laboratories enhances the knowledge sharing and new findings.

Reviewer 3:
The reviewer said that it is a collaborative project but also includes London. The reviewer expressed surprised there is not more collaboration though given the number of people working in this area.

Reviewer 4:
The reviewer said that the contractor has achieved reasonable technical progress within about 1.5 years and noted that the percent completion is claimed to be 45%. The reviewer questioned if another 55% of the work will be accomplished in less than 1.5 years.

Reviewer 5:
The reviewer said that the collaboration with other national laboratories and university will lead to better understanding of the model.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future research proposal covers broad details of meso-scale modeling approach, electrode effectiveness, and validation plans.

Reviewer 2:
The reviewer said that the proposed future work is good and that the model may provide more benefit to users if it can address the statistical nature of microstructures in life.

Reviewer 3:
The reviewer said that the future work seem good and the reviewer would focus on validation. The reviewer would also like the project team to look into a different mesh for the DNS simulation. The reviewer said that the project team should be able to use a non-structured mesh to better resolve shape and actually save on number of mesh cells.

Reviewer 4:
The reviewer said that the future work is the logical things to do and follows the plan.

Reviewer 5:
The reviewer said that direct measurement of effective properties is planned.

Reviewer 6:
The reviewer said that perhaps the future microstructure characterization and model parameter research could consider temperature dependence.

Reviewer 7:
The reviewer referenced a previous comment.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that characterizing the electrodes and other materials in the battery is very critical to support the DOE petroleum displacement objectives. The reviewer said that the authors clearly identifies the necessary steps with supporting research in that direction.

Reviewer 2:
The reviewer said that this project is an integral part of efforts to develop validated modeling tools to accelerate development of batteries, in support of vehicle electrification R&D to reduce dependence on imported oil.

Reviewer 3:
The reviewer said definitely and if it succeeds will help speed penetration of battery electric vehicles (BEVs) and reduce gasoline use. The reviewer said that the aim of predictive (not simulation after the fact) capability is excellent.

Reviewer 4:
The reviewer said that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 5:
The reviewer said yes, this supports the DOE mission and focuses on understanding the electrolyte.

Reviewer 6:
The reviewer said that the model will accelerate the battery development and may reduce the total cost.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that all of the major milestones are satisfied successfully.

Reviewer 2:
The reviewer said that the contractor appears to have sufficient resources in conducting the proposed work.

Reviewer 3:
The reviewer said that the project seems to have what they need and the progress is about appropriate.

Reviewer 4:
The reviewer said that the resources seem sufficient and that the reviewer is unsure what high-performance computing (HPC) resources are available.

Reviewer 5:
The reviewer said yes, and referenced a prior comment. The reviewer said that statically designed experiments after modelling completed will be valuable (Taguchi fractional factorial with small set of experiments).

Reviewer 6:
The reviewer said that the laboratory resources and the university capabilities are sufficient for the success of the model.

Presentation Number: es300
Presentation Title: Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment
Principal Investigator: John Turner (Oak Ridge National Laboratory)

Presenter

Srikanth Allu, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

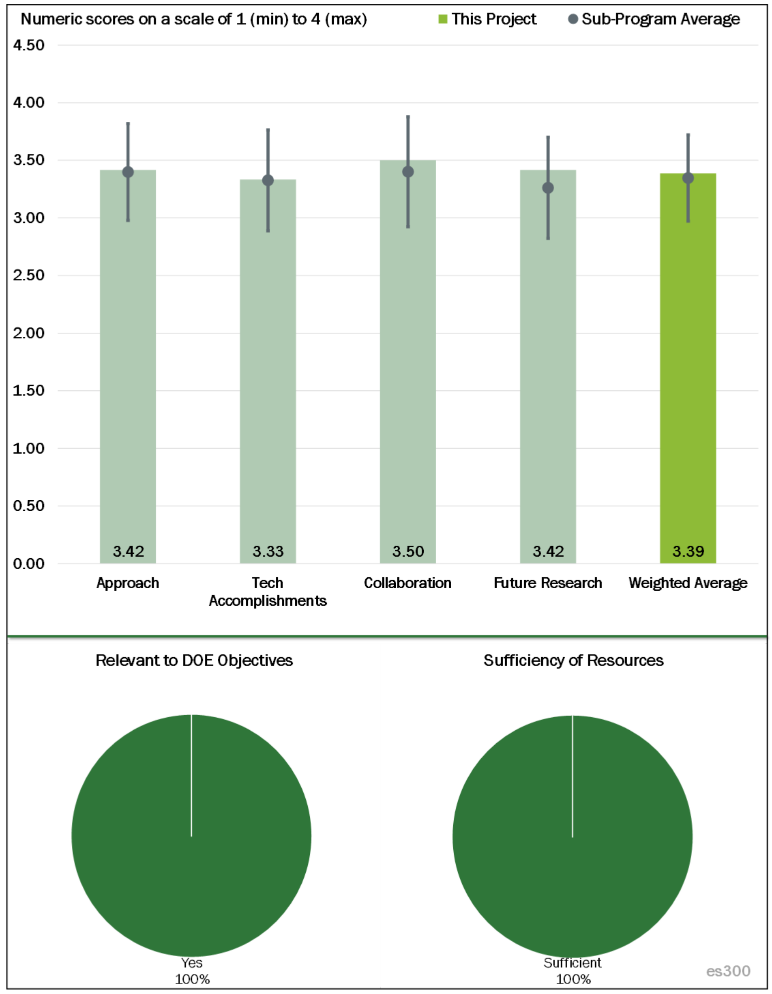

Figure 3-57 - Presentation Number: es300 Presentation Title: Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment Principal Investigator: John Turner (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that it is well planned.

Reviewer 2:

The reviewer said that the project appears to be well designed and addressed technical barriers properly as planned.

Reviewer 3:

The reviewer said that the approach is valid even though the slides on approach really are more about implementation that the actual approach which is to develop and validate physics based software that predicts the performance and abuse tolerance of cells.

Reviewer 4:

The reviewer said that the approach seems okay but the reviewer was unsure what models the project is using, and asked if it is all explicit FEA. The reviewer will assume it is all explicit FEA. The reviewer saw a LS-Dyna simulation in slides and questioned if the understood approach is to develop a python wrapper to launch the FEA codes.

Reviewer 5:

The reviewer said that the virtual integrated software will be more user-friendly than the current software tools.

Reviewer 6:

The reviewer said that, regarding “upscaling effective properties from microstructure simulation,” the reviewer did not see the effects of temperature being considered.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that the reduction of simulation time by approximately 50% is impressive.

Reviewer 2:
The reviewer said that the project improved the execution time significantly.

Reviewer 3:
The reviewer said that the accomplishments seem good and that the project is able to run some different simulation; however, the different types of simulations were not specified. The reviewer said that it was also not clear if the python wrapper parses the output.

The reviewer said that it seems hard to believe that an explicit heat transfer model is the bottleneck in the simulation. The reviewer saw that the electrical model is actually the limiting case. The reviewer asked what the mesh looks like for these. Again, the reviewer noted, no details on the modeling approach so the reviewer is assuming explicit FEA.

The reviewer said to quickly move past these static indentation tests and move on to higher strain rates that are more representative of actual failure.

Reviewer 4:
The reviewer said that the project demonstrated the feasibility to construct three-dimensional (3D) meshes from electrodes using micro-tomography and that good correlation was established with mechanical indentation test.

The reviewer said that the effect of binder distribution and what adhesive mechanisms is not very clear.

Reviewer 5:
The reviewer said that the contractor has achieved reasonable technical progress as planned.

Reviewer 6:
The reviewer said that the milestone on shorts seems like a good goal but it is not clear how well it simulates real data.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the collaboration with other national laboratories, Ford, and NHTSA will result in a more meaningful development tool.

Reviewer 2:
The reviewer said that the members of this project have good collaboration with each other and the project leverages experiments and developments in other CAEBAT projects efforts.

Reviewer 3:
The reviewer said that the project is collaborating in a sense in team but not a great deal outside it seems.

Reviewer 4:
The reviewer said that the collaborators are all national laboratories and that it may be worthwhile to collaborate with university on how to speed up heat transfer model. The reviewer said that this should not be that slow and noted again, that it is missing lots of details about mesh and scheme.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the authors cover a broad range of future research from reduced order modeling to scalability of properties.

Reviewer 2:
The reviewer said that fine tuning of the model and reduced order of modeling is planned.

Reviewer 3:
The reviewer said that the future work are good things to work on, but that even better would be if the software could detect stiff problems and drop out of the reduced order model and go to the full model automatically.

Reviewer 4:
The reviewer asked does the proposed understanding of the influence of temperature variations during dynamic discharge of battery module cover automotive battery working range.

Reviewer 5:
The reviewer would like to see some more details about heat transfer model and mesh. The reviewer thought a mesh study is in order if it has not been conducted and that this will be critical to resolving thermal gradients at indentation.

The reviewer said that it would also be worthwhile to maybe write a python graphical user interface (GUI) to run these simulation and culminate results. The reviewer said that nice plotting can be done with python and this is idea of a wrapper is what python was made for.

The reviewer also said it would be nice to see more details on message passing, sockets or files. The reviewer asked if the PI has the source to these FEA codes.

Reviewer 6:
The reviewer said that perhaps the influence of temperature can be considered for "upscaling effective properties under varying porosities and binder re-allocation."

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that the simulation identifies many aspect of battery materials some of which cannot be determined from test and that this project aims to address some of those critical aspects and meet overall DOE objectives.

Reviewer 2:
The reviewer said that this project of enhancing the open architecture software (OAS) is an integral part of efforts to develop validated modeling tools to accelerate development of batteries, in support of vehicle electrification R&D to reduce dependence on imported oil.

Reviewer 3:
The reviewer said that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 4:
The reviewer said that being able to predict performance and abuse impacts would definitely help put EVs on the road.

Reviewer 5:
The reviewer said that this project supports the DOE mission and might be a little ahead of the other modeling efforts but very relevant.

Reviewer 6:
The reviewer said that the tool will reduce time to develop batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the author has achieved milestones deliverables in a timely fashion.

Reviewer 2:
The reviewer said that the contractor appears to have sufficient resources in conducting the proposed work.

Reviewer 3:
The reviewer said that work is moving well and that there is no obvious wastage.

Reviewer 4:
The reviewer said that the laboratory testing and software development resources are sufficient.

Presentation Number: es301
Presentation Title: Experiments and Models for the Mechanical Behavior of Battery Materials
Principal Investigator: John Turner (Oak Ridge National Laboratory)

Presenter

Sergiy Kalnaus, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

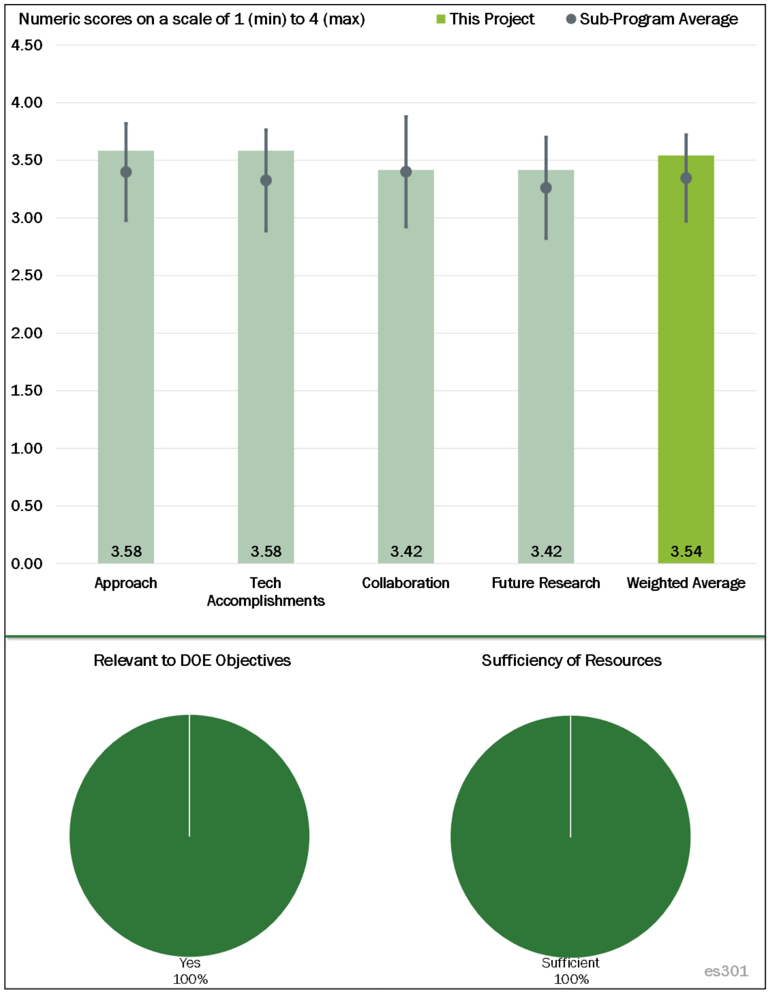

Figure 3-58 – Presentation Number: es301 Presentation Title: Experiments and Models for the Mechanical Behavior of Battery Materials Principal Investigator: John Turner (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the approach appeared to be well conceived, logical, and suitable for the associated objectives.

Reviewer 2:

The reviewer commented that a significant effort was made to understand the behavior of the separators which are a critical component of Li batteries. Three commercial separator models were evaluated and their performances compared in order to quantify the understandings. Differences in anisotropic behavior, yield strength and failure modes were demonstrated. Overall the reviewer noted that this was very well done.

Reviewer 3:

The reviewer noted that the modeling that was based on experimental testing will provide robust models.

Reviewer 4:

The reviewer stated that the project addressed technical barriers of insufficient understanding of the underlying physical phenomena that limit battery performance and safety, particularly the role of microstructure.

Reviewer 5:

The reviewer noted the presence of experiments and models with validation by temperature. Several sorts of separators were studied. While the project has intention to do parametric variation to try to capture the variation in real results, the methodology was not clear to the reviewer. The reviewer observed that one omission is ceramic fill which is a fairly common type and more tests of the penetration depth to failure were needed. These thoughts are offered more in aide of developing these methods. The reviewer concluded that this was a very well organized project.

Reviewer 6:

The reviewer said that the approach seemed fine. There were no real details on what type of modeling was being done; the reviewer guessed that it was molecular dynamics (MD). The reviewer questioned what software was being used, and were there details about pair potentials. The reviewer liked the approach of different strain rates. This is critical to get meaningful information out of the studies.

The reviewer would expect strain hardening from polymer-based separators. The reviewer suggested checking the simulations. The reviewer noted that when conduction explicit FEA simulations with solid elements, at least three elements are needed through the thickness. The reviewer recommended an independent mesh study. The reviewer noted that somewhere the units of g/mil were used, which is an unusual unit. One thing that would be interesting would be to determine residual stress from the FEA model.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that excellent progress was achieved on the milestones. The project showed stress strain data on several major separators and two manufacturing types with very different failure modes. The reviewer noted that temperature resolved the data. The reviewer also noted the importance of ball indentation tests. Both postmortem and computed tomography investigation were used so the details and *in situ* results were seen. The reviewer also noted that the calendaring study achieved different porosity and microstructure and performance.

Reviewer 2:

The reviewer said that the strain distribution and failure were captured in MD simulation and presented in the report. The reviewer also noted that temperature dependent behavior of separators and critical short circuit condition were also shown. Overall the reviewer stated that the project demonstrated very good progress towards DOE goals.

Reviewer 3:

The reviewer commented that the contractor has achieved good accomplishments as planned.

Reviewer 4:

The reviewer said that separators and electrode mechanical properties were explored successfully.

Reviewer 5:

The reviewer said that accomplishments seemed good. The reviewer suggested focusing more on a material understanding of what was going on.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that collaborating with DOE national laboratories and industry partner(s) was “a plus”.

Reviewer 2:

The reviewer commented that the members of this project have good collaboration with each other and the project leverages experiments and developments in other CAEBAT projects efforts.

Reviewer 3:

The reviewer noted the presence of both inter-partner collaboration with several partners but also collaboration outside the partnership. The reviewer stated that this seemed like “real” collaboration not just a chance conversation.

Reviewer 4:
The reviewer commented that collaboration within Consortium for Advanced Batteries Simulation (CABS) members and others was well practiced.

Reviewer 5:
The reviewer highlighted the fact that collaboration consisted mainly of DOE national laboratories with Ford. It might be worthwhile to collaborate with universities to understand polymer-based mechanics of materials.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that future research considers some critical aspects such as other modes of cell deformation, electrodes testing at different temperature and strain rate sensitivity of separators. This research helps to understand the risk well and helps in finding a mitigation strategy.

Reviewer 2:
The reviewer stated that the conducted work and proposed research seemed to cover limited battery materials such as separators.

Reviewer 3:
The reviewer noted that proposed future work was planned to address the remaining challenges.

Reviewer 4:
The reviewer stated that the challenges are correct, only the statistical treatment of many simulations to match experiment is not well defined. Validation is critical and a good item in the list of future work to focus on.

Reviewer 5:
The reviewer suggested the need to look into strain hardening and non-linear material models.

Reviewer 6:
The reviewer commented that given the findings shown, one could assume that any thermal sensitivity associated with the “failure criteria for layered battery structure“ and “microstructure-based continuum model“ would be considered. Perhaps the “microstructure-based continuum model” could account for the bending moment as well.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 2:
The reviewer stated that better knowledge of all the components in a battery will achieve DOE the petroleum displacement objective(s).

Reviewer 3:
The reviewer said that this project of enhancing the OAS is an integral part of efforts to develop validated modeling tools to accelerate development of batteries, in support of vehicle electrification R&D.

Reviewer 4:
The reviewer simply said that separator failure is important in safety.

Reviewer 5:
The reviewer remarked that this activity accelerates cell development and may reduce the cost of batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the contractor appears to have sufficient resources in conducting the proposed work.

Reviewer 2:
The reviewer observed fairly efficient use of money, and noted that the project was not strained for cash.

Reviewer 3:
The reviewer commented that the national laboratories have sufficient funding and resources.

Presentation Number: es302
Presentation Title: Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

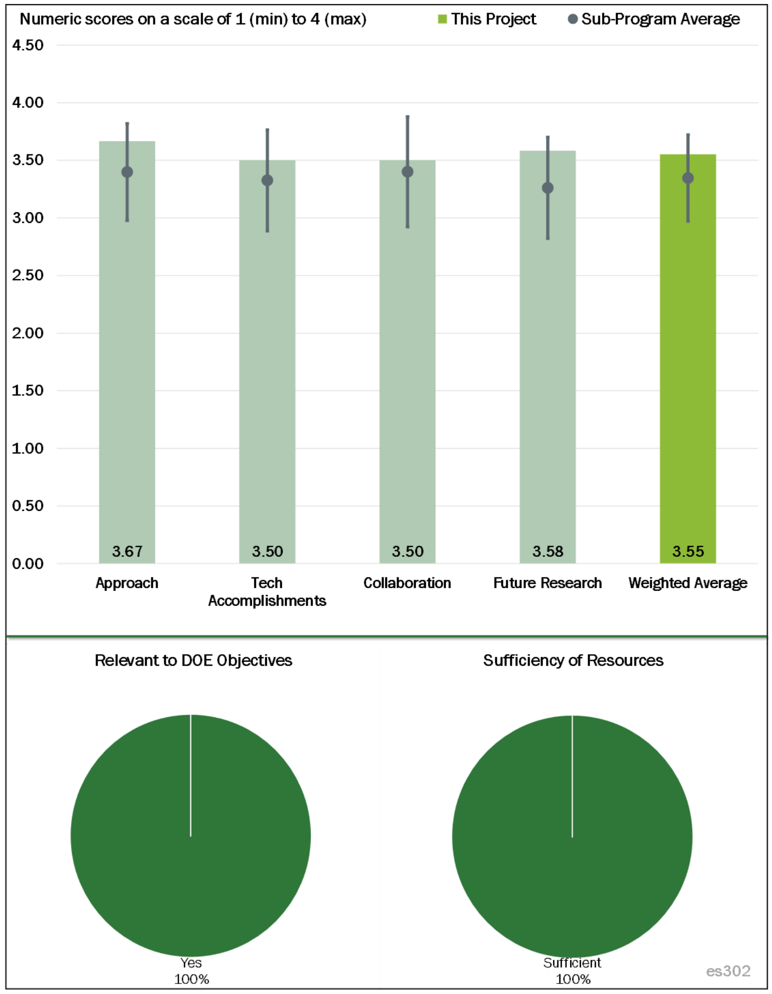

Figure 3-59 - Presentation Number: es302 Presentation Title: Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter

Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer remarked that the project aims to deliver accurate input data for the CAEBAT teams which is an essential element of successful analysis.

Reviewer 2:

The reviewer stated that the technical approach has been successful in providing electrode microstructure data and generating surface meshes and concentration-dependent electrolyte transport property to support battery modeling and simulation (M&S) work.

Reviewer 3:

The reviewer commented that this activity provides accurate simulation data, which are needed for robust model development.

Reviewer 4:

The reviewer said that the approach for obtaining “electrode microstructure data” under realistic conditions is valuable for increasing the accuracy of the CAEBAT input parameters and resulting modeling predictions.

Reviewer 5:

The reviewer remarked that the project seemed to be making the right measurements to serve the team. Setting a range of specified pressure for measurement conditions would be better.

Reviewer 6:

The reviewer noted that the approach seems good. No details were given on the modeling approach in terms of size of domain and time step, etc. The reviewer asked if diffusion is through a medium being calculated or just self-diffusion. These details should be provided. Details on boundary conditions would also be useful. The reviewer asked if these are temperature driven or gradient driven, and what are the initial conditions. That being said, the reviewer further noted that this is a useful study. These quantities are necessary for the FEA models that have been presented alongside this presentation.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that very good progress has been made to capture the electrodes in real battery environment settings. Construction of electrode regions from TEM images adds more value in CAEBAT simulations.

Reviewer 2:
The reviewer said that the technical accomplishments and progress achieved were as planned.

Reviewer 3:
The reviewer noted that the project measured electrode internal structure wet and dry (and noted changes). The reviewer assessed this to be a very good technique. The reviewer also said that electrolyte diffusion and convection properties were measured and transport coefficients were generated. The reviewer observed that a checkpoint with known literature values was used. The project also showed ion pairing that lowers conductivity even at lower concentration. The reviewer also remarked on seeing multiple ways to get transport numbers which is very valuable.

Reviewer 4:
The reviewer stated that the accomplishments were okay. The project started in 2015 and the reviewer expected some more results by now. However, the results that were presented were good.

Reviewer 5:
The reviewer noted that the project produced electrolyte transport and electrode properties.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the collaboration among CABS and other institutions is excellent.

Reviewer 2:
The reviewer stated that the members of this project have good collaboration with each other and the project provided useful experimental data to support other CAEBAT projects efforts.

Reviewer 3:
The reviewer noted that the project worked with several partners, also with PNNL outside the group, but with a big group, this will suffice.

Reviewer 4:
The reviewer was not sure what CD-adapco was providing but they should provide some code development. If not, the reviewer would recommend changing the approach. These diffusion coefficients could be obtained using a molecular dynamic approach. The reviewer inquired if this is what was being using at the beginning. The reviewer further noted a lack of model information. This seems to be a common theme across all presentations. The reviewer suggested collaborating with a DOE laboratory that develops MD software; SNL's Large-scale Atomic/Molecular Massively Parallel Simulator (LAAMPS) for example. This will also resolve

the ion pairing. Once the diffusion that length scale is understood then work can be done on the continuum diffusion problem.

Reviewer 5:
The reviewer stated that a lack of industry partner was seen in this project. Industry partners brings unique values to R&D from a customer point of view. The reviewer stated that the software vendor represents a good collaboration in developing robust software.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed the presence of logically planned future research.

Reviewer 2:
The reviewer commented that, if moving smoothly, the proposed research will make the project be conducted successful.

Reviewer 3:
The reviewer noted that appropriate plans were presented; for example, diffusivity as a function of concentration and temperature. The epoxy filled imaging versus wet tomography is a valuable plan. The reviewer said that cycled electrodes will also be illuminating.

Reviewer 4:
The reviewer suggested doing a microscale MD simulation and then working on continuum level diffusion.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that all the work in this project is relevant to DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer stated that this project is relevant to DOE objectives and it can provide accurate simulation input data for CAEBAT teams, enabling construction of accurate models to guide cost and performance optimizations.

Reviewer 3:
The reviewer remarked that, yes, the project supported overall DOE objectives. The reviewer commented that solving the diffusion problem would be necessary for FEA work.

Reviewer 4:
The reviewer stated that the models will accelerate the battery development cycle.

Reviewer 5:
The reviewer noted that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Reviewer 6:
The reviewer commented that, without good input data, the simulators have no chance. The simulation work will help with safety and cost.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the funding and resources are sufficient.

Reviewer 2:
The reviewer commented that the project may be successfully accomplished if funding can be provided as budgeted.

Reviewer 3:
The reviewer stated that this seems to be good work and not simple work. If less funding must be given, do not trim this project much. Otherwise, the project data will be impacted. A much better solution would be to keep funding and ask for more variation as a function of other variables.

Reviewer 4:
The reviewer noted that the project will need HPC resources for MD simulations.

Presentation Number: es303
Presentation Title: Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3D Mesoscale Simulations
Principal Investigator: Scott Roberts (Sandia National Laboratories)

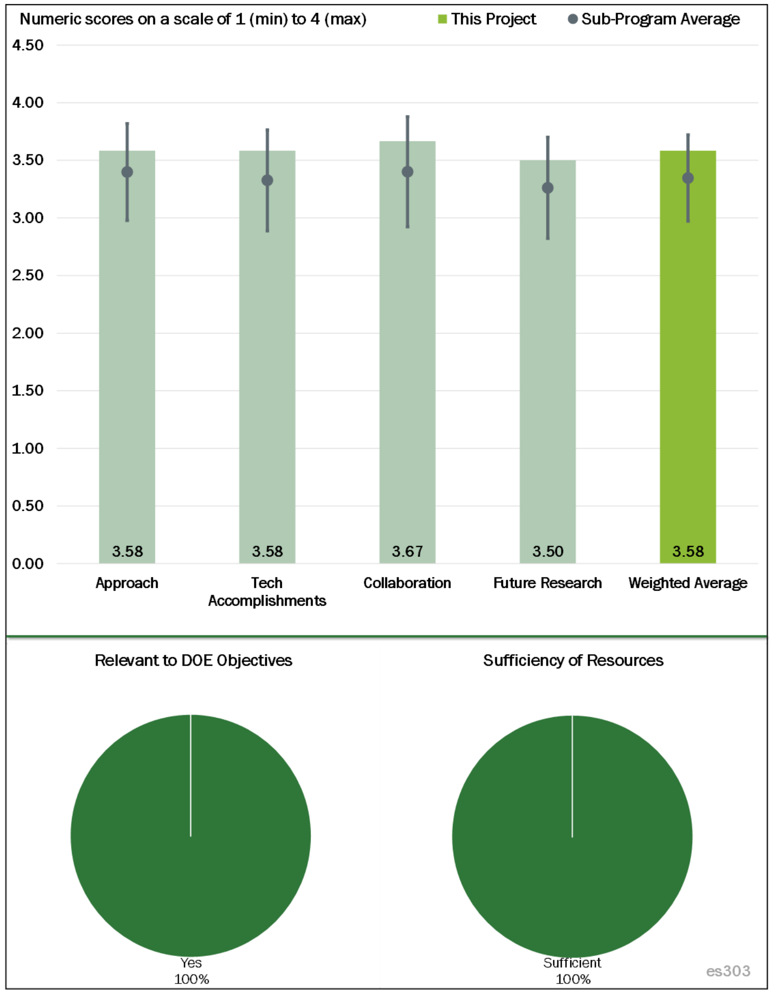

Figure 3-60 - Presentation Number: es303 Presentation Title: Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3D Mesoscale Simulations Principal Investigator: Scott Roberts (Sandia National Laboratories)

Presenter

Scott Roberts, Sandia National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project had a well-planned approach to capture the tasks.

Reviewer 2:

The reviewer noted that the battery scale-up simulation of abuse scenarios provides the basis for a safe battery.

Reviewer 3:

The reviewer said the approach appears to be well conceived, logical, and suitable for the associated objectives.

Reviewer 4:

The reviewer commented that the project aims to improve the ability to assess battery response to abuse scenarios computationally, enabling many parametric computer tests rather than expensive and dangerous experiments through the creation and application of microscale (particle-scale) electrode simulation. It is an integral effort of CAEBAT effort.

Reviewer 5:

The reviewer stated that the model methods are good, and that intent to run fast with low deviation from real electrode was good too. The addition of binder is a good thing as it is often ignored and plays a role mechanically and in the transport of ions.

Reviewer 6:

The reviewer said that the approach seems great. The reviewer liked the mesh. The reviewer remarked that this was much better than other approaches presented. The reviewer suggested collaborating with other projects on mesh strategies. The reviewer’s only concerns were whether surface tension was considered during solidification of secondary phases. The reviewer also questioned where the properties of secondary phases were being obtained from. Combining this with amorphous can result in some inconsistent properties.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked that the accomplishments presented were great. Keep going on the same trajectory. The mesh study was refreshing.

Reviewer 2:
The reviewer commented that demonstration of the 3D model of electrode work was successful.

Reviewer 3:
The reviewer noted that this project has achieved reasonable progress and demonstrated microstructure simulations of a NMC cathode, including a manufactured representation of active binder phase.

Reviewer 4:
The reviewer that good milestone progress had been achieved. The project has validated convergence in its NMC sample. The project verified the reduction in resolution does not cause meaningful uncertainty at domains of 80 μ cube edges. Binder inclusion is important and the project developed some methods to test with validation.

Reviewer 5:
The reviewer noted that the effect of lithiation, porosity, and binder distribution on electrical conductivity was investigated. The reviewer questioned whether the thermal sensitivity of those relationships considered.

Reviewer 6:
The reviewer said that very high resolution X-ray tomography data provided good insight to inside the microstructure. Creating a high-quality microstructure mesh of cathode nano particles was very promising. The reviewer stated that one concern was when the author mentioned that particles are held together by constrained nodal rigid bodies. This will eliminate the free motion of particles and it will be hard to quantify the inter-particle forces. The reviewer asked what the effect is of damping and friction between particles.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted good collaboration between industry and academia along with other DOE laboratories.

Reviewer 2:
The reviewer stated that the project members appear to have good collaboration with six other institutions in developing the M&S efforts.

Reviewer 3:
The reviewer commented on the presence of collaboration inside and out of the group.

Reviewer 4:
The reviewer remarked that the project seemed to have everything under control.

Reviewer 5:
The reviewer said that collaboration among CABS members and other institutions was very efficient.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future research is tailored to address millstones.

Reviewer 2:
The reviewer stated that in addition to efficient and robust microscale electrochemistry, inter-particle movement characterization will add more value to simulation capabilities.

Reviewer 3:
The reviewer noted that the only item not well covered is how variation across other chemistries will be handled.

Reviewer 4:
The reviewer commented that the only additional suggestion is to really nail down the properties of the secondary phase.

Reviewer 5:
The reviewer suggested determining the robustness and efficiency of microstructure of the electrodes.

Reviewer 6:
The reviewer remarked that perhaps the proposed “microscale simulations of coupled electrochemical-mechanical performance of NMC,” and predictions of “electrode swelling during operation” can be performed in such a way that temperature-dependence is considered.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that all the efforts support the DOE objectives.

Reviewer 2:
The reviewer said that this project addresses DOE/VTO objectives of promoting vehicle electrification by developing microscale (particle-scale) electrode simulations to support CAEBAT.

Reviewer 3:
The reviewer commented that the simulations envisioned are going to be helpful in terms of speed to market, cost, and safety. All of these aspects are important to the objective of more BEVs and PHEVs.

Reviewer 4:
The reviewer said that the model will accelerate the battery development and reduce cost.

Reviewer 5:
The reviewer stated that this project does support the overall DOE objectives of petroleum displacement because it facilitates the usage of LIB systems (thus decreasing the size of any required petroleum-fueled power source) by further developing LIB modeling and simulation capability for design and analysis purposes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the contractor appears to have sufficient resources to conduct the proposed research.

Reviewer 2:

The reviewer noted that the laboratory funding and resources are sufficient.

Reviewer 3:

The reviewer stated that the project needs more HPC time with these mesh sizes.

Presentation Number: es304
Presentation Title: Extreme Fast-Charge and Battery Cost Implications
Principal Investigator: Shabbir Ahmed (Argonne National Laboratory)

Presenter
Shabbir Ahmed, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

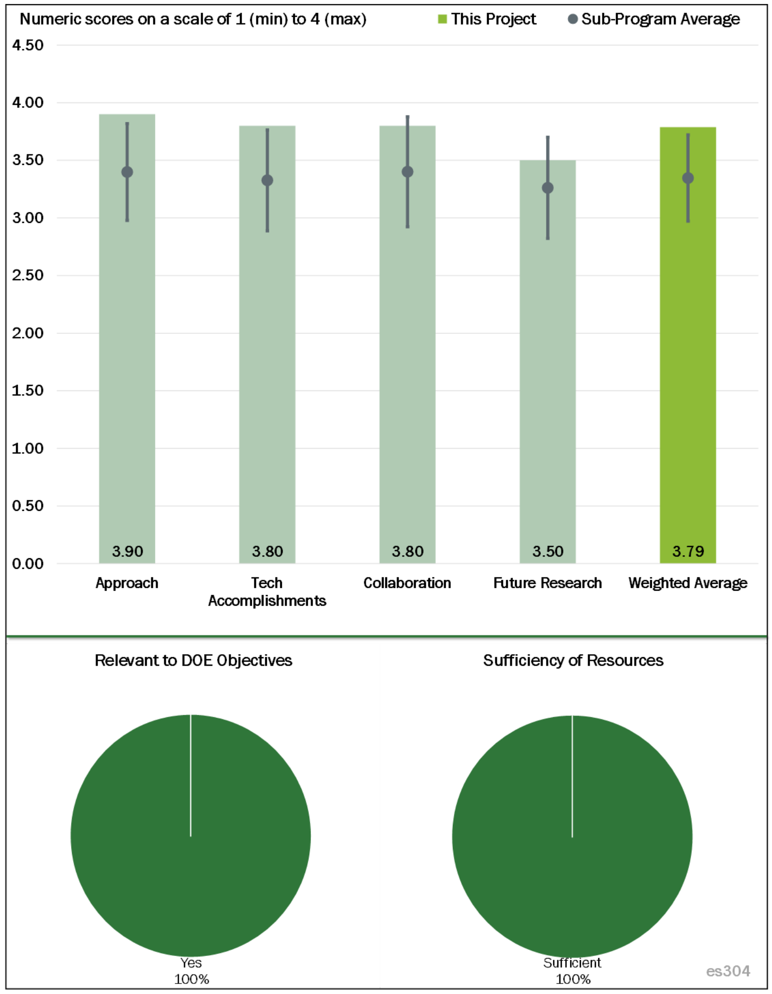

Figure 3-61 - Presentation Number: es304 Presentation Title: Extreme Fast-Charge and Battery Cost Implications Principal Investigator: Shabbir Ahmed (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer asserted that this was a well-focused and well-designed project to identify technological barriers and to quantify their cost impacts for enabling extreme fast charging (XFC) of vehicle batteries. This study, using the BatPac cost model, took a comprehensive look at cell and system design factors to derive the cost implications of extreme fast charging.

Reviewer 2:
The reviewer stated that the project seemed well structured, feasible, and well integrated with related efforts.

Reviewer 3:
The reviewer commented that including industry, which must implement the work and sell it, is great.

Reviewer 4:
The reviewer noted that it was an excellent idea and a difficult task to organize fast charger stakeholders.

Reviewer 5:
The reviewer said that the modification and use of the existing BatPac model allows a very comparative baseline for this analysis.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer pointed out that the project made a comprehensive review of the various cell and system components that will be required to enable XFC. Then using a threshold current density that has been shown to trigger Li plating in BEV cells, the BatPac model was used to estimate the impacts on battery cost. As an aside, the reviewer noted that, of course, the estimation will be highly dependent on this threshold value and it needs to be verified in actual systems for corresponding cell chemistries and battery systems.

The reviewer noted that extensive calculations entailing charge limits as a function of anode thickness, lower resistance, and higher capacity electrodes along with effect of time to charge, charger limits, thermal considerations, etc., have been carefully assessed and this estimation can serve as a solid basis for future studies. Of course, availability of anodes having faster charging capability will eliminate most of the barriers highlighted here but it currently is a remote possibility (but at least the potential has been shown here). The reviewer found that overall, this was excellent work that will aid in DOE efforts to enable fast charging.

Reviewer 2:

The reviewer found this project to be well designed to support DOE goals. The original project scope was completed so progress was excellent.

Reviewer 3:

The reviewer stated that this project, one of a set, was intended to analyze the potential cost implications to a fast-charge capable battery pack. The project was successful in describing and quantifying the attributes that were assumed (and intuitive) to many people. The reviewer said that the study showed no bias to either acceptance or denial of technology adaptation (allowing for market based choices to prevail).

Reviewer 4:

The reviewer observed that the battery cost analysis based on the thin electrode architecture provided the estimate for a fast charging cell.

Reviewer 5:

The reviewer said that the project looked at thermal and design aspects and correctly found that thinner electrodes were needed; however, these electrodes increase the cost. Higher allowable current density helps a lot, as might be expected. This sets the goals well, but it does not say how to achieve them. Although that is not the objective here, it is okay. The reviewer pointed out that at the 4 mA/cm^2 limit, the mass increases and thickness drops faster than the heat generation, so no cooling is needed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that, by design, this collaboration was multi leveled. DOE structured a stakeholders' meeting at NREL and then subdivided the tasks into four projects while leveraging the work of all the laboratories toward the same goals. It was collaboration among the laboratories at its best.

Reviewer 2:

This reviewer opined that collaboration had lots of outsiders, but could not have been much better unless there had perhaps been an outside review of the final report prior to publishing it.

Reviewer 3:

The reviewer pronounced the participation of national laboratories and outside institutions in information exchange as successful.

Reviewer 4:
According to the reviewer, there was outstanding collaboration among various stakeholders, such as the national laboratories, government agencies, universities, and OEMs. Again, the only representatives missing are those from pack component makers, such as the ones dealing with high-voltage and high current.

Reviewer 5:
The reviewer noted that there appeared to be good collaboration within DOE, but outside of DOE exchanges seemed to be one way.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Even though the project has ended, the reviewer hoped that this study will be used to develop research work toward enabling fast-charging by DOE. This model can be easily adapted to other case scenarios to quantify the impact of a certain change in the assumed values due to cell and system change.

Reviewer 2:
The reviewed summed up future work as including fine tuning of the cost model, collecting data for thin electrodes, and running various scenarios.

Reviewer 3:
The reviewer said that this project was not intended for lengthy future analysis. It was short, to the point, and well defined. However, the reviewer had questions as to the effect of advanced materials, i.e., graphene anodes, which may have a considerable performance and cost basis for a successful system. The reviewer realized that some of these considerations will come as an output of the other projects but perhaps at that time may require further analysis in this BatPac environment.

Reviewer 4:
It was not clear to the reviewer about whether or not the project had ended. The reviewer remarked that overall it seemed like there was a good future plan, but it also seemed like the higher level project was over.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer offered that EVs capable of fast charging will make them more attractive to average customers and help in their proliferation to meet the DOE's overall goal of petroleum displacement.

Reviewer 2:
The reviewer found the project to be highly relevant. Fast charging puts BEVs on a par with ICEs for long-trip refueling and arguably better for refueling when time is no object. This matters to a good portion of customers.

Reviewer 3:
If successful with fast charging techniques, the EV will gain more popularity according to the reviewer.

Reviewer 4:
The reviewer said that by supporting increased use of electricity, the project would decrease petroleum usage.

Reviewer 5:
As this project has a definite objective to address barriers to EV acceptance and adoption, the reviewer commented that the general EV petroleum math applies to this project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer thought the amount of funds made available to the project was appropriate.

Reviewer 2:
The reviewer found the funding to be appropriate to the goals.

Reviewer 3:
The reviewer said that this project appears to have met its stated goals and objectives in a timely manner.

Reviewer 4:
The reviewer stated that funding was sufficient and the project is also complete.

Reviewer 5:
The reviewer commented that the laboratory resources are sufficient.

Presentation Number: es305
Presentation Title: Extreme Fast-Charging—A Battery Technology Gap Assessment
Principal Investigator: Ira Bloom (Argonne National Laboratory)

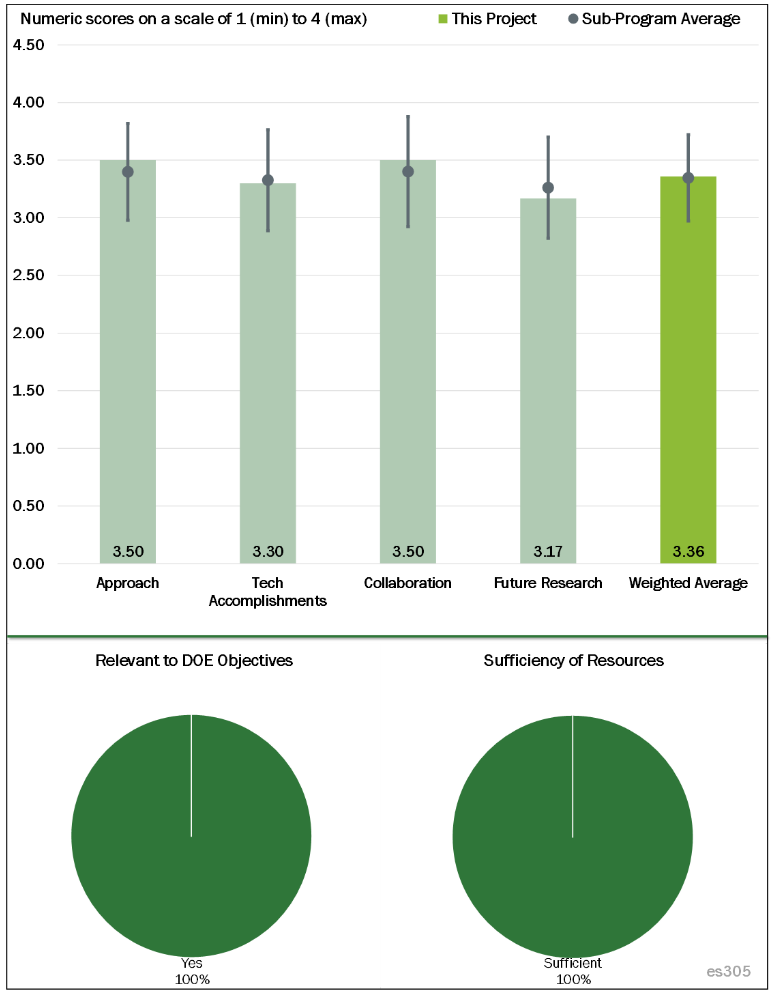

Figure 3-62 - Presentation Number: es305 Presentation Title: Extreme Fast-Charging—A Battery Technology Gap Assessment Principal Investigator: Ira Bloom (Argonne National Laboratory)

Presenter
Ira Bloom, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that this was a highly focused task to identify technological and commercial gaps for XFC of vehicle batteries. The multi-laboratory team approach was an effective one in nailing down the various factors that are challenges to XFC.

Reviewer 2:
According to the reviewer, it is important to bring fast charging of batteries to fruition for widespread use of EVs. For this purpose, various factors that can impact cell performance and cost as well as define current limitation need to be identified. The reviewer said that this project takes a thorough approach to understand, identify, and come up with practical solutions for XFC.

Reviewer 3:
The reviewer asserted that the assessment of XFC is critical for the future direction for EV development.

Reviewer 4:
The reviewer stated that the project team used experts who identified the correct questions like design, heating, abuse impacts, heating, cost and so on via literature review.

Reviewer 5:
The reviewer thought that the work is mostly a literature review. The approach needs to be well defined, and the outcomes from the study—gaps and challenges and what direction DOE should take for the future—need to be considered.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed that the team had made a list of likely problems based on expertise and discussion. The list seems pretty complete.

Reviewer 2:
The reviewer said the technical accomplishments are satisfactory.

Reviewer 3:
The reviewer remarked that it is a good, extensive summary of many aspects that should be considered for XFC. It could have been much better if this study included quantitative analysis to some extent and showed practical examples. The summary was good but too generic. The reviewer was looking forward to seeing detailed findings in an upcoming publication in *J. Power Sources*.

Reviewer 4:
The reviewer summed up by saying that the assessment was complete and it provided a gap analysis. It also provided the list of components that will need a redesign for fast charging.

Reviewer 5:
The reviewer noted that the authors were able to comprehensively capture most of the items of relevance to XFC, such as at the cell level in a component as well as the pack level. However, some of the recommendations that were made, such as new anode and cathode materials that can withstand XFC need to developed, are redundant because battery developers have that goal in mind on a daily basis and these recommendations do not add anything new to what the developers are well aware of. The reviewer commented that statements about electrode and electrolyte designs for faster diffusion are also obvious.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that a good team of researchers was built for the study.

Reviewer 2:
The reviewer stated that the national laboratories collaborated to accomplish the objectives of the program.

Reviewer 3:
The reviewer commented that the analysis and summary are results of good collaboration among participants. Participation of industry could have made this effort more fruitful.

Reviewer 4:
The reviewer commented that there was inherent collaboration inside the group but it was not clear if there was all that much consulting outside the group.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer offered an opinion that we need to be very selective about topics for future research. Generic topics, such as electrodes and electrolytes with faster kinetics, are nothing new—people have been always exploring these—and unless someone comes back with a novel idea, such research should not be funded.

Reviewer 2:
The reviewer stated that the assessment is complete and there is no need for future activities.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated it definitely does. XFC capability will make EVs very attractive to the masses.

Reviewer 2:
The reviewer said the project is highly relevant to making EVs attractive and thus displacing petroleum.

Reviewer 3:
The reviewer responded yes, as the focus is on EVs.

Reviewer 4:
The reviewer found the project to be highly relevant to successful EV deployment.

Reviewer 5:
The reviewer observed that fast charging will help with determining the probability of success for EVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that sufficient funds were provided.

Reviewer 2:
The reviewer said that the project is complete so this question really does not apply.

Reviewer 3:
The reviewer stated that resources were sufficient.

Presentation Number: es306
Presentation Title: Thermal Implications for Extreme Fast Charge
Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

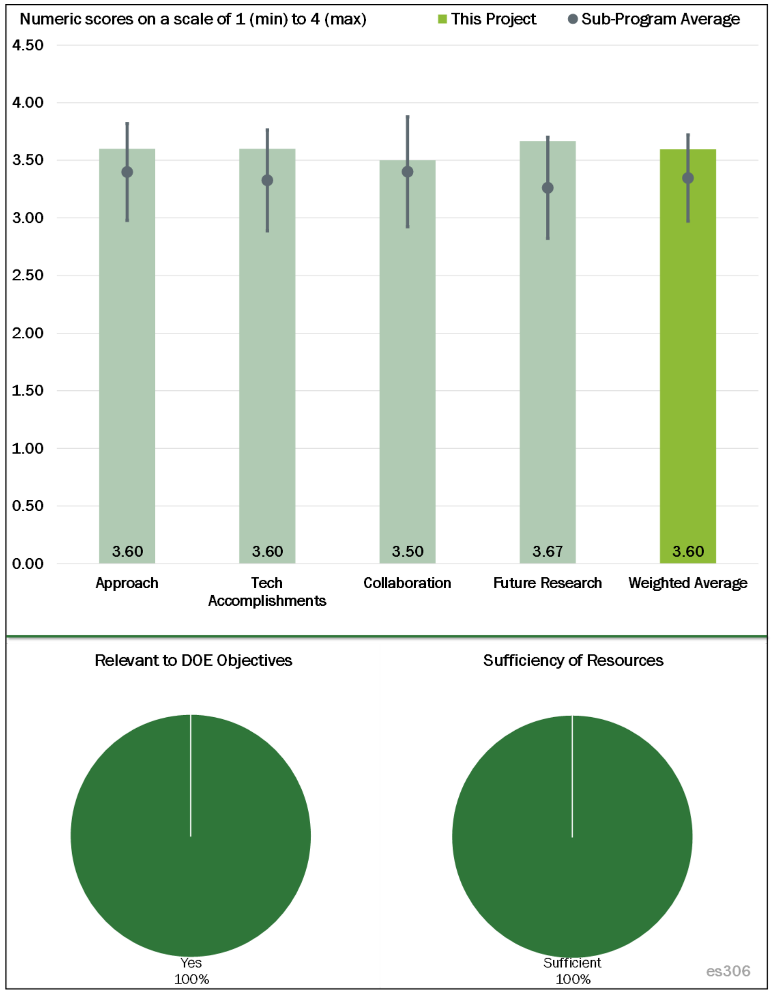

Figure 3-63 - Presentation Number: es306 Presentation Title: Thermal Implications for Extreme Fast Charge Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

Presenter

Matthew Keyser, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer acknowledged that the approach is very well designed. It takes into consideration all the factors (especially thermal) relevant to XFC charging, such as impact on durability, system management, and cost based on current cell and thermal management systems.

Reviewer 2:
According to the reviewer, to successfully deploy EVs that would be accepted by general users, fast-charging is extremely important. Finding and designing adequate chemistry and electrode structure that can withstand the XFS with minimal degradation should be done. Thermal aspects of cells and packs related to passing high current through the cells and packs are also to be considered because cell and pack temperature significantly affects their performance and life. In these respects, this project took appropriate approaches.

Reviewer 3:
The reviewer pointed out that the thermal characterization testing of the Li-ion cells provides the thermal management needed for a long life automotive battery system.

Reviewer 4:
The reviewer found the approach to be quite reasonable, considering the various aspects of the battery cell.

Reviewer 5:
The reviewer commented that heat transfer is a major problem with fast charging and this is appropriate work to identify the problems. As with others, stakeholder information should be gathered.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer asserted that excellent progress has been made in characterizing the current cells' thermal capabilities and limitations that will be highly valuable to develop future thermal requirements for XFC applications. Cells were characterized; various design options assessed with respect to their thermal footprints under various charge and discharge conditions and impact on heat efficiency; and assessments were made for future thermal systems.

It is an exhaustive study with valuable feedback that will be highly useful to DOE and other users.

Reviewer 2:
The reviewer commented that the project showed the need for higher heat venting in energy cells and what sort of property groupings might work. Based on the presented work, counter tab cell design works best. The reviewer emphatically stated that interconnects could add more heat than the cells.

Reviewer 3:
According to the reviewer, the progress was satisfactory with DOE goals met at the end of the project.

Reviewer 4:
The reviewer remarked that this project demonstrated good methodology to measure temperature variation during fast-charging and discharging. The cell temperature variation study according to cell geometry and tab structure is also useful. The suggestion from this study on practical capability of current thermal management system and desirable one is also good. The reviewer also liked the idea of additional cooling at the charging station so that the battery pack does not have to be overdesigned for XFC, which will not happen frequently.

Reviewer 5:
The reviewer observed that thermal characterization of various cells and batteries was successfully completed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that collaboration with cell and battery suppliers is very efficient in testing and finding design solutions.

Reviewer 2:
The reviewer noted that there are lots of different input groups and lots of discussion.

Reviewer 3:
The reviewer commented that collaboration with other laboratories was effective; however, OEMs need to be involved to understand the realistic approach to changing design of the electrodes.

Reviewer 4:
The study is the result of excellent collaborative work among key stakeholders involving national laboratories, universities, OEMs, and suppliers. Again, the reviewer was not sure that it included pack mechanical and electrical component suppliers who have a good stake from thermal system as well as high-voltage and high current points of view.

Reviewer 5:
The reviewer offered that participation from commercial sector would have made this effort much better.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the conclusions that stemmed from this study will deal with cell design, efficiency, size of thermal system, etc., which are valuable inputs for DOE for future program directions as well as for the battery community in general.

Reviewer 2:
The reviewer commented that innovative thermal designs and managements are explored.

Reviewer 3:
The reviewer said not applicable.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that development of an appropriate thermal system is a key requirement for the efficient operation of EVs capable of XFC. This project has contributed toward that goal.

Reviewer 2:
According to the reviewer, after safety, heat is likely the most relevant question. All of this supports consumer acceptance of EVs that displace gasoline and diesel fuel as fast as any method.

Reviewer 3:
The reviewer said yes. The project focused on improving reliability of future battery technology for EVs.

Reviewer 4:
The reviewer stated that this project showed, with some quantitative measures, the impact of fast charging on cell performance and suggested factors that needed consideration in order to make XFC a reality.

Reviewer 5:
The reviewer opined that the thermal management of Li-ion cells and batteries will meet the USABC life targets and make the systems affordable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the funding and resources are good enough for the testing, design, and supporting the development for new cells.

Reviewer 2:
The reviewer observed that the allocated resource was appropriate for this project.

Reviewer 3:
The reviewer stated that the project has also finished so its resources do not matter too much anymore.

Presentation Number: es307
Presentation Title: Discovery of High-Energy Lithium-Ion Battery Materials
Principal Investigator: Wei Tong (Lawrence Berkeley National Laboratory)

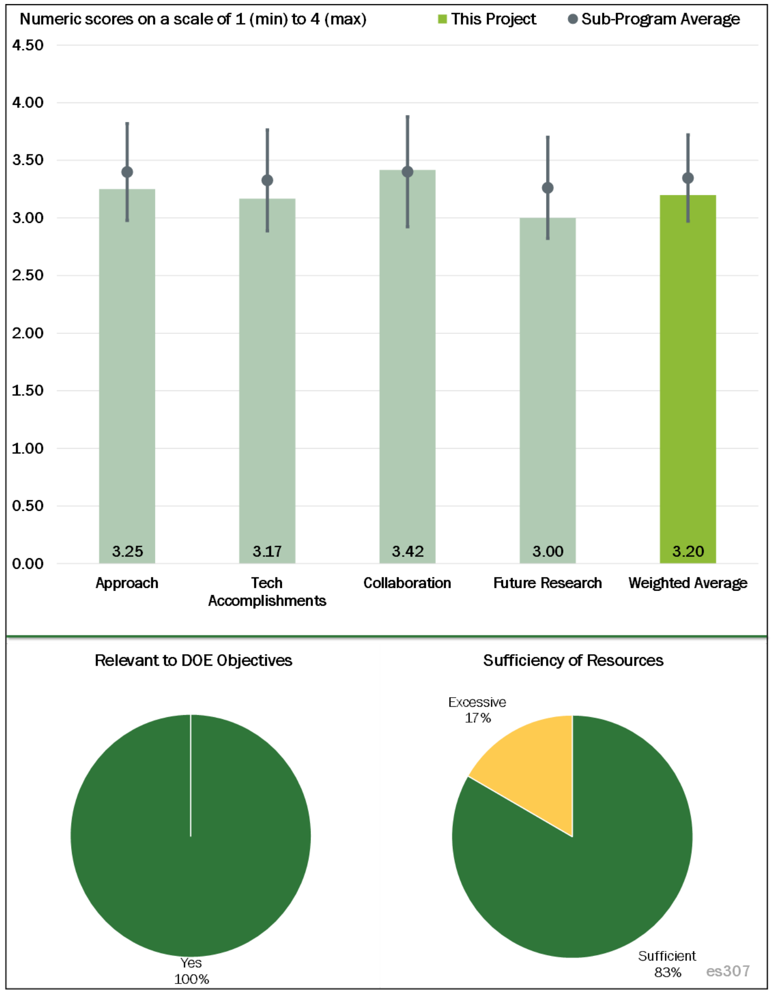

Figure 3-64 - Presentation Number: es307 Presentation Title: Discovery of High-Energy Lithium-Ion Battery Materials Principal Investigator: Wei Tong (Lawrence Berkeley National Laboratory)

Presenter

Wei Tong, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the objective here is to develop high-capacity cathode with greater than 200 mAh/g with minimal capacity and voltage fade exhibiting minimal capacity and voltage fade, from the Li-rich compositions in Li-Ni-O_2 chemical space, with the expectation to possibly utilize the Ni^{2+}/Ni^{4+} redox process for more than one Li per transition metal. These new cathode materials are expected to address the technical barriers of energy density, cycle life, and safety of the current Li-ion cells. The strategy here is to integrate a second transition metal on the first and second row in the Li-rich layered oxides to improve the structural stability and explore the participation of cationic and anionic redox activity and understand the correlation between composition and electrochemistry and the impact of transition metals on oxygen reactivity. The approach here is to utilize high-capacity Li-rich oxide cathodes, design compositions with Li excess and Ni^{2+} to Ni^{4+} redox along with a second transition metal, and investigate anionic O_2 reactivity using differential electrochemical mass spectrometry and advanced synchrotron core-level spectroscopic techniques. Li-rich LL oxides and Ni-rich NMC layered oxides have shown great promise for high capacity, which may be related to the O_2 redox. For the development of new compositions in this family of cathodes, it is essential to understand the role of transition metal substitution in the structural stability and O_2 redox, which this project is duly addressing. In this reviewer's opinion, this project is well designed, feasible and integrated with other DOE efforts.

Reviewer 2:

The approach is well thought out and outlined in a comprehensive fashion. The reviewer commented that the investigation into the impact of transition metals on O_2's involvement in capacity is highly relevant in today's push for higher capacity cathode materials.

Reviewer 3:

The reviewer stated that the project has great hypothesis-driven research and beautiful characterization and that this is a very relevant area of research. The characterization work is done with the end of improving the materials in mind.

Reviewer 4:

The reviewer noted that the work is systematic and focused on the project objectives.

Reviewer 5:

Significant voltage fade of Li- and Mn-rich layered oxides is well known and has been extensively studied. For these oxides to be adopted in practical Li-ion cells, the voltage fade issue should be thoroughly understood and solved. Even though current trend in high-capacity cathode development efforts is shifting from Li- and Mn-rich layered oxide to Ni-rich ones, there should be continuous research efforts to come up with cheaper, safer cathode materials with higher capacity.

Reviewer 6:

If the PI intends to utilize Ni2+ to 4+, the reviewer noted that coordinating with high-voltage electrolytes efforts may be required.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The team has achieved excellent progress to date in this reviewer's opinion. The investigators have demonstrated the impact of transition metal on O_2 reactivity in Li-rich layered oxides.

Reviewer 2:

The reviewer commented that the team has made good progress in designing new compounds in the Li-rich layered oxides to understand the role of transition metal on the structural stability and oxygen redox. Li-rich Ni-based oxides were designed and synthesized, lithium nickel manganese oxide (LNMO) and LNRO exhibited common features in crystal structure, morphology, and electrochemistry (discharge profile and capacity based on the number of Li). However, there was a distinct difference in charge profile observed in high-voltage region, evidenced by a 4.55V plateau for LNMO versus none for LNRO, which this reviewer finds fascinating. These compounds with commonality in structure and electrochemistry but distinct charge profile provide a platform to study the O_2 reactivity/behavior and potential impact of transition metal on oxygen reactivity in Li-rich layered oxides. In contrast to LNMO, where O_2 redox activity contributes to exceptionally high capacity and gas evolution, no O_2 activity was detected in LNRO. Instead, Ni and ruthenium (Ru) redox contribute to its high capacity, suggesting the potential impact of transition metal on the activation of O_2 redox. These finding are quite fascinating and are likely to result in new formulations with high capacity but without the complications of O_2 redox. Overall, the reviewer found the accomplishments notable, the progress measures well against the performance indicators, and the project is in tune with DOE goals.

Reviewer 3:

The reviewer stated that the project appears to be on track and meeting goals so far. This is an ambitious project, as these are complicated materials. The team is doing an excellent job bringing a variety of techniques to bear on the problem in this reviewer's opinion.

Reviewer 4:

Even though it may be a small quantity, the reviewer cautions that CO_2 and/or O_2 evolution warrants capacity fades with cycles. In the LMNO, the early charging at below 4.5V should be due to Mn(III) to Mn(IV), indicating a significant amount of Mn(III) corresponding to the oxygen deficiency. The reviewer stated that Ni alone cannot explain the low voltage capacity. The CO_2 evolution onset is about 4.0V, which indicates instability of the material even at low voltages. The claim of no changes in the Mn oxidation state is not convincing to this reviewer. RIXS is not clear for Mn. In the case of Ni, it is clear because it involves 2e changes, and is obviously more noticeable. The reviewer asked why the team did not collect the usual XANES for Mn Potassium (K)-edges.

Reviewer 5:
Some XAS study looks interesting, but this reviewer does not see any new findings in this study. The presenters claimed that Li-rich Ni-based oxides, LNMO and LNRO designed and synthesized, but these oxides have long been studied by many researchers, the results of which can be found in a Google search. Charge compensation mechanisms of LNMR and LNRO also have been studied and published, which is not much different from the results in this work. This reviewer had a difficult time understanding what the team is trying to achieve from this work. Ru might be an interesting element in that it could be oxidized/reduced between 6+ and 4+ state, but it is impossible to adopt Ru as a major component due to its extremely high cost.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
There are several useful collaborations, in this reviewer's opinion, within the DOE national laboratories and with university researchers in the material characterization through various sophisticated spectroscopic techniques, gas evolution studies and material development.

Reviewer 2:
The reviewer commented that the assembled team is outstanding, including many leaders in the field.

Reviewer 3:
The reviewer applauded the great coordination of a lot of collaborators who bring different skills to the project and recommended the team keep seeking out what you need to understand and improve these materials.

Reviewer 4:
This project includes a very nice group of collaborators. But considering the number of collaborators, the reviewer commented that the presented results are not as original and thorough as one would expect from such an excellent group of collaborators.

Reviewer 5:
There are too many collaborators in this reviewer's opinion.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The PI is proposing future work that is well-planned, comprehensive and has appropriate decision points. The reviewer noted that identification of the O_2 source by *in situ* DEMS through O_2 isotopic labeling is novel work.

Reviewer 2:
This reviewer likes that the PI is expanding studies on phase formation, etc. to better understand structure-property relationships. With the types of experiments you are doing, the PI is in a position to put these together.

Reviewer 3:

The reviewer said that appropriately, the future studies are to continue these studies to establish the phase transformation mechanism in LNRO and identify the limitation in LNRO rate and cycling performance; confirm the O_2 source in gaseous phases by *in situ* DEMS through O_2 isotopic labeling; further expand the studies on phase formation, crystal structure, and O_2 behaviors within LNRO composition space; and continue to explore other layered/rock-salt oxides to integrate Ni redox and other transition metals. The reviewer stated that these studies are consistent with the DOE goals of high specific energy, low-cost, and safe LIBs.

Reviewer 4:

Rather than emphasizing on charge storage on O_2, which would fade during charged storage by O_2 evolution/CO_2 evolution, the reviewer wondered why the team is not pursuing preventing decomposition.

Reviewer 5:

The reviewer said that from a fundamental point of view, crystallographic and electrochemical aspects of LNRO would be interesting. However, Ru cannot be utilized from a practical point of view, even though it would be a good model system. If the team wants to keep studying LNRO, then this reviewer would suggest a really fundamental and thorough study that could give a complete understanding of the material system. The reviewer suggested that the team move away from changing the composition and then performing a similar analysis and test that will result in only partial understanding. Or this reviewer strongly recommends focusing on other materials system as suggested in "Future Work" (other layered/rock-salt oxides).

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

In the sense that this project aims to develop high-capacity cathode materials, the reviewer finds that this project supports the overall DOE objectives.

Reviewer 2:

The reviewer said that for a widespread use of EVs and PHEVs, it is imperative that the LIBs are lightweight, compact, safe and of low-cost. The state of art materials are inadequate to fulfil these needs. High-energy density electrode materials are required to improve the specific energy for Li-ion cells and thus increase the range for the vehicle and reduce overall cost for the battery. The reviewer pointed out that the state of art cathode materials provide capacities of only 170 mAh/g, about half of the capacities possible from the carbon anodes. In this reviewer's opinion, we need to explore new cathode materials, which the present project is duly addressing.

Reviewer 3:

The reviewer commented that the work is highly relevant to the overall DOE objectives.

Reviewer 4:

This reviewer said yes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are adequate for the scope of the project.

Reviewer 2:

The reviewer commented that the resources are sufficient in order to successfully complete the effort in a timely manner.

Reviewer 3:

This reviewer stated there was too much garden variety and would prefer to see more focus.

Presentation Number: es309
Presentation Title: Electrode Materials Design and Failure Prediction
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

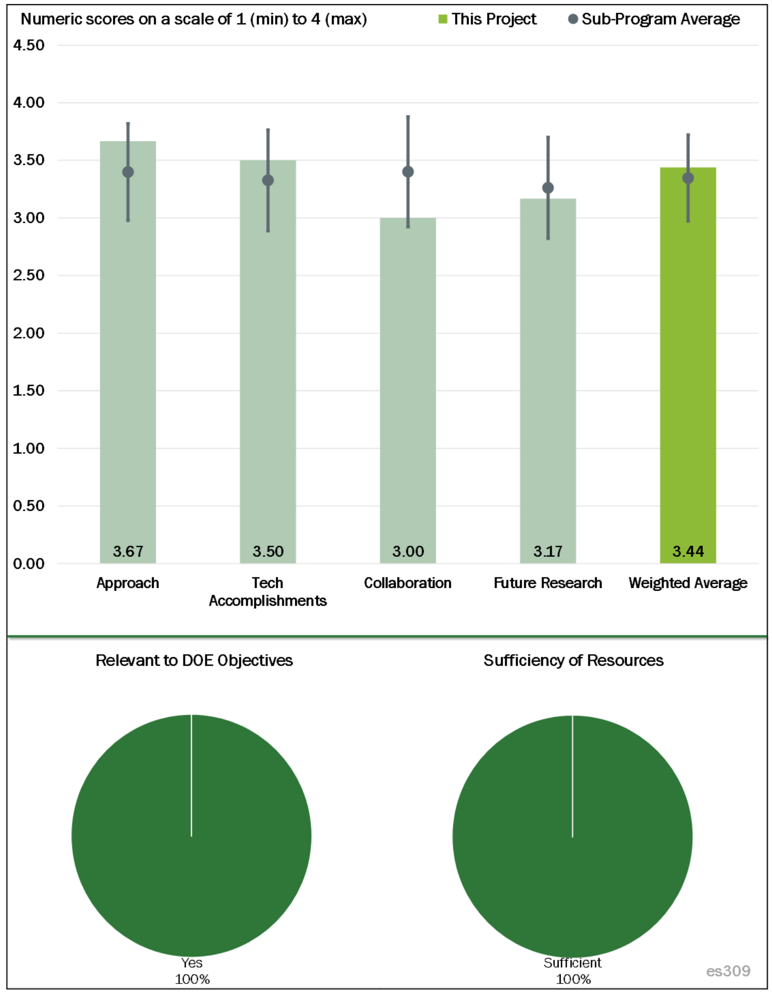

Figure 3-65 - Presentation Number: es309 Presentation Title: Electrode Materials Design and Failure Prediction Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter
Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that this modeling approach is a good first step toward more realistic framework to deal with Li-metal dendrite formation and growth. It applies stress induced current distribution disparity and explains the propagation of such disparity into dendrite formation. It also includes plasticity to explain the modulus changes with the composition and the extent of dendrite growth. The reviewer noted that future incorporation of SEI properties and more mechanical stress field into the model could have some interesting results. It is still too early to tell if the approach is feasible or not, especially the difficulty in obtaining reliable data for the model and simulation. However, it is a good approach to begin with in this reviewer’s opinion.

Reviewer 2:
The reviewer said that this coupled electro-chemical-mechanical modeling predicted the relationship between current density versus Li dendrite growth tendency. The computational predictions qualitatively agreed with experimental observations. The reviewer noted that the team presented the model assumptions very clearly. These assumptions gave the bounds for the modeling conclusions.

Reviewer 3:
The reviewer noted that the approach is general and flexible enough to build off of previous idealized analyses and can potentially grapple with more realistic systems, while allowing sufficient abstraction to derive design insights.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The model gave design maps that point to approaches to suppress dendrite growth. The reviewer stated that this is valuable to guide battery design with Li-metal electrode, which will help to meet DOE's energy density target.

Reviewer 2:
The reviewer commented that the project is just getting started with good progress so far. The next 6-9 months will be critical in determining overall impact in this reviewer's opinion.

Reviewer 3:
In its initial period of the project, the results and progress are promising and interesting. It is not clear to this reviewer if the team has planned sufficient data collection for this project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there are well-defined collaborations that appear to be fruitful.

Reviewer 2:
The reviewer commented that the collaboration is limited only with colleagues in LBNL and possibly ANL. The reviewer suggested the PI look for more experimentalists for collaboration to strengthen the data collection effort to aid model simulation.

Reviewer 3:
The reviewer noted that the work would benefit from mechanical property measurements on the Li anode.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Considering the SEI layer in the model seems to be necessary and challenging, in this reviewer's opinion.

Reviewer 2:
The focus for the future work is well thought, but the plan for execution is not clear to this reviewer. This is particularly problematic with SEI and the application of a mechanical stress field. How the team will accomplish these tasks to collect meaningful data is a bit unclear to this reviewer.

Reviewer 3:
The team presented a lot of options for future work, but the reviewer would like to see further definition and clarification. Ideally, the reviewer hopes the team will focus on 1-2 potential problems and solve them rather than making many shallow contributions to lots of different problems.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that li-metal deposition and dendrite growth problems are critical for the design and fabrication of high-energy rechargeable Li batteries. With proper model simulation, this project has a good

opportunity to develop a useful knowledge based guidance for the development of the next generation of rechargeable Li batteries. The reviewer pointed out that it may impact the DOE objectives in a noticeable way.

Reviewer 2:

The reviewer noted that this project is significantly related to petroleum displacement, as it will enable higher energy density batteries.

Reviewer 3:

In this reviewer's opinion, enabling Li-metal anodes would be a game-changer for electrochemical energy storage, from both energy density and cost perspectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that resources are appropriate.

Reviewer 2:

The reviewer said that the support for the current work seems adequate. However, the reviewer suggested planning more experimental work to collect relevant data for the model and simulation work. This will require more funding support or the team would need to leverage existing projects to collaborate.

Presentation Number: es310
Presentation Title: Advancing Solid-State Interfaces in Lithium-Ion Batteries
Principal Investigator: Nenad Markovic (Argonne National Laboratory)

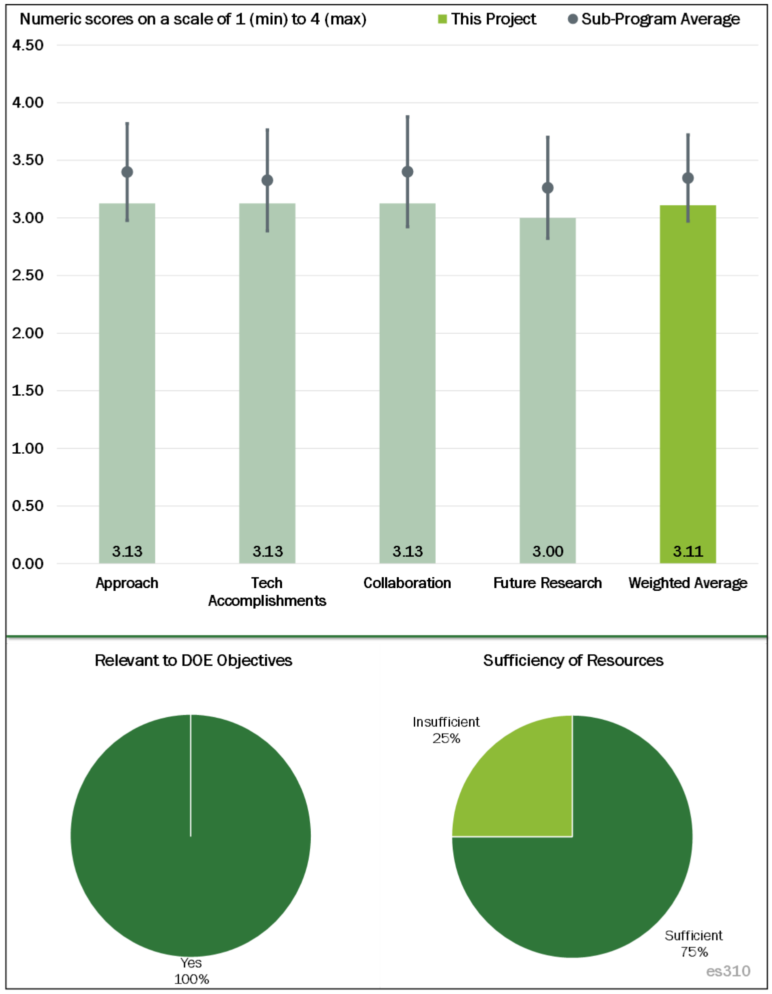

Figure 3-66 - Presentation Number: es310 Presentation Title: Advancing Solid-State Interfaces in Lithium-Ion Batteries Principal Investigator: Nenad Markovic (Argonne National Laboratory)

Presenter

Nenad Markovic, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer pointed out that the electrochemical interface between the electrolyte and electrode materials controls the battery performance, and is a main limiting factor for solid state batteries. The interface of the electrochemical system is also the most difficult to study. The approach to investigate this interface using both controlled experiments and modeling is excellent.

Reviewer 2:

The team provided clear descriptions on the synthesis routes and characterization tools to understand how the interface affect the bulk ion transport; however, the team did not address risks and risk mitigations. This reviewer recommended that the team provide some quantifiable milestones based on the interface modeling.

Reviewer 3:

The overall objectives are admirable—to advance our fundamental understanding of electrochemical interfaces. This reviewer's concern is that the experiments are too far afield from relevant systems. This reviewer has no objection to working with model systems, but the model systems should be chosen with more emphasis on relevance to practical systems. For example, the relevance of strontium titanate ($SrTiO_3$) substrates is unclear. Also, the reviewer suggested that LiPON should be seriously considered as a model solid electrolyte system as it is the only "known good" material.

Reviewer 4:

This reviewer is concerned that the materials being used here, such as the surface treatments and electrolytes and the nano-Li islands, bear little or no resemblance to the actual interfaces in Li batteries. The PI stated that one needs "well defined interfaces" to understand what is going on. The issue is that the Li interface appears to be very messy, and that is what we have to learn to deal with.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The results shown to date are generally positive. The project is new, but the reviewer found some of the results interesting. This is a long-term project and it is important that the resources stay allocated for this to achieve its intended impact.

Reviewer 2:
The reviewer noted that the work is only a few months into the three-year long project, and 15% accomplished so far. The reported activities are focusing on leveraging existing capabilities and experimental system set-up. The preliminary results from studying the Li/STO system are interesting and encouraging to this reviewer, and provide validation to the proposed approach.

Reviewer 3:
Results are minimal at this point, although the reviewer notes that the project has only just started.

Reviewer 4:
The reviewer detailed that the project was kicked off in November 2016 and the team's limited results showed that Al-doped LLZO seemed to be kinetically stable with Li-metal based on XAS.

It was not clear to this reviewer how their results on Li/STO surface interaction can be applied to practical Li-ion or future solid state cells. The team did not demonstrate their knowledge on semiconductor optical amplifier (SOA) understanding of the interfacial mechanisms that affect bulk ion transport. The reviewer recommended that the team include Li/LiPON and LiPON/cathode as part of the model interfaces to be studied because LiPON-based solid state cell is the only rechargeable solid state cell that has been commercialized. Insights gained from the study of the LiPON system using their SOA surface characterization will be very useful to the development of new solid state cells in this reviewer's opinion. In addition to the surface chemistry characterization, the reviewer also recommended that the team characterize bulk properties such as lattice mismatch and how that mismatch affects ion transport through at the interface.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the collaboration within ANL is excellent, and that the external collaborators are well thought-out and carefully chosen.

Reviewer 2:
The reviewer commented that there are well-defined and fruitful collaborations.

Reviewer 3:
According to the reviewer, the team has sufficient equipment and facility for this effort, but the roles of their collaborators were not specified.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the research plan for future work is well developed and covers both material development and diagnostic methods developments. The plan effort leverages the exiting capabilities and also develops unique capabilities for this work.

Reviewer 2:
The future work proposed is reasonable. The reviewer encouraged the PI to collaborate with Nancy Dudney at ORNL, who has many years of experience depositing Li films and solid electrolyte films for thin film batteries. Many of these techniques might be useful here.

Reviewer 3:
The reviewer recommended the team devote more effort to understand the electrolyte/cathode interfacial resistance issue. Specifically, ion transport from polycrystalline solid state electrolyte to polycrystalline cathode.

Reviewer 4:
The reviewer reiterated the concern about the choice of model systems. The careful selection of industrially-relevant model systems is critical. Furthermore, selective introduction of controlled defects will be essential to achieve the intended outcomes. These should be defined with considered input from industry.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The electrochemical interface is the critical aspect for solid state battery in this reviewer's opinion. A solid state battery has the promise of better safety, higher energy density, and will be the future battery for EV.

Reviewer 2:
The reviewer commented that this project, if successful, will enable a fundamental understanding of interfaces in solid-electrolyte systems that can revolutionize the safety of electrochemical energy storage devices.

Reviewer 3:
This reviewer noted that it is important to understand how the interface affect bulk ion transport in solid state and hybrid solid state cells.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The funding level is sufficient for the work in this reviewer's opinion.

Reviewer 2:
The reviewer stated that $1.5 million/year for 3 years should be sufficient for this effort.

Reviewer 3:
The reviewer commented that the resourcing for this project seems too low relative to the stated objectives.

Presentation Number: es311
Presentation Title: Understanding and Mitigating Interfacial Reactivity between Electrode and Electrolyte
Principal Investigator: Larry Curtiss (Argonne National Laboratory)

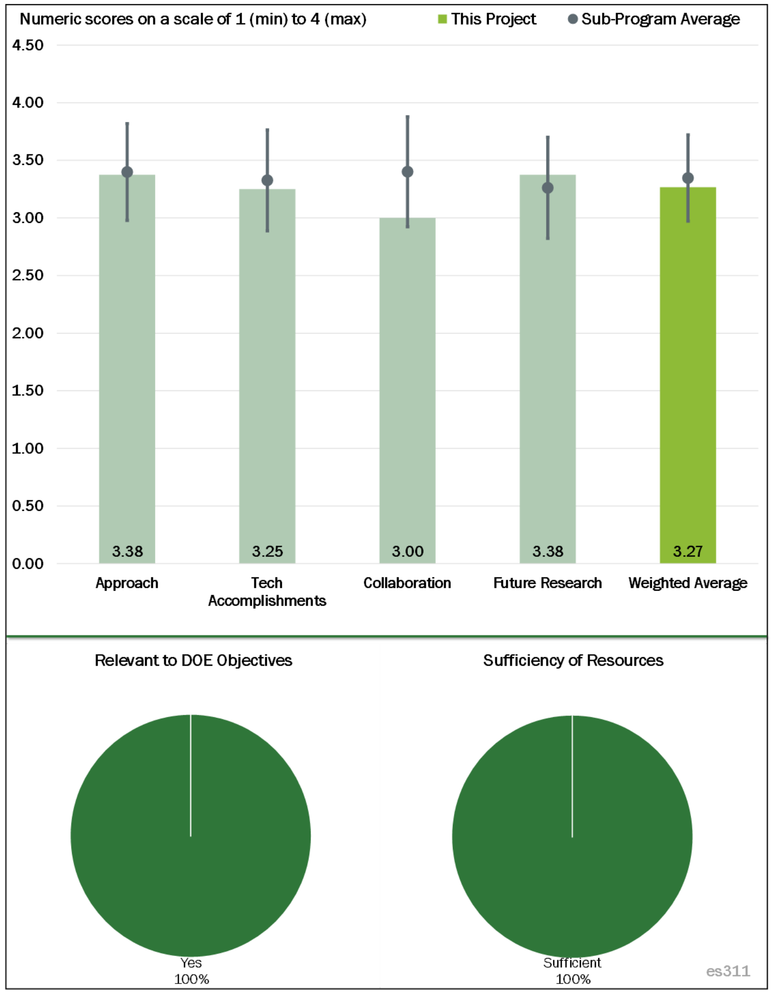

Figure 3-67 - Presentation Number: es311 Presentation Title: Understanding and Mitigating Interfacial Reactivity between Electrode and Electrolyte Principal Investigator: Larry Curtiss (Argonne National Laboratory)

Presenter
Larry Curtiss, Argonne National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that understanding and mitigating the interfacial side reactions between the electrolyte and electrolyte are important to achieve longer life/high voltage rechargeable batteries. Combining experiments and modeling is a very effective approach to tackle this problem, opined this reviewer. Additionally, the choices of system and testing methodologies are very relevant to the problems. The reviewer further noted that experiments and modeling are well designed to understand the mechanisms.

Reviewer 2:
This reviewer commented that the approach is well considered. The experimental capability that this project aims to develop can provide critical insights and fundamental measurements that can directly and immediately impact the design of high-energy, long-life batteries.

Reviewer 3:
The reviewer noted a good strategy to start with characterizing the lithium cobalt oxide ($LiCoO_2$)/electrolyte then applying the insight to the nickelate/electrolyte system. The project team also provided details on how it plans to use high-precision cycler, gas chromatography/DEMS, surface characterization tools, and modeling to understand the electrolyte/cathode interface. Although the milestones were clearly specified, this reviewer observed that the project team did not provide risks or risk mitigations.

Reviewer 4:
This reviewer observed a good approach to use first principal's modeling and surface characterization techniques to try and understand the NMC/electrolyte interface. Although the focus on Al corrosion is a good

way to prove out the techniques, the reviewer was not convinced that Al corrosion is a first order problem with high-V Li-ion cells. The reviewer has seen little evidence for this even after many years of study in the 1990s at LBNL, and through multiple interactions with Li-ion cell developers.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

Although a new start and only 15% into the project, this reviewer commented that the project team has already generated results on the understanding of interface reactivities in the electrochemical system, particularly for the Al current collector (cc) corrosions. The milestones have been clearly spelled out and progress has been well documented. The reviewer observed a lot of effort on technique, protocol, and instrumentation development in the first half year to pave the way for future investigation.

Reviewer 2:

The reviewer noted very good accomplishments, especially the construction of a micro-amp measurement device for the detection of leakage currents due to side reactions. It was encouraging that the team developed a method to detect Co dissolution from an LCO cathode. When this is applied to NMC, the reviewer expressed interest in the detected current as it relates to Mn dissolution, Ni dissolution, and Co dissolution.

Reviewer 3:

This reviewer asserted that the project team already achieved good understanding on the corrosion of the Al current collector via the use of high precision cycler, and developed a good mechanism on the aluminum fluoride (AlF_3) passivation layer on Al cc, even though the project was only 15% complete. The project team demonstrated good understanding of the various corrosion mechanisms on Al cc, and its *in situ* dissolution study of LCO provided an understanding of the instability of LCO greater than 4.6V. The reviewer indicated that the project team needs to couple its surface characterization with electrochemical characterization to understand the decomposition mechanism as a function of charge cut-offs, which would enhance understanding of the electrolyte/cathode interfacial issue at high voltages.

Reviewer 4:

The reviewer offered the following observations: the experiments to date are interesting to demonstrate the capability, but the impact is unclear; the reviewer added that studying Al passivation is interesting, but the significance is not immediately clear; and the mechanistic understanding is admirable, but one additional step is needed to connect this to practical implications. Moving forward, this reviewer advised that it will be critical to probe relevant model systems. Of particular importance would be to understand the catalytic changes that occur when moving from moderate Ni (50-60 mol%) to high Ni (greater than 70 mol%) materials. Clear, simple conclusions with statements of practical importance are achievable with the unique experimental capability this team has developed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer described collaboration within the ANL team as excellent, and noted that each team member contributes uniquely to this project.

Reviewer 2:

Good collaboration was observed by this reviewer, who added that the roles of each collaborator were specified.

Reviewer 3:
The reviewer noted evidence of collaboration, but the degree of coordination could be increased to enhance the impact of the work.

Reviewer 4:
The reviewer expressed surprised that this PI from ANL does not list any of the following as collaborators: the ANL-led high-capacity high-voltage cathode work group; Daikin, who is developing high-V electrolytes for use with high-Ni NMCs; or other developers of high-V cells. As indicated by this reviewer, the ANL HEHV team's mission is to understand and improve high-Ni NMC cathodes operated at high-voltage. Perhaps this collaboration will emerge when the PI moves onto NMC cathodes. The reviewer noted that most of the current work has been on LCO to establish the project's techniques.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The stated future work is clear and the potential impact is enormous from this reviewer's perspective.

Reviewer 2:
The reviewer commented that it is good the project team is moving on to NMC.

Reviewer 3:
This reviewer asserted that milestones for the remaining of the year are well thought and a logical continuation of earlier milestones. The next year's planned activities are very relevant to this year's work. The reviewer added that planned activities on the cathode materials address the need for critical high-voltage materials. This reviewer suggested including appropriate decision points in the planned activities.

Reviewer 4:
The reviewer noted that the proposed effort to further study the coated nickelate/electrolyte interface and understand the effect of voltage on metal dissolution and other decomposition products is greatly needed. This reviewer recommended that the project team also characterize the coated Al cc as part of the cathode/electrolyte study.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer asserted that stability of high-Ni NMC/electrolyte interfaces at high voltage is a critical issue for LIBs.

Reviewer 2:
The reviewer commented that understanding and mitigating interface side reactions may lead to long life time and high energy density rechargeable batteries.

Reviewer 3:
This reviewer noted that this work can provide clear results to enable long-life high-energy batteries.

Reviewer 4:
The reviewer indicated that understanding the electrolyte/cathode interface is key to improving stability of the high-voltage Li-ion systems. To make it more relevant, this reviewer suggested that the project team apply its

Al corrosion study to the coated Al cc and study AlF_3 passivation layer stability as a function of the charge cut-off voltage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that resources are sufficient for the planned work.

Reviewer 2:
This reviewer indicated that $800,000/3 years is sufficient for this effort.

Reviewer 3:
The resources appear to be adequate from this reviewer's perspective.

Presentation Number: es312
Presentation Title: Daikin Advanced Lithium-Ion Battery Technology—High-Voltage Electrolyte
Principal Investigator: Joe Sunstrom (Daikin America)

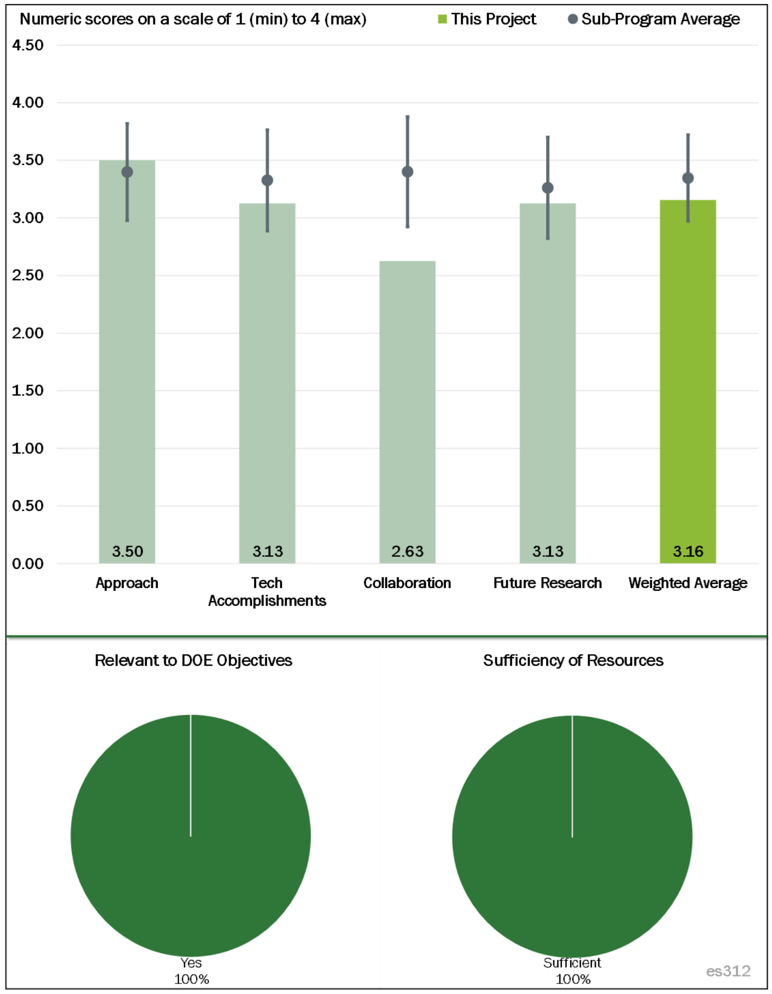

Figure 3-68 - Presentation Number: es312 Presentation Title: Daikin Advanced Lithium-Ion Battery Technology—High-Voltage Electrolyte Principal Investigator: Joe Sunstrom (Daikin America)

Presenter
Joe Sunstrom, Daikin America

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer commented that fluorinated carbonates solvents and additives have been known to stabilize high-voltage cells, and that systematic investigation of this class of materials is very beneficial to improve performance of high-voltage LIBs. Additionally, the reviewer noted that Daikin America Inc. is uniquely suitable to perform this investigation, as it both a fluorinated compounds manufacturer and an electrolyte company.

Reviewer 2:
The reviewer liked the approach of trying to understand the role of fluorinated additives on the stability of electrolytes at high V, as well as the use of three go/no go decision points. Using this approach in other BMR projects was also encouraged by this reviewer. The reviewer liked the goal of 5V stable electrolyte that is self-extinguishing, and suggested putting more weight on the 5V stability.

Reviewer 3:
The reviewer noted that this is a good systematic study of the voltage cut-off impact on the stability of electrolyte with fluorinated additive. The combination of electrochemical and analytical characterizations should provide good understanding of the failure mechanism in high-voltage electrolyte and enable optimization of electrolytes for high-voltage cells. This reviewer observed a lack of quantified milestones and that technical risks and risk mitigations were not discussed.

Reviewer 4:
This reviewer indicated that development of electrolytes that are stable to high-voltage is an important area with clear impact. The reviewer advised that greater attention should be paid to ensuring the compatibility of these solutions with practical (e.g., graphite) anodes, or the utility will be diminished.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
This reviewer observed good accomplishments to date tying together gassing and likely internal cell reactions.

Reviewer 2:
The reviewer reported that this project is a new start and only a half-year into a three-year project. The work so far has been mainly in establishing baseline performance of classic electrolyte and FEC additives in high-voltage cells, which is a correct initial step for new electrolytes and additives development. This reviewer opined that progress is normal and the overall work supports DOE goals.

Reviewer 3:
The reviewer indicated that although the project is a new start and 17% complete, the project team has already made significant progress on characterizing the stability of electrolytes as a function of gas generation at increasing charge cut-off voltages. Gas generation results confirmed current understanding that the cathode/electrolyte interaction dominated the instability issue of high-voltage cells. This reviewer added that the project team needs to demonstrate understanding of the electrolyte/high-voltage cathode stability issues and provide a rationale for how its fluorinated additives will enable stability above 4.6V

Reviewer 4:
This reviewer commented that the work is addressing high-voltage stability at the cathode/electrolyte interface. However, the results to date show poor anode/electrolyte interface stability and no clear work plan was presented to improve this critical characteristic.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated that it is appropriate this project is entirely within Daikin.

Reviewer 2:
Although it is not explicitly mentioned in the presentation file, this reviewer noted that Daikin American has collaborations with both national laboratories and industry.

Reviewer 3:
This reviewer encouraged the team to reach out to the ANL HEHV cathode team.

Reviewer 4:
The reviewer observed that the project team had not identified collaboration partners. Additionally, it was unclear where the project team will perform some of the surface characterizations, such as ToF-secondary ion mass spectrometry, and XPS.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer asserted that stability of the anode/electrolyte interface must be improved for these electrolytes to have practical applications.

Reviewer 2:
In addition to the proposed effort, this reviewer noted that the project team may want to devote some effort to understand whether the fluorocarbon performance decrease between 4.5V and 4.6V is due to the cathode or electrolyte.

Reviewer 3:
The reviewer commented that the proposed detailed study of gas composition and kinetics as a function of voltage and detailed study of electrolyte film are very important areas to investigate electrolyte failure at high-voltage. However, the project team needs to establish a strong connection between these studies and the overall objective of developing high-voltage solvent systems and additive packages.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer asserted that the project is highly relevant to both DOE and industry objectives.

Reviewer 2:
This reviewer explained that high-voltage stable electrolyte is a critical component for enabling a high-energy battery. The reviewer further commented that this project is aimed at understanding the failure mechanism of baseline electrolyte at high-voltage, and developing high-voltage stable electrolyte solvent systems and additive packages.

Reviewer 3:
The reviewer indicated that nearly all roadmaps for advanced batteries call for high-voltage systems; this is a critical area of development.

Reviewer 4:
This reviewer commented that this is a very relevant study needed to understand and stabilize the electrolyte for high-voltage Li-ion cells.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that resources are appropriate.

Reviewer 2:
This reviewer commented that $1.8 million over 3 years should be sufficient for this effort.

Reviewer 3:
The reviewer opined that the cost share by Daikin is good, 30%. Cost is relatively high compared to other projects at this level of commercial maturity.

Reviewer 4:
Sufficient resources were observed by the reviewer for this project to achieve the milestones. This reviewer added that lab expansion is needed to be able to evaluate the different electrolyte samples.

Presentation Number: es313
Presentation Title: Performance Effects of Electrode Processing for High-Energy Lithium-Ion Batteries
Principal Investigator: David Wood (Oak Ridge National Laboratory)

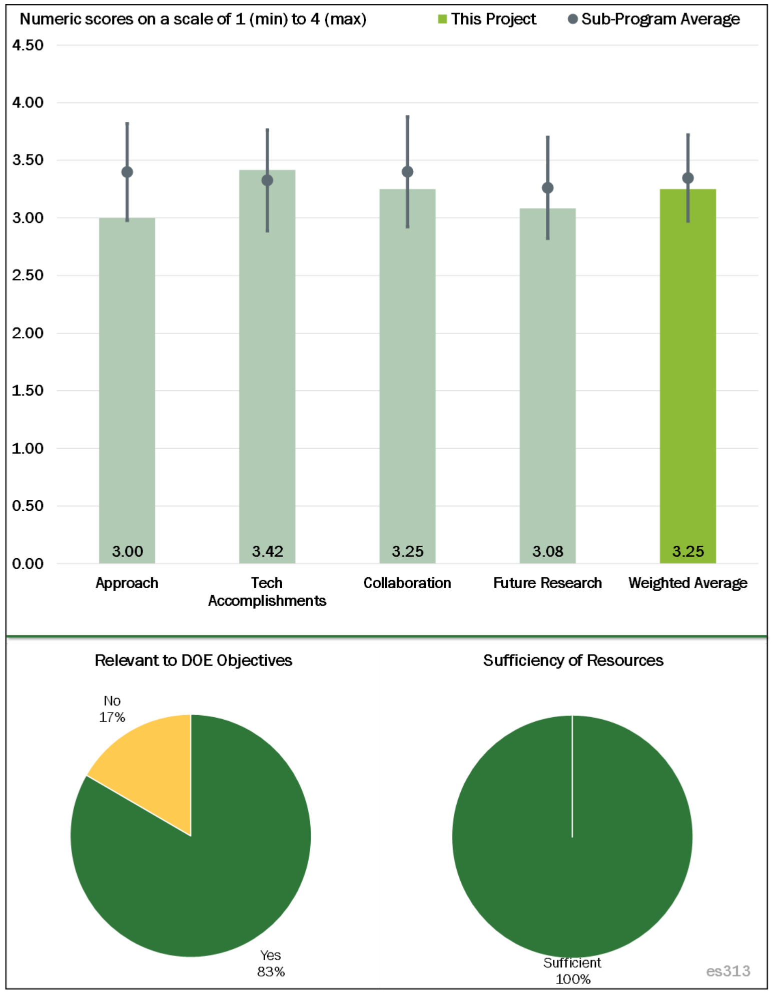

Figure 3-69 - Presentation Number: es313 Presentation Title: Performance Effects of Electrode Processing for High-Energy Lithium-Ion Batteries Principal Investigator: David Wood (Oak Ridge National Laboratory)

Presenter

David Wood, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer described the approach as well-outlined. If successful, the effort will result in a better understanding of the process-property-performance relationships for Li-ion electrodes. The reviewer asserted that this type of strategy is necessary to meet low-cost, high-performance battery goals.

Reviewer 2:

The reviewer commented that this project aims to develop an aqueous-based electrode processing procedure for high-energy NMC and NCA cathode materials. The reviewer noted that the project appears to be well-designed, difficult but feasible, and aligned with other DOE efforts.

Reviewer 3:

This reviewer indicated that the project is highly relevant for reducing the cost of manufacturing cells with high specific energy.

Reviewer 4:

The reviewer reported that the approach is to reduce cost by developing aqueous-based process for nickelate electrodes and improve energy density by making thick electrodes. This reviewer also observed quantifiable milestones based on measuring the cathode stability and subsequent cell performance as a function of exposure time to water. The reviewer added that nickelate materials are irreversibly degraded by moisture; unless this barrier is addressed first, it makes no sense to develop an aqueous-process for the nickelates electrode.

Reviewer 5:

The reviewer observed that this project has substantial overlap with the much larger (in terms of funding) project, ES164 (i.e., Thick Low-Cost, High Power Lithium-Ion Electrodes via Aqueous Processing). Given the overlap in technical foci, lead laboratory (ORNL), partners, and staff, the reviewer commented that it is a poor approach to treat this as a separate project. This reviewer further noted that most of the results of this project are integral to the success of ES164. The reviewer explained that the approach is acceptable if the two projects are fully integrated at the performance level and the separation into two distinct designations is simply an artifact of funding. This project certainly addresses issues that must be resolved to produce reliable, consistent, high-performing cells in large quantities. This reviewer also noted it is good the project recognizes that processing characteristics of some of the newer materials (e.g., Ni-rich cathode materials) may be different from current, common materials.

Reviewer 6:

Although several different research areas were highlighted, this reviewer commented that the “sharp focus” of the program was a little bit unclear. The reviewer explained that “manufacturing improvements” is a very broad category; there may be some benefit to detailing the focus, timeline, and objectives. This reviewer also indicated that tracking progress on so many different activities towards a general DOE goal is hard.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

Given that this project had only been active for a few months before the poster paper was prepared, this reviewer commented that the results reported are reasonable and appropriate. The reviewer explained that new battery materials will be required to meet DOE's goals; some of these new materials may require modifications in the way that they are processed relative to current practice. This reviewer asserted that the project is designed to identify any required modifications. The reviewer noted that some sections of this project (e.g., investigating cell formation processes) focus on reducing the time and cost of aspects of cell manufacture, which clearly supports DOE's goals for lower cost batteries.

Reviewer 2:

This reviewer indicated that the work done is systematic and directly addresses project goals. Coating from aqueous slurries, chemical and mechanical stability of the electrodes and SEI, and the effect of formation protocols on cycling performance are all very relevant to developing efficient and effective processes for manufacturing.

Reviewer 3:

The reviewer noted that this project just started this fiscal year and has made considerable progress thus far. This reviewer explained that it is well known that the graphite surface plays an important role in electrolyte wettability, reduction potential, and SEI formation. The project demonstrated that UV light can control oxygen levels on graphite resulting in improved cycle life. Additionally, the reviewer reported development of a new method to form cells that can dramatically reduce time.

Reviewer 4:

This reviewer acknowledged that it is early in the project timeline (i.e., only six months of work) and the project is progressing well with the NMC532 cathodes. There is still substantial work to be done with powder stabilization in water, leaching minimization, and improving electrochemical rate performance, but the reviewer opined that the project team has a good start. The reviewer asserted that more electrochemical analysis of aqueous-produced cathode electrodes is required to determine progress towards goals, and that approach feedback from a major cell manufacturer would lead to increased credibility and validity of the project team’s approach. This reviewer also commented that it is unclear when or how the project team plans to determine the cost benefits of its approach.

Reviewer 5:

This reviewer reported the following: the project team's study provided valuable data on the stability of different NMC materials as a function of exposure time to water; a shortened formation protocol was developed; and a correlation between rate capability versus electrode loading as a function of porosity was established. Based on understanding of the instability of water-exposed NMC materials, the reviewer recommended that the project team propose a mitigation to reduce the impact of water on aqueous-processed NMC electrodes.

Reviewer 6:

The reviewer commented that there may be some information that can strengthen US supply chain processing knowledge, but this was not demonstrated in some of the examples. For instance, continued this reviewer, shortening the formation process from 5 C/20 cycles is unlikely going to help battery manufacturers. As the presenter remarked, this is because formation protocols likely are shortened and more specific than this pattern already. While it may be good knowledge for ORNL to improve their testing throughput, this reviewer doubted that it will be informative for cell manufacturers today. The reviewer further indicated that specific thickness/porosity tradeoffs are likely part of a cell manufacturer's optimization design of experiments already, and may not be very applicable in broad strokes.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that strong collaborations exist with many institutions.

Reviewer 2:

It appeared to this reviewer that ORNL is working well with many external partners.

Reviewer 3:

This reviewer observed good collaboration with various team members, and that the role of each member was clearly specified.

Reviewer 4:

The reviewer commented that the project lists adequate collaborations, but did not indicate whether ORNL or a partner will develop cost-benefit analysis of aqueous processing.

Reviewer 5:

This reviewer reported that collaborative partners are identified and specific tasks for several of them are clearly stated. The reviewer noted the following collaboration weaknesses: lack of a battery manufacturer who has a significant business base in cells for use in passenger vehicles; and the lack of stated coordination with ES164.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

This reviewer reported that proposed future work is focused on areas highly relevant to achieving DOE goals. These include lowering the formation and wetting time of the cell to less than 24 hours and investigating different Si anode manufacturing methods.

Reviewer 2:

The reviewer described future work as reasonable.

Reviewer 3:
Future work to this reviewer seemed logical, but lacks appropriate decision points and clear alternative development pathways for risk mitigation. High energy cathodes with protective coatings should be considered as alternative materials pending continual leaching problems. The reviewer advised a focus on substantial electrode processing characterization and cost analysis.

Reviewer 4:
This reviewer recommended that the shortened protocol should be further validated for SEI stability by measuring the self-discharge rate. The reviewer further observed a need to quantify the performance of dried water-exposed NMC cathodes in cells.

Reviewer 5:
The reviewer expressed difficulty with judging proposed future work. This reviewer noted a wide range of topics being studied, and there did not seem to be clear gates or planned milestones.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that this effort is very relevant to overall DOE objectives. The development of high-performance, low-cost electrodes for LIBs is at the core of the petroleum displacement objective.

Reviewer 2:
This reviewer commented that decreased processing costs can translate to decreased cell costs, increased EV adoption, and, therefore, potential petroleum displacement.

Reviewer 3:
The reviewer explained that new battery materials and new manufacturing processes will be necessary to meet DOE goals for battery cost, energy density, and specific energy. This reviewer opined that the questions addressed by this project are all relevant to understanding these new materials and processes. This understanding is necessary before the materials and processes can be used in a manufacturing environment.

Reviewer 4:
This reviewer asserted that low-cost manufacturing processes for batteries will help increase the adoption of electric vehicles.

Reviewer 5:
The reviewer commented that it is well known that nickelates are irreversibly degraded by moisture. Thus, it was not clear to this reviewer why there is a need to investigate aqueous-based process for the nickelates electrodes, even if there might be cost benefit.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted sufficient resources to achieve stated milestones in a timely fashion.

Reviewer 2:
This reviewer commented that the resources are sufficient in order to successfully complete the effort in a timely manner.

Reviewer 3:
The reviewer remarked that $1 million should be sufficient for the three-year effort.

Reviewer 4:

This reviewer indicated that the facilities and staff of the lead laboratory and its partners are clearly adequate to accomplish the goals of this project. Although no detailed financial data are provided, the reviewer described the total funding as reasonable.

Presentation Number: es315
Presentation Title: Developing Flame Spray Production Level Process for Active Materials
Principal Investigator: Greg Krumdick (Argonne National Laboratory)

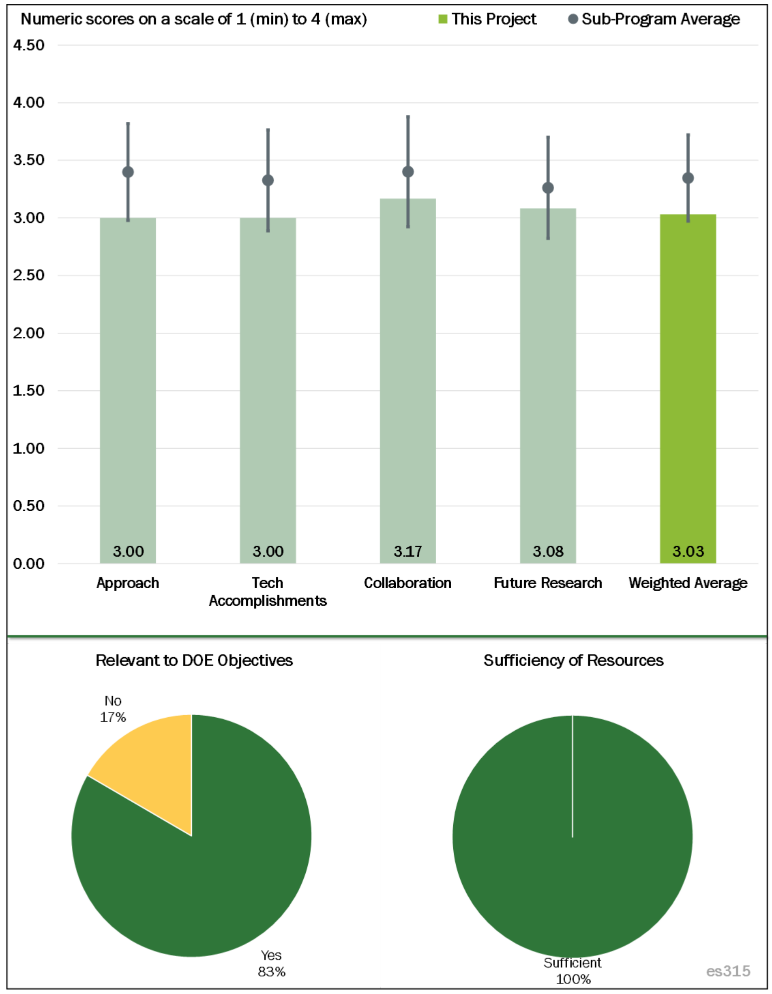

Figure 3-70 - Presentation Number: es315 Presentation Title: Developing Flame Spray Production Level Process for Active Materials Principal Investigator: Greg Krumdick (Argonne National Laboratory)

Presenter
Greg Krumdick, Argonne National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer viewed the approach as relevant, and reported that the project team will develop a flame spray pyrolysis synthesis procedure with guidance from an industrial partner to ensure affordable, high-performance materials.

Reviewer 2:
The reviewer observed an excellent approach for establishing the capability to utilize the flame spray pyrolysis method. However, it was unclear to this reviewer how the method will be evaluated in comparison with standard methods.

Reviewer 3:
This reviewer described the approach as interesting, and inquired about the cost by kg.

Reviewer 4:
The reviewer commented that flame spray combustion synthesis is an industrial technology used for the synthesis of carbon nanoparticles and simple oxides. This project aims to use the knowledge of the existing technology and adopt it for the manufacturer of more complex transition-metal oxides that are used as electrode in LIBs. The reviewer noted that one barrier to the adoption of this technology is the small size of particles synthesized by combustion methods. In order to address this issue, the reviewer reported that the project team modified the system by increasing the exposure time to high temperatures. At elevated temperatures, particles usually agglomerate and form larger particles. This reviewer added that the concern here is presence of weak agglomerates with poor attachment of particles, which could result in degradation of battery electrodes.

Reviewer 5:
The reviewer noted a reasonable approach to reduce cost by eliminating the calcination step and combining the cathode and carbon matrix during the flame spray synthesis. It was recommended by this reviewer that the project team provide a cost model and show how the flame spray process can reduce cost versus traditional calcination.

Reviewer 6:
This reviewer expressed interest in more convincing details or evidence that flame spray pyrolysis can deliver the claimed benefits (e.g., reduced cost, better purity, crystallinity, etc.). One of the key needs in active materials is uniformity in particle size, and yet having particles large enough to be easily handled. It was not convincingly demonstrated to this reviewer how this work would do on this metric.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked that good progress was achieved this past year: system engineering was completed; major components were ordered; and several of the major components were installed.

Reviewer 2:
The reviewer reported that the flame spray synthesis system and all the necessary equipment are successfully installed and tested. The preliminary results show that complex cathode compositions can be obtained and the proposed system can simplify the battery manufacturing and is a step toward roll-to-roll battery manufacturing.

Reviewer 3:
Although this review was early in the method development, the reviewer commented that the project seems to be on schedule to begin making materials.

Reviewer 4:
This reviewer highlighted possibly mislabeled fiscal years on Slide 5. If so, it appeared to the reviewer that the project is on track toward a completed device. The device seems well-designed and robust. However, this reviewer preferred to see more validation steps built into the progress steps, and added that it seems as if the device will be turned on at the end of the project at which point the project team will find out if it works or not.

Reviewer 5:
The reviewer acknowledged that the project team set up the equipment, but it was difficult to assess project success. The reviewer commented that there is no analytical data or performance data on the materials produced by the flame spray analysis, and that analytical and performance data should be part of the quantifiable milestones.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
This reviewer indicated that the project team is collaborating with the leading companies in flame spray technology.

Reviewer 2:
This reviewer opined that the inclusion of Cabot and Praxair is promising for developing a practical application of these methods.

Reviewer 3:
The reviewer noted good collaboration with industrial partners and that the role of each member was specified.

Reviewer 4:
This reviewer observed good collaboration with other institutions, including Cabot, Praxair, and Professor Pratsinis (ETHzurich).

Reviewer 5:
It seemed to this reviewer that there should be more collaboration or regular discussions with Pratnisas, who is the acknowledged expert on this technology. Other than that, the reviewer remarked that inclusion as part of MERF ensures pretty good collaboration with battery researchers once this project is completed.

Reviewer 6:
More collaboration with cathode producers was indicated by this reviewer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This reviewer described future plans, in regards to powder production scale-up and roll-to-roll battery electrodes manufacturing, as well-detailed and aligned with the project goal.

Reviewer 2:
The reviewer indicated that future plans are a logical extension of the past year, and reported that plans are in place to begin developing the NCM procedure with Cabot and Praxair.

Reviewer 3:
The reviewer observed many exciting materials to be made with this device, once it is up and running.

Reviewer 4:
This reviewer commented that very little detail about the future experiments was given, but acknowledged that it is early in the process.

Reviewer 5:
The reviewer reported that the project is 95% complete and suggested a focus on characterizing the materials produced by the flame spray method rather than exploring different aerosol synthesis with the remaining funding.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this effort is relevant to the overall DOE objectives. The development of affordable, high-performance cathode materials for an EV LIB is at the core of the petroleum displacement objective.

Reviewer 2:
This reviewer indicated that the project will enable low-cost production of high-quality cathode materials with enhanced performance. This will accelerate use of high-energy LIBs in the automotive industry and other sectors.

Reviewer 3:
The reviewer remarked that this work improves U.S. technological ability to improve manufacturing of electrode materials for vehicle electrification.

Reviewer 4:
This reviewer stated that new methods should be evaluated to try to develop superior processes.

Reviewer 5:
It is unclear to this reviewer why ANL, a national laboratory, is investigating methods to reduce cathode synthesis cost. Per the slides, ANL followed the guidance of industrial partners, which led the reviewer to question why an experienced industrial company was not contracted for this task. The reviewer added that this task is better suited for a commercial cathode company.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer remarked that the project team has access to sufficient resources and collaborations in order to perform the proposed tasks.

Reviewer 2:
The reviewer described resources as sufficient to successfully complete the effort in a timely manner.

Reviewer 3:
This reviewer commented that resources appeared adequate.

Reviewer 4:
The reviewer opined that $500,000 is insufficient for this project, and noted that most of the funding was used to set up the flame spray equipment. This reviewer explained that there should be sufficient funding for capital cost and materials characterization for work to be done at a commercial cathode company.

Presentation Number: es331
Presentation Title: Development of a High-Energy Density EV Cell
Principal Investigator: Mohamed Alamgir (LG Chem Power)

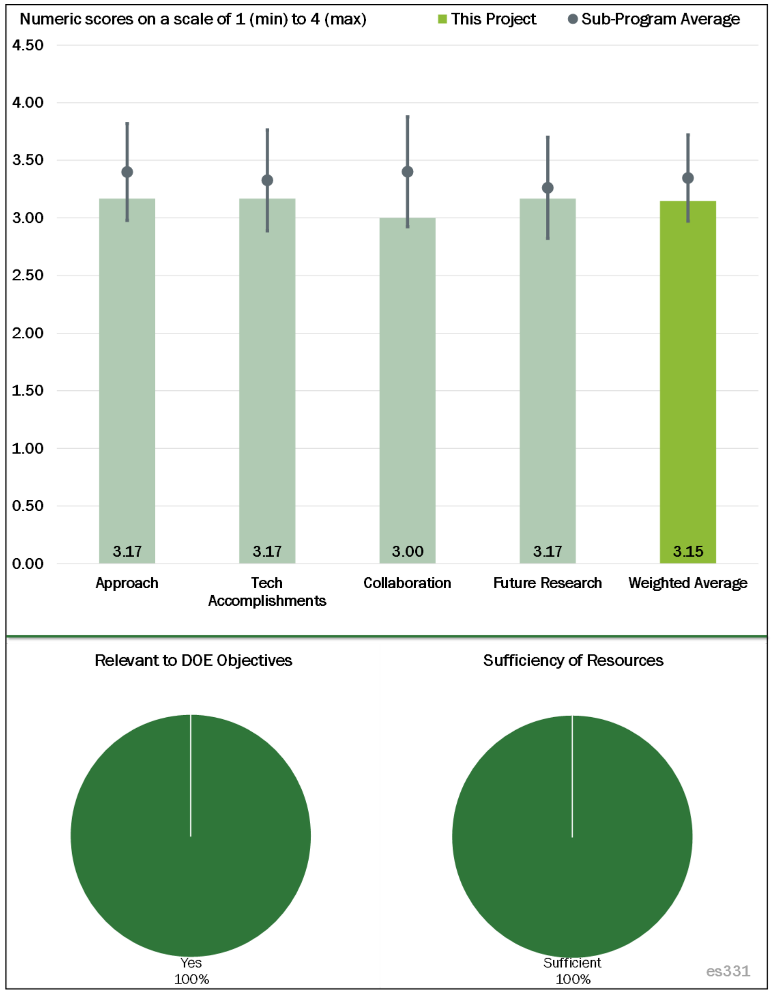

Figure 3-71 - Presentation Number: es331 Presentation Title: Development of a High-Energy Density EV Cell Principal Investigator: Mohamed Alamgir (LG Chem Power)

Presenter

Mohamed Alamgir, LG Chem Power

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The objective for this project, as understood by this reviewer, is to develop a high-energy and low-cost Li-ion cell and module that will provide 200-mile range per charge, as desired by the USABC BEV program. The reviewer reported that specific cell-level performance targets are 750 Wh/l and $100/kWh, which require high specific energy (high capacity and/or voltage) cathodes, such as the Mn- and Ni-rich LL composite oxides and high capacity anodes (e.g., Si anodes). The plan is to deliver the cells and modules with these enhanced performance characteristics to DOE laboratories for testing. The reviewer stated that the approach focuses on Mn-rich cathodes and Si-based anodes, as well as improving performance and life by optimizing electrode structures, surface coatings, and electrolyte compositions. Eventually, low-cost modules will be designed with adequate mechanical integrity, fabricated for performance demonstration. Appropriately, the materials tested here are among the most promising options. Overall, this reviewer described the project as well designed and integrated with other efforts.

Reviewer 2:

This reviewer explained that the LG Chem project studies Mn-rich cathode using scaled-up ALD coating, paired with SiO anode, to deliver cells meeting the USABC target specifications (i.e., 750 Wh/l and $100/kWh). The reviewer added that this is a practical and promising approach to goals in the 200-mile USABC BEV program.

Reviewer 3:

The reviewer commented that the original scope and approach of the project is changing, based on discussions with the PI. The original emphasis on LMR-NMC is shifting to a high-Ni NMC. This was quite understandable to the reviewer, considering the challenges of LMR-NMC. This reviewer added that the project team will be giving something up in energy, but should gain in life.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
Without describing a lot of the details, the reviewer remarked that the PI presented data from a number of tests, mostly based on cycle life, and examined various active materials.

Reviewer 2:
This reviewer observed good progress made in evaluating Mn-rich and Ni-rich materials as high-capacity cathodes and various Si-based materials as anodes. Studies were carried out to demonstrate the stability of Mn-rich and Ni-rich cathode materials with ALD coatings. The reviewer explained that these coatings improve the cyclic stability of these cathodes, especially when cycled to high charge voltages, while thicker coatings affect the rate capability. Although trends are clear on the cycle life benefits, this reviewer pointed out that the cycle life data shown here is not stellar, with a high capacity fade (i.e., 10% over 50 cycles). Also, studies were carried out with dense electrodes (i.e., with high loadings of active materials), but the reviewer found that the details are not provided here on this aspect. Likewise, comparative studies were made on various Si-based anode materials (e.g., SiO, Si alloy, and Si-C composites) with different binders, electrode porosities, and electrolytes. Low volume expansion and good cycle life have been reported with the SiO-based anode, though the reviewer highlighted that details also are lacking on the loadings (or mAh/cm^2). The performance in full cells is not that encouraging in terms of cycle life. Based on the data presented, it was difficult for the reviewer to know where the project is in terms of meeting the DOE goals of 750 Wh/l (specific energy not targeted). Similarly, this reviewer advised that proper cost analysis needs to be made showing that the proposed material and cell/module designs will get the project closer to the cost goals. Overall, the reviewer asserted that progress is consistent with the scheduled milestones and DOE goals.

Reviewer 3:
According to the reviewer, the project team demonstrated that ALD coated Mn-rich cathodes have greater than 80% capacity retention for up to 50 cycles. However, the reviewer observed no data from uncoated cathodes for comparison. The project team also demonstrated that more ALD coating will lower rate capability. This reviewer explained that the project team needs to find an optimized amount of coating for maximum electrochemical performance. The project team also compared the cycling performance of Si-alloy- and SiO-based full cells. The reviewer reported that results show SiO is significantly better in terms of cycle-life.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
Only a limited number of collaborations were observed by this reviewer.

Reviewer 2:
Although there are no collaborations on this project for the material or cell/module development for proprietary reasons, this reviewer pointed out that there are on-going collaborations with DOE laboratories to evaluate cells and modules delivered in this project.

Reviewer 3:
This reviewer commented that LG Chem does not show any collaboration with universities and national laboratories. However, the reviewer acknowledged that LG should have enough resources internally, and that the project team also communicates with USABC team members.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This reviewer observed a good path forward, and also pointed out that the project team has a ways to go for a vehicle battery.

Reviewer 2:
The reviewer reported that LG Chem's future work will be concentrated in both materials improvement and cell design optimization.

Reviewer 3:
This reviewer opined that planned future work is logical and consistent with USABC goals. Future studies, as observed by this reviewer, will do the following: continue to improve cell energy density, by improving the materials (i.e., cell components); improve cell design optimization; and, in particular, improve SiO anode durability. Based on the data presented here, the reviewer indicated that the project is still farther away to demonstrate adequate performance (specific energy and durability) from the materials to meet the targets battery goals. Subsequent to this material development, this reviewer also noted large-sized EV cells will be built and delivered to DOE laboratories for evaluation.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that this project targets the DOE objective of petroleum displacement by developing battery cells for use in the 200-mile USABC BEV program very well.

Reviewer 2:
This reviewer described the project team's work as very relevant.

Reviewer 3:
The reviewer explained that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. High capacity cathode and anode materials are required to improve the specific energy of Li-ion cells. Additionally, new, low-cost modules designs are required to bring the battery cost to $100/kWh. This reviewer concluded that successful implementation of this project will thus address the key barriers of low energy densities and high cost for EV batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer described the project team resources as sufficient.

Reviewer 2:
The reviewer opined that resources are adequate based on the project scope ranging from material development and cell fabrication to module development.

Reviewer 3:
LG Chem demonstrated to this reviewer that it can conduct the project with its own technologies.

Presentation Number: es332
Presentation Title: High Electrode Loading EV Cell
Principal Investigator: William Woodford (24M Technologies)

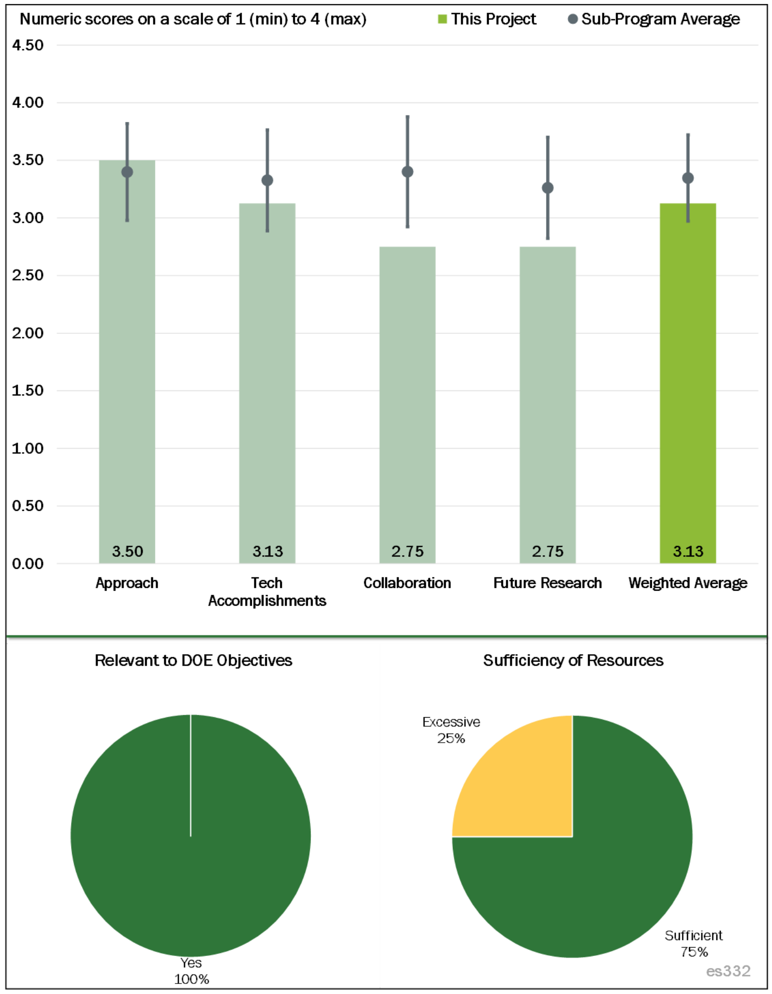

Figure 3-72 - Presentation Number: es332 Presentation Title: High Electrode Loading EV Cell Principal Investigator: William Woodford (24M Technologies)

Presenter

William Woodford, 24M Technologies

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer commented that 24M is working on the three most critical barriers for further commercialization of EVs (i.e., cost, performance, and safety).

Reviewer 2:

The reviewer remarked that this is a very novel and exciting approach for making LIB electrodes. Advantages identified by this reviewer include cost, abuse tolerance, and energy density.

Reviewer 3:

Referencing a number of background slides that described the project team's technology, this reviewer described the approach as interesting and unique.

Reviewer 4:

The reviewer recounted that the objective is to develop EV-rated Li-ion cells using proprietary semi-solid electrode technology; specifically, to increase the energy density of semi-solid electrodes through chemistry and cell design improvements (with reduced separators and current collectors), and to demonstrate scalability and abuse tolerance with semi-solid electrode architecture. This architecture will address two critical barriers for current Li-ion cells: inactive material fraction is too high; and the project team's percentage of cost is too high. The reviewer noted that these flowable high-energy density Li-ion electrodes allow for low-cost manufacturing and provide high area-specific capacity (mAh/cm^2), specific energy, and energy density. Enabling proper use of the active material in these dense electrodes, the porosity/tortuosity needs to be sufficiently high, as is being done here using magnetic methods. With fewer unit operations for the electrode fabrication and low capital equipment costs compared to the conventional Li-ion cells, the reviewer indicated that this modified design is expected ease scale up and be amenable for high volume manufacturing. It was unclear to the reviewer how this semi-solid electrode design will provide improved abuse tolerance. Overall, this reviewer opined that the approach addresses two main technical barriers of Li-ion cells; also, the project is well designed and integrated with other efforts.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer reported that the energy density goal has been met, on schedule, but also observed there is a long way to go to prove viability, including low-temperature performance because of thick electrodes.

Reviewer 2:

The reviewer explained that 24M's flowable Li-ion cathode and simpler device architecture enable improved energy density at lower cost. Additionally, the 24M cell design has unique abuse tolerance. The reviewer did highlight some delays in the anode active materials downselection.

Reviewer 3:

This reviewer commented that good progress has been made with the high-capacity cathode materials in this architecture. High areal capacities (10 mAh/cm^2) have been demonstrated in several Ni-rich cathodes in pouch cells. The reviewer reported that the versatility of the semi-solid electrode platform is being demonstrated with the NCM111/Graphite couple. Additionally, high power-to-energy performance has been claimed in semi-solid cells with high areal capacity electrodes. The reviewer also noted that both cell chemistry and architecture improvements are being improved to further increase energy density toward the EV 2020 targets. Assuming it would not be proprietary, and to appreciate the capabilities of this architecture, it would have been helpful to the reviewer if some rate data was presented on the cells containing these dense electrodes. The anticipated Phase-1 goals in the Gap Analyses have been met in most of categories, except low-temperature performance, as may be expected. The reviewer also suggested it would be useful to know which of the dense electrodes (i.e., NMC11 or graphite) is rate-limiting at low temperatures. Also, it appeared to this reviewer that the anode development appears to be lagging behind for want of personnel. The round-trip energy efficiency of 90% reported in the early work is lower than normal (95%), implying higher electrode polarization. Further, the reviewer found that no information is provided on the specific energy and energy density of cells, or on the cost benefits associated with this design. Generally, the reviewer observed little performance data to make a proper assessment of this architecture. Overall, this reviewer remarked that the technical accomplishments are notable; progress is good and consistent with DOE goals.

Reviewer 4:

This reviewer had many questions about the stability and performance of the project team's thick "clay-like" electrodes, and pointed out that there are only limited results presented, generally. The reviewer highlighted that the project team even redacted the discharge capacity of its cathodes, using standard electrode materials, which made the reviewer wonder what the project team is trying to hide.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer remarked that an Advanced Research Projects Agency—Energy program gives the project team a good set of collaborators.

Reviewer 2:

The reviewer commented that 24M did not list any collaborators from other universities and national laboratories. However, it is understood that the company has close links to the MIT battery group led by Professor Chiang. This reviewer also noted collaboration with ANL on cell testing.

Reviewer 3:

The reviewer observed no external partners mentioned, but acknowledged that there will be collaborations with the DOE laboratories to have the cells tested for an independent assessment

Reviewer 4:
No real collaboration was apparent to this reviewer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that 24M a detailed plan for future work, including phase 2 and 3 deliverables (i.e., downselect coating process, final lock electrolyte, and cost optimization).

Reviewer 2:
As relayed by this reviewer, proposed future studies include the following: continue Phase 1 development and deliver Phase 1 deliverable cells for testing at ANL by June 15, 2017 (30x cell); and execute on high-energy density initiatives to achieve Phase 2 and Phase 3 targets. However, the reviewer advised that it would be helpful if there are numbers associated with the demonstration of enhanced performance or reduced cost, which are the technical barriers for the DOE VTO program.

Reviewer 3:
This reviewer observed little detail in the project team's future work.

Reviewer 4:
Although the challenges are clear, the reviewer was unsure how the project team plans to meet them.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer noted extremely high relevance, if successful.

Reviewer 2:
The reviewer described this project as very well designed and conducted to support DOE objectives of reaching the EV 2020 targets.

Reviewer 3:
This reviewer asserted that the project team's work is relevant.

Reviewer 4:
The reviewer explained that low specific energies and high costs of LIBs are serious impediments to their widespread adoption in vehicles. Additionally, fabrication of conventional Li-ion cells involves complex, wet/dry/wet operations with an expensive infrastructure and a high proposition of inactive materials resulting in lower specific energy/energy density and higher costs. This reviewer further commented that new methods of electrode fabrication are desired that would lead to improved energy densities, reduced cost, and increased ease of scale up, which are being addressed by the project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer pointed out that 24M has demonstrated records in achieving its goals in novel battery development.

Reviewer 2:
The project team’s resources seemed to be sufficient from this reviewer’s perspective.

Reviewer 3:
This reviewer described project resources as okay.

Reviewer 4:
The reviewer remarked that project resources seemed to be excessive because little information is being disseminated for DOE’s benefit, and the project is essentially a continuation of the project team’s previous DOE project.

Presentation Number: es333
Presentation Title: Silicon Electrolyte Interface Stabilization Focus Group
Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

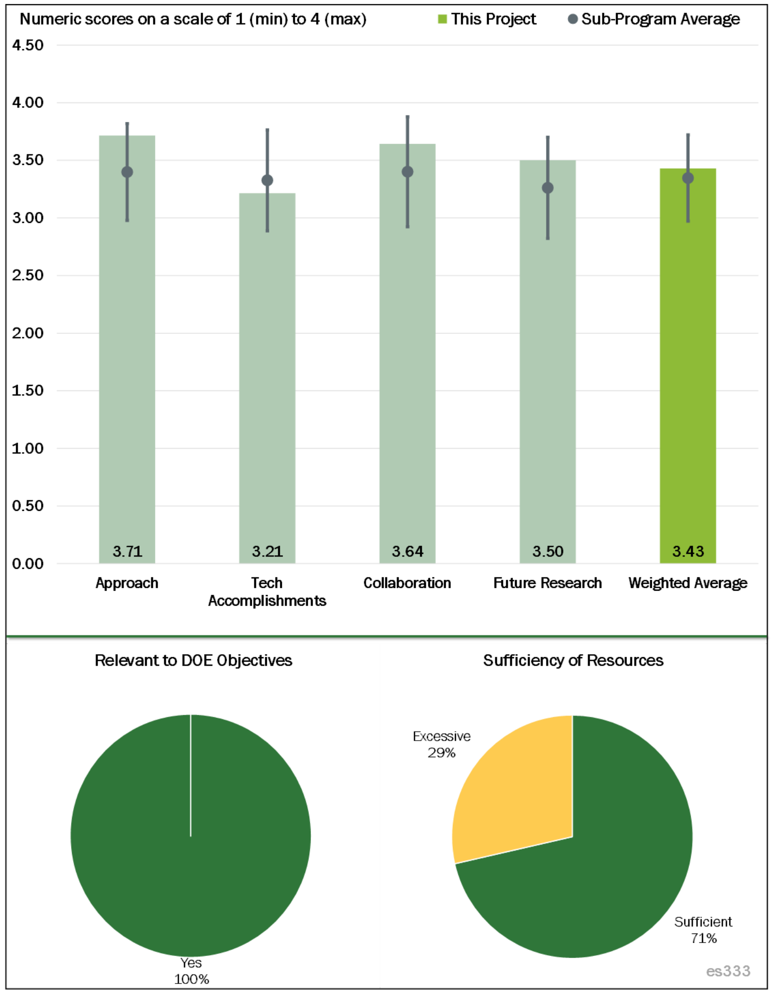

Figure 3-73 - Presentation Number: es333 Presentation Title: Silicon Electrolyte Interface Stabilization Focus Group Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

Presenter

Anthony Burrell, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer observed an outstanding approach that addresses calendar life and cycle life issues.

Reviewer 2:

The reviewer recounted that the team is proposing to understand the fundamental issues for Si anode first before proposing new solutions to address them. It was noted by this reviewer that standard protocols for materials synthesis and characterizations are established in the first year and validated through round robin sample analysis. The reviewer opined that this effort is urgently needed in battery research and appreciated.

Reviewer 3:

This is a critical—but unrecognized—issue, asserted this reviewer. Additionally, the reviewer commented that irreproducibility in the Si electrode field is significant, and Burrell is attacking that through a very careful source identification.

Reviewer 4:

The reviewer explained that the approach to understand now and develop a fix based on that understanding is prudent and suitable for DOE work. Understanding the chemical makeup and properties is important; also important is recognizing that it may be different on Si and Si composite and SiO_x.

Reviewer 5:

The reviewer indicated that this well-designed project is appropriate for bridging the gap between fundamental characterization of surfaces and performances of particulate-containing electrodes. By using flat surfaces treated with different materials, advanced characterization methods can best resolve interfacial structures, and performance in cycling provides a link to the application.

Reviewer 6:

This reviewer described the approach as fundamentally sound. It would have been useful for this reviewer to have an organizational chart-type of slide that summarized activities occurring at each laboratory/University. The reviewer continued that such a slide would better showcase that there is, presumably, minimal duplication of effort simply from having a larger team with more researchers involved. The most promising technical approach observed was incorporation of plasma spray generated Si nanoparticles, but this reviewer strongly advised including industry partners capable of producing this material, rather than it being made at NREL alone. Similarly, because buying powders "off the shelf" may not lead to repeatable results (or even starting materials) in the future, the reviewer recommended attempting to incorporate industrial manufacturers and having the team oversee real production processes to support the synthesis of quality, reproducible materials with known properties.

Reviewer 7:

This reviewer commented that there seems to be considerable overlap both in terms of project scope and participants between this project and several other projects, noticeably ES261, ES262, and ES335. The reviewer also noted the following observations: the connection is tenuous between planned measurements on Si single crystals and nanoparticle Si-electrodes because SEIs are expected to be different; the mechanical properties of SEIs, which are known to be important, are overlooked; the advantages of the "Standard Cell Design" over the other three electrode cell designs are unproven; and the ability to make Si nano particles of more than a few nm in diameter by the RF-Enhanced Plasma Reactor method (L.M. Wheeler et al. Chem. Mater. 2015, 27, 6869) is also unproven.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer observed significant progress in this project with a coordinated effort among national labs. Identifying appropriate team members helps lead to success in this project. The reviewer agreed that "understand first, fix it later" is the right way to proceed with improving performance in these electrodes.

Reviewer 2:

Although the project just began, the reviewer noted that progress is being made.

Reviewer 3:

This reviewer remarked that it is still very early in this project.

Reviewer 4:

The reviewer indicated that most of the results are preliminary and inconclusive, probably because the project is relatively new.

Reviewer 5:

This reviewer provided the following observations of the project team: developed and validated protocols; testing lab to lab error; generated Si nanocrystals from silane (i.e., high purity) and showed they were quite reactive with standard electrolyte and even reactive with coated Si; and starting to understand the composition. While good work, the reviewer indicated that for nearly four million dollars and five labs, it seems a bit slow; it will probably speed up in the coming year now that the project team is rolling.

Reviewer 6:

The reviewer noted that the team developed standard testing protocols for effective evaluation of new materials and methods. Good progress has been demonstrated with focused areas defined. The reviewer's only concern is that there are already many published results on Si and its interfaces. The project needs to avoid a rehash of what has been known on the fundamental understandings. This reviewer recommended that more effective solutions be proposed to address the challenges.

The reviewer added that model Si anode is very important, and observed the team has selected at least three different materials for round robin tests. This is very critical to ensure that results are consistent among different teams. The reviewer expressed interest in the differences between materials tested in the project and currently adopted by industry. Although the model materials are for fundamental understanding only, the reviewer inquired whether the knowledge will be directly transferrable to the practical applications. Further, this reviewer cautioned that the strategy to scale up plasma synthesis of Si nanocrystals using SiH_4 needs to be carefully considered.

The reviewer explained that SEI on Si largely depends on the electrolyte and additives used in addition to Si surface, and suggested more electrolyte work to speed up the progress. This reviewer also advised that effective electrolyte recipes be developed and understood before throwing all kinds of characterization onto the system.

Reviewer 7:

The reviewer highlighted that the statement of work and associated deliverable cells to validate 10+ year life and 1,000 DST cycle life are not documented in the plan.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

This reviewer observed clear evidence of collaboration and coordination, especially between ORNL and NREL.

Reviewer 2:

The reviewer noted that the team has frequent communications and shares information to accelerate the research. Materials tested are from the same source and use the same protocol, ensuring effective data analysis.

Reviewer 3:

This reviewer described this effort as inherently collaborative.

Reviewer 4:

The reviewer reported that samples will be circulated among different labs to determine where irreproducibility exists.

Reviewer 5:

This reviewer commented that this is a well-coordinated, but expensive project.

Reviewer 6:

The reviewer stated that all national laboratory collaboration is necessary and will help solve the problem. If the electrolyte additives provide the solution, the reviewer recommended that a Li-ion electrolyte supplier be added for collaboration.

Reviewer 7:

The role of each national laboratory and university was unclear to this reviewer, who observed a lot of repetitive work, such as measuring the same samples using "standardized protocols" and "reproducibility across the team (multiple labs)."

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that Burrell has made extensive and careful plans for developing clear protocols to get highly reproducible Si results

Reviewer 2:
This reviewer noted that future work in SEI growth characterization toward establishing general rules for the effects of surface structure and composition on properties is a promising way forward.

Reviewer 3:
The reviewer described the proposed future research as sound.

Reviewer 4:
This reviewer highlighted an excellent work plan, but commented that the timing is a little vague.

Reviewer 5:
The reviewer reported that mechanical property measurements of the SEIs may be added to the future plan.

Reviewer 6:
This reviewer regarded the future work as general. The reviewer expressed that the team can specify more details on the following: the kind of new interfaces that the team is going to identify; the kind of *in situ* and *ex situ* characterizations tools that will be developed; whether these characterizations clearly quantify SEI compositions; and whether any promising additives will be employed. The reviewer indicated that characterization is mainly based on thin film electrode, and suggested future evaluation of SEI and Si properties on the thick electrodes.

Reviewer 7:
The reviewer opined that future work should include validation of calendar life and cycle life.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
Aside from general safety improvements, the reviewer noted that this project may yield the largest breakthrough toward EV adoption by completely removing range anxiety.

Reviewer 2:
This reviewer asserted that the project supports the overall DOE objectives with a focus on Si anode for high-energy and low-cost batteries. Advanced characterizations are being developed and conducted on model Si systems, which may be broadly applicable for energy storage research.

Reviewer 3:
The reviewer explained that, clearly, Si negative electrodes are an important technology area for making BEVs a cost-effective norm in America and, subsequently, displacing petroleum-based fuels.

Reviewer 4:
This reviewer commented that improving LIB performance will enable increased utilization of fluctuating renewables and decrease reliance on petroleum.

Reviewer 5:
The reviewer relayed that the advanced anode will help meet USABC criteria and replace ICE vehicles with Li-ion EVs.

Reviewer 6:
This reviewer described this project's relevance as okay.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This reviewer remarked that the national laboratories have more than sufficient, advanced tools to conduct the work. The PI has made a good plan on the task assignment and a single team works on a single goal to avoid overlap.

Reviewer 2:
Resources appeared sufficient to this reviewer. For example, the PIs were able to supply all labs with the same materials, which is an important factor in conducting consistent experiments.

Reviewer 3:
The reviewer described the project resources as okay.

Reviewer 4:
This reviewer commented that $3.9 million and about 40 researchers should be enough to troubleshoot and fix problems.

Reviewer 5:
Resources should be more than adequate, opined this reviewer, provided that industrial participation is planned.

Reviewer 6:
This reviewer observed a highly funded program and good work, but expected more at this resource level. The reviewer expressed hope of seeing more progress next year, budget allowing.

Reviewer 7:
The reviewer cautioned that there seems to be considerable overlap between this and several other DOE VTO projects.

Presentation Number: es334
Presentation Title: Insights from Mesoscale Characterization Guides Rational LIB Design
Principal Investigator: William Chueh (Stanford University)

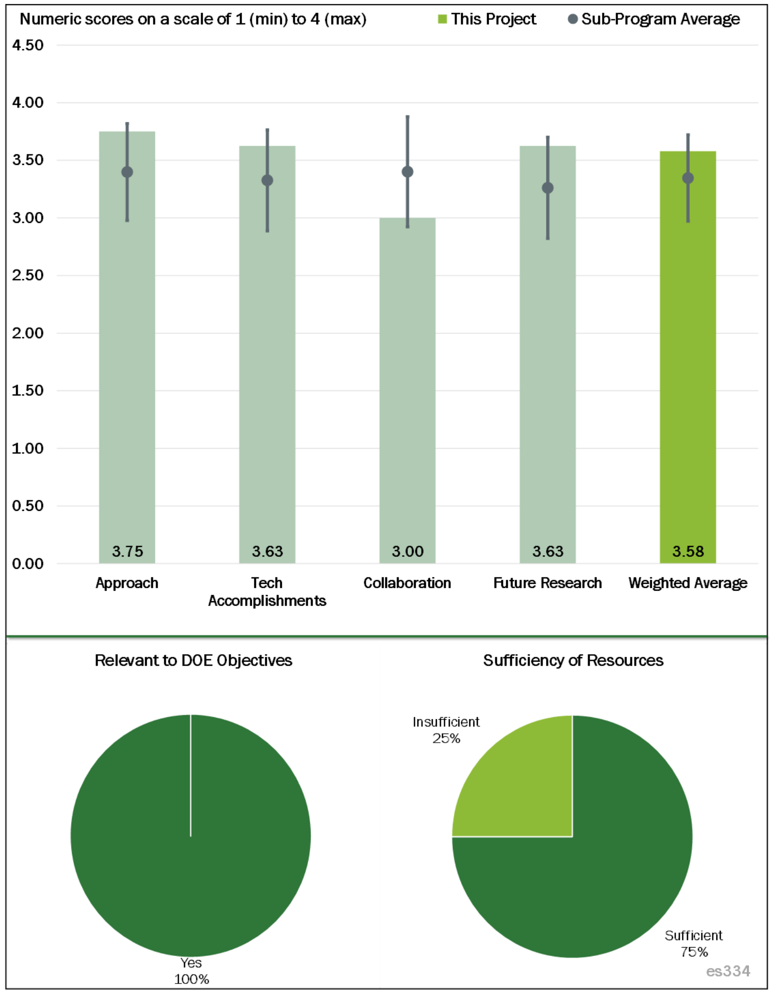

Figure 3-74 - Presentation Number: es334 Presentation Title: Insights from Mesoscale Characterization Guides Rational LIB Design Principal Investigator: William Chueh (Stanford University)

Presenter
William Chueh, Stanford University

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
What a wonderful project. This reviewer thought the approach was fantastic, the results very new and compelling, and the PI gave a wonderful talk. This person had nothing to say except the best things about this project and thinks it will open the doors to rethinking how we model batteries.

The PI's presentation was excellent and this reviewer enjoyed following it. The PI's approach is very

Reviewer 2:
The reviewer applauded the approach as outstanding.

Reviewer 3:
According to the reviewer, the PIs try to correlate the microstructure and local crystal structure and chemistry to the electrochemical performance of battery material taking the advantages of X-ray spectro-microscopy. The reviewer stated that the approach is very fundamental for the understanding of the root cause of many problems associated with battery active materials.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commended the excellent accomplishments across the board.

Reviewer 2:
The PIs provided concrete experimental evidence showing the anisotropic chemical expansion for all layered materials, including oxide and graphite, the source of non-uniform strain for the secondary particles. In this reviewer's opinion, the results could be beneficial for the material synthesis, especially co-precipitation synthesis.

Reviewer 3:
The quality and quantity of the PI's work is very high and the PI presented a number of conclusions. The reviewer would have liked to see the PI better describe which conclusions were new and which confirmed previous work in the literature by other researchers.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the PI has several collaborations with LBNL and Samsung.

Reviewer 2:
This reviewer would highly encourage the PI to expand collaboration to other groups that have been working on this class of cathode materials for many years. There is a large group in the DOE ABR program actually called High-Energy, High-Voltage (HEHV) cathode material R&D. The reviewer thought it would be valuable for the PI to collaborate with them.

Reviewer 3:
The PIs have adequate collaboration with LBNL and Samsung. The reviewer encouraged the PIs to collaborate more with the institutions strong in electrochemical analysis and material synthesis.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The proposed future work will expand the current accomplishments. The reviewer understands that the PI will investigate the stress profile and preferred orientation of material primary and secondary particles, especially to relate the fundamental studies to the real performance of the materials.

Reviewer 2:
The reviewer stated that there is little detail, but the project generally extends present studies.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
As with other projects attacking the issues with HEHV cathode degradation mechanisms, the relevance of this work is very high in this reviewer's opinion.

Reviewer 2:
The reviewer commented that the capacity or voltage fade is critical to the development of long cycle life LIB systems.

Reviewer 3:
The reviewer stated that the work is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources are sufficient in this reviewer’s opinion.

Reviewer 2:

The reviewer commented that it is very reasonable funding for the work performed.

Reviewer 3:

The reviewer noted that the PIs have adequate resources for the proposed project.

Presentation Number: es335
Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Materials Advancements
Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

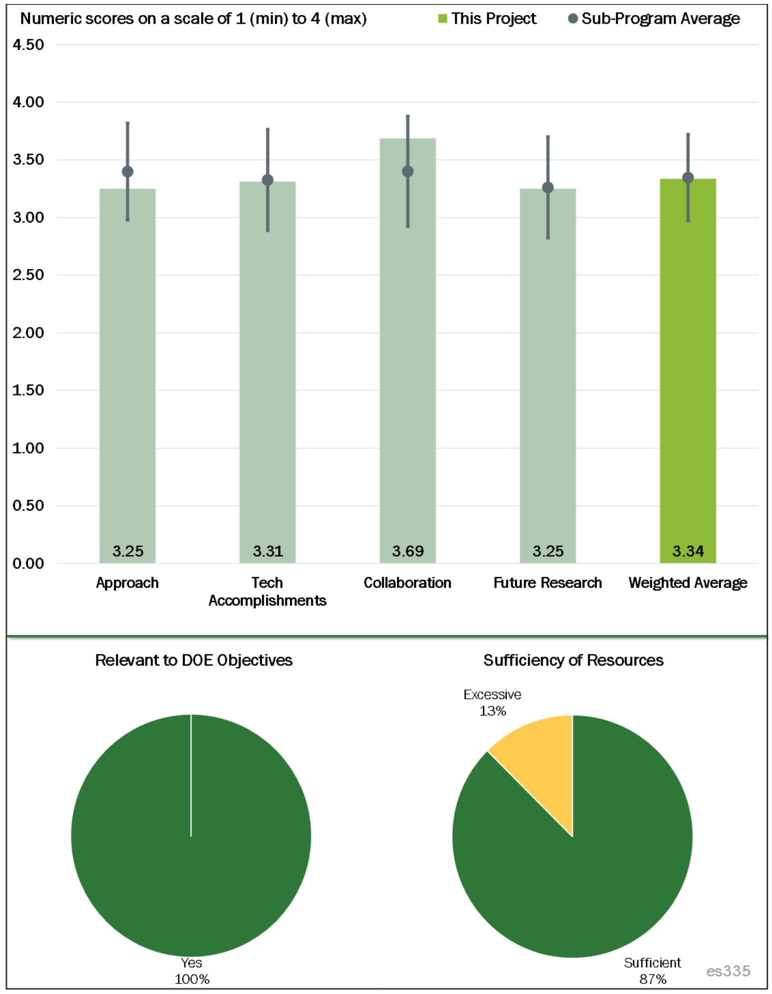

Figure 3-75 - Presentation Number: es335 Presentation Title: Next-Generation Anodes for Lithium-Ion Batteries: Materials Advancements Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

Presenter

Zhengcheng Zhang, Argonne National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer applauded the excellent, thorough approach to understand and develop new anode material.

Reviewer 2:

The program does an excellent job at looking at a frontier material, SI-tin (Si-Sn), for anodes. It then addresses a critical issue, the binder, in a way this reviewer finds interesting.

Reviewer 3:

The X-ray diffraction pattern of "amorphousSi0.64Sn0.36" shows multiple relatively sharp peaks. The material appears to be crystalline, not amorphous. The PI overlooked the mechanical properties and adhesion between polymer binder molecules and Si, in this reviewer's opinion.

Reviewer 4:

This project addresses the technical barriers in a Si anode by systematically studying the functional binders, atomic layer coatings (at electrode level), electrolyte/additive screening Li inventory. The reviewer commented that the project is well-designed and integrated with other team efforts. While Si itself is very challenging, it is not clear if a Si-Sn alloy will mitigate the problem because SEI on either Si or alloy are instable, but is the key parameter that dictates the electrochemical behaviors. The reviewer states the team may consider the adoption of SiO_x (with graphite) in addition to Si, which is currently what industry is using. Although the PI conducts and compares three different thickness of MLD coating, all of the Si loadings in the electrodes coated reside in "thin-film" i.e., less than 1 mg/cm^2 loading. Therefore, it was hard for this reviewer to tell if MLD coating is still effective at the electrode level.

Reviewer 5:

The Sn-coated Si particles provide an improvement in performance compared to uncoated Si. The approach to studying grafting poly acrylic acid (PAA) onto chitosan compared to linear analogs provides comparable studies of similar materials with potentially different mechanical properties, but it is unclear to this reviewer why the PI chose certain functionalities. It is also unclear to this reviewer if there is a rational design behind the targets in the polysiloxane project and what the PIs intend to learn from the structural variations.

Reviewer 6:

There seem to be too many approaches to this project to yield important results in the time allotted. Also, this reviewer thought it was unclear how many people are involved in this effort.

As this reviewer understands it, the approach will involve all of the following: alternative high-energy metals: $Me_xSi_{0.66}Sn_{0.34}$ (Me: Cu, Ni, iron [Fe], Mn); interfacial modifications by ALD or MLD and *in situ* formation of robust SEI by functional electrolyte/additive; functional polymer binders for improved adhesion and performance; Li inventory to offset the large irreversible capacity of Si anode; and alternative high-energy metals: $Me_xSi_{0.66}Sn_{0.34}$ (Me: Cu, Ni, Fe, Mn). A more clear-cut approach statement would be very helpful to the reviewer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This reviewer described the results on iron oxide (lithium iron oxide [LFO]) as particularly promising. The reviewer asked if the PI is sampling this material to industrial partners, and if the PI has investigated alternative, industrialized methods of pre-lithiation. It would be interesting to this reviewer to more fundamentally understand the reason for improved stability with alucone coating. The reviewer wonders if there is a difference in CE versus the uncoated sample (the graph is too zoomed out or maybe the equipment is not sensitive enough). The reviewer asked if it is stabilizing the particle structure.

Reviewer 2:

The reviewer commented that this is an extremely large project and certain areas are advancing more quickly than others. The presentation materials do not provide sufficient details on the “25 milestones” for this reviewer to have a more complete understanding of the accomplishments and progress.

Reviewer 3:

This reviewer indicated that there have been considerable accomplishments on the Sn system and on new binders. It is not clear to this reviewer that the coatings work is breaking any new ground, either in performance or in diagnostics/understanding. This reviewer is impressed that the project team is including studies of electrolyte additives and LFO.

Reviewer 4:

The reviewer noted that the performance of Si/Sn electrodes has been reported, but no results are reported for the siloxane polymers, on which numerous targets were reported. The reviewer asked if there is a beneficial effect in introducing polysiloxanes as binders.

Reviewer 5:

It was obvious to this reviewer that the team has applied much attention and effort to this project, with research directions spanning over most aspects of Si anode materials. However, the experiments seem to be still in early stage because the reviewer heard no clear conclusions presented, and saw no selection of a clear path toward a practical Si anode.

Reviewer 6:

While there were clearly a number of interesting experiments carried out, it was not clear to this reviewer that the team has drawn any conclusions regarding these experiments. There was no assessment of which of the many binders discussed were better than the others, nor was there a conclusion regarding the different metals and alloys. One particular MLD surface treatment was applied, but no statement of comparison with other materials was made. It was also not clear to this reviewer how the Li inventory results would be applied to a functioning anode.

Reviewer 7:

The team investigated quite a few different components in Si electrode, which this reviewer recognized as a large amount of effort. Dr. Zhang is a well-known expert on electrolytes and interfaces and he leads the team progress well towards the right direction. A few comments here from this reviewer for the team to consider.

The multi-grafting chitosan-g-LiPAA showed some improvement compared to PVDF and its linear analogues. However, the differences between PAA1-4 and this multi-grafting chitosan is not obvious to this reviewer. It is not clear to the reviewer if the PI has a baseline electrode to compare the electrochemical performances. Sometimes, LiPAA is compared with PPy, while sometimes it is compared between multi-grafted and linear version. The reviewer asked if there is any conclusion on which binder the team will focus on in the future.

The reviewer recommends that the team consider Li inventory in Si anode and the team proposed using anti-fluroite type Li_5FeO_4 as the Li-inventory additive. The reviewer is uncertain whether the extra Li+ source from LFO will be stored in the anode side or trapped during the oxidation reaction on the cathode and stated that the team needs to conduct more work in order to make a go/no-go decision here.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer understands it takes a huge effort to make teams run well and collaborate effectively. The PI has done a great job in terms of collaboration within ANL and with other institutions. In the reviewer's opinion, the PI's strong electrolyte expertise and work will provide valuable information to the team and move the program move forward.

Reviewer 2:

It appeared to this reviewer that the institutions work well together.

Reviewer 3:

Many workers and laboratories were indicated, but the effort of all these collaborators was not clear to this reviewer.

Reviewer 4:

There was an enormous list of contributors and very nice intra-laboratory coordination, but the reviewer saw no indication what their level of contribution was.

Reviewer 5:

The reviewer thought the project could be further enhanced by collaborating with experts outside the national laboratories, especially in the area of mechanical measurements, including coupled electrochemical-mechanical properties and interface adhesion.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

Proposed research on scale-up of some materials and testing others in full cells are reasonable next steps. This reviewer was not sure what convergent/divergent means (the reviewer saw this on the slides after visiting the poster) and how it is beneficial to project design.

Reviewer 2:

Future research directions are mainly aimed at continuing what the project team is doing. The reviewer would have preferred to see some new ideas here. The scaling up production is good.

Reviewer 3:

This statement of future research has the same problem as the accomplishments in this reviewer's opinion, in that there does not seem to be an evaluation of results that will lead to future experiments to validate or extend the promising results while discarding the unpromising ones.

Reviewer 4:

This reviewer noticed that one of the "Remaining Challenges and Barriers" of "Particle cracking, particle isolation, and electrode delamination" is not addressed under "Future Work."

Reviewer 5:

Future plans mention a divergent/convergent approach of multiple exploratory paths. However, it is not clear to this reviewer if the plans include a more iterative approach toward screening and improving materials, which should allow an earlier focus on fewer candidates.

Reviewer 6:

The PI will consider full cell format testing in the future, which will be very critical for Si evaluation. ANL has strong capabilities on characterization which will help identify the structure-property relationship for Si-based electrodes. It is not clear to this reviewer if SiO_x will be included in the future work. The reviewer would like the PI to justify why Si-Sn alloy is being studied at the same time, considering either Si or Sn is challenging when there is still no clue about the electrolytes/additives. Before scaling up any new materials such as MLD coating or binder synthesis, the reviewer recommended confirming the effectiveness of these new materials in full cells. The PI may need to consider the cost of MLD coating as well.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

This project is highly relevant to DOE objectives to develop high-energy battery technologies for vehicle electrification. Electrolytes, additives, binders and Li inventory are all critical for the success of high-performance Si anode in this reviewer's opinion.

Reviewer 2:

The reviewer noted that high-energy anodes are clearly relevant.

Reviewer 3:

This reviewer is especially interested in the work on additives and LFO.

Reviewer 4:

The reviewer said yes and commented that improving the LIB performance will allow for a greater incorporation of renewable energy sources.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources for the project appear to be sufficient.

Reviewer 2:

The reviewer found the resources okay.

Reviewer 3:
The reviewer suggested adding mechanical property measurements.

Reviewer 4:
In this reviewer's opinion, ANL, along with other national laboratories, has more than sufficient facilities and resources to conduct the proposed research and meet the milestones.

Presentation Number: es336
Presentation Title: Extreme Fast Charging (XFC) Gap Assessment
Principal Investigator: Christopher Michelbacher (Idaho National Laboratory)

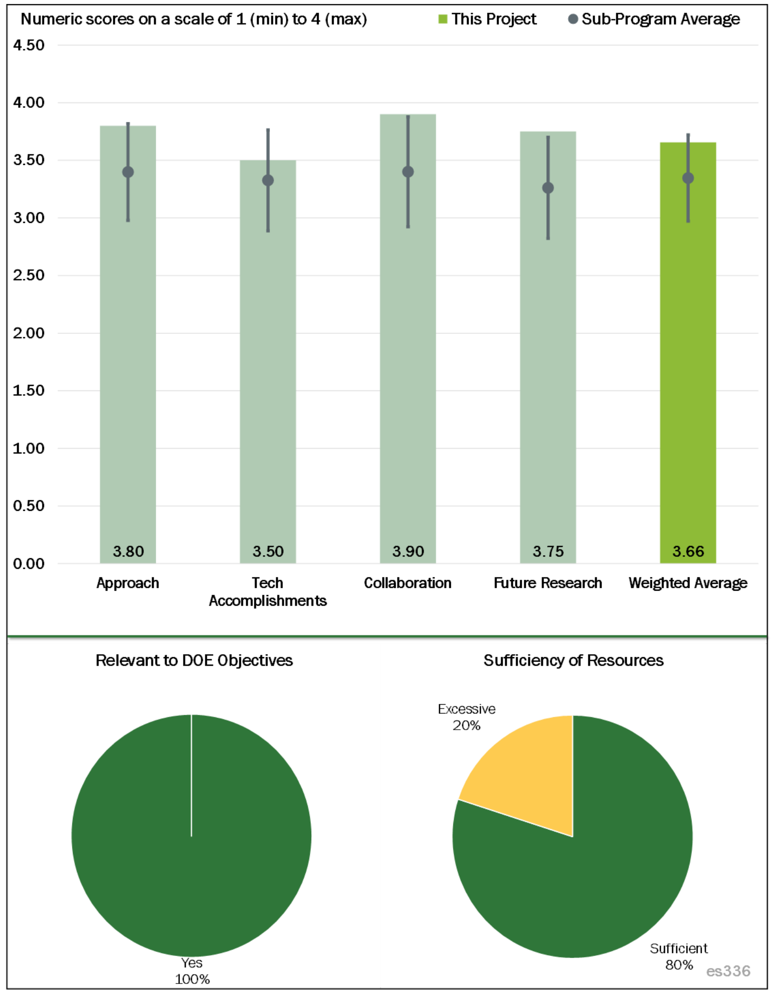

Figure 3-76 – Presentation Number: es336 Presentation Title: Extreme Fast Charging (XFC) Gap Assessment Principal Investigator: Christopher Michelbacher (Idaho National Laboratory)

Presenter

Christopher Michelbacher, Idaho National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This is a very good approach to getting into a new subject. This is an excellent precursor to any new area of research, in this reviewer’s opinion.

Reviewer 2:

The reviewer noted that the project reached out to the key stakeholders to help outline the issues and needs, involved technology experts, and reviewed the impact from a cost perspective.

Reviewer 3:

The reviewer commented that stakeholder meetings, collaboration among the national laboratories, literature search, and a case study are very effective and comprehensive approaches to understand the technical gaps for enabling fast charging.

Reviewer 4:

This reviewer thought that most technical barriers have been identified. There might not be clear solutions for all of them, but in this reviewer’s understanding, identifying the barriers was the primary goal of the program, which the reviewer believes was accomplished.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said excellent, and that the results basically confirm most peoples’ intuition about the issues with XFC but the reviewer found it reassuring to see that done with actual data.

Reviewer 2:
The team demonstrated excellent accomplishments in the four key areas of concern. On the technical side these areas were the battery, the vehicle, and the infrastructure. Additionally, the team also considered economic feasibility and compared the effect of charge rate against several key cell metrics and tabulated. All of these data meet the goals of the project in the reviewer's opinion.

Reviewer 3:
The reviewer stated that this investigation provides clear, concise answers to a range of problems facing fast-charging, including battery technology, vehicle design, economics and infrastructure.

Reviewer 4:
This is a very thorough project, looking at all aspects of XFC. The reviewer noted that the data were studied from multiple angles and at each level affected by XFC, from cells and batteries to charging infrastructure and economics.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer found very good involvement of all involved parties, including national laboratories, battery manufacturers, charger manufactures, and automotive OEMs.

Reviewer 2:
The reviewer noted that automotive OEMs, battery suppliers, utility suppliers, electric vehicle supply equipment (EVSE) manufacturers, and all key players, were involved and contributed.

Reviewer 3:
The reviewer commented that this work involves the close collaboration of three national laboratories, and solicited inputs from wide variety of related industries.

Reviewer 4:
The reviewer stated that the team included many potential stakeholders in discussions.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer liked that there is no future work because the project is complete. The reviewer hoped we can encourage the majority of PIs to "finish" projects when they reach their objectives, and then propose to move on to new or modified subjects.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said yes, and commented that this work provides guidance to the VTO to prioritize its R&D activities.

Reviewer 2:
This project is to help develop technology that will relieve consumer "range anxiety" and allow for easier adoption of the technology in this reviewer's opinion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Everything about this project was excellent. This reviewer's impression is that the cost was on the high side, but still an excellent project and end product.

Reviewer 2:
The reviewer noted that the program has ended and the data provided were complete.

Reviewer 3:
The resources are sufficient for this amount of work in this reviewer's opinion. The money is distributed to three national laboratories based on effort.

Acronyms and Abbreviations

°C	Degrees Celsius
3D	Three-dimensional
A	Ampere
ABR	Advanced Battery Research
AFM	Atomic force microscopy
Ah	Ampere-hour
Al	Aluminum
Al_2O_3	Aluminum oxide
ALD	Atomic layer deposition
AlF_3	Aluminum fluoride
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARL	Army Research Laboratory
ATR	Attenuated total reflectance
BEV	Battery electric vehicle
BMR	Battery Materials Research
BNL	Brookhaven National Laboratory
C	Carbon
CABS	Consortium for Advanced Batteries Simulation
CAE	Computer-aided engineering
CAEBAT	Computer-aided engineering of batteries
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CB	Carbon black
CCD	Critical current density
CE	Coulombic efficiency
CEI	cathode electrolyte interfacial
cm	Centimeter

CMC	Carboxymethyl cellulose
Co	Cobalt
CO_2	Carbon dioxide
Co-Ex	Co-extrusion
CPE	Composite polymer electrolytes
Cu	Copper
CuF_2	Copper (II) Fluoride
DEC	Diethyl carbonate
DEMS	Differential electrochemical mass spectroscopy
DFT	Density functional theory
DNS	Direct numerical simulation
DOE	Design of experiments
DOE	U.S. Department of Energy
DST	Dynamic stress test
EB	Electron beam
EDS	Energy dispersive spectroscopy
EERE	Energy Efficiency and Renewable Energy
EM	Electron microscopy
EOL	End-of-life
EV	Electric vehicle
Fe	Iron
FEA	Finite element analysis
FEC	Fluoroethylene carbonate
FTIR	Fourier transform infrared
FY	Fiscal year
GM	General Motors
HA	High active
HEV	Hybrid electric vehicle

HPC	High-performance computing
HRTEM	High-resolution transmission electron microscopy
HXN	Hard X-ray nano-probe
ICE	Internal combustion engine
IL	Ionic liquid
INL	Idaho National Laboratory
IP	Intellectual property
kg	Kilogram
kWh	Kilowatt-hour
l	Liter
LBNL	Lawrence Berkeley National Laboratory
LCO	Lithium cobalt oxide
LFO	Lithium iron oxide
LFP	Lithium iron phosphate
Li	Lithium
Li_3PO_4	Lithium phosphate
LIB	Lithium-ion battery
$LiCoO_2$	Lithium cobalt oxide
LiFSI	Lithium bis(flurosulfonyl)mide
Li-ion	Lithium Ion
$LiPF_6$	Effective electrolyte salt for lithium-ion battery
LiPON	$Li_{2.88}PO_{3.86}N_{0.}14$
Li-S	Lithium-sulfur
LL	Layered-layered
LLS	Layered-layered spinel
LLZO	Lithium lanthanum zironate
LMNO	Lithium manganese nickel oxide
LMO	Lithium manganese oxide

LMR	Lithium manganese rich
LNMO	Lithium nickel manganese oxide
LTO	Lithium titanium oxide
M&S	Modeling and simulation
mA	Milliampere
MD	Molecular dynamics
MERF	Materials Engineering Research Facility
MLD	Molecular layer deposition
Mn	Manganese
MRI	Magnetic resonance imaging
NCA	Battery cathode material (nickel cobalt aluminum oxide)
NCM	Nickel cobalt manganese oxide
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel
NMC	Nickel manganese cobalt oxide
NMO	Nickel manganese oxide
NMP	N-methylpyrrolidone
NMR	Nuclear magnetic resonance
NREL	National Renewable Energy Laboratory
NSLSII	National Synchrotron Light Source II
NYBEST	New York Battery and Energy Storage Technology Consortium
O_2	Oxygen
OAS	Open architecture software
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OS	Organosilicon
PAA	Polyacrylic acid
PDF	Paired distribution function

PHEV	Plug-In hybrid electric vehicle
PI	Principal investigator
PNNL	Pacific Northwest National Laboratory
PPy	Polypyrrole
PSD	Particle size diameter
PVDF	Polyvinylidene difluoride
R&D	Research and development
RPT	Reference performance test
S	Sulfur
SBIR	Small Business Inngovation Research
SEI	Solid electrolyte interface
Si	Silicon
Si-C	Silicon Carbon
SiO_x	Silicon oxide
SLAC	Stanford Linear Accelerator Center
SME	Subject matter expert
Sn	Tin
SNL	Sandia National Laboratories
SOA	Semiconductor optical amplifier
SOC	State of charge
SRL	Surface reconstruction layer
$SrTiO_3$	Strontium titanate
SSRL	Stanford Synchrotron Radiation Lightsource
STEM	Scanning transmission electron microscopy—electron energy loss spectroscopy
SUNY	State University of New York
SWCNT	Single wall carbon nanotube
TEA	Technology-Economic Analysis
TEM	Transmission electron microscopy

TEY	Total electron yield
TM	Transition metal
TRL	Technology Readiness Level
TXM	Transmission X-ray microscopy
U.S.	United States
UIC	University of Illinois at Chicago
USABC	United States Advanced Battery Consortium
UV	Ultraviolet
V	Volt
VC	Vinylene carbonate
VOPO4	Vanadium phosphate
VTO	Vehicle Technologies Office
W	Watt
WFO	Work-for-others
Wh	Watt hour
Wh/l	Watt hour per liter
XANES	X-ray absorption near edge structure
XAS	X-ray absorption spectroscopy
XFC	Extreme fast charging
XPD	X-ray powder diffraction
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
μ	Micron

4. Energy-Efficient Mobility Systems

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

VTO launched Energy Efficient Mobility Systems (EEMS) to leverage emerging disruptive technologies such as connected and autonomous vehicles, information-based mobility-as-a-service platforms, and advanced powertrain technologies to identify and exploit energy efficiency opportunities at the transportation system level. The knowledge generated by this effort will strengthen understanding of how evolving technology impacts energy efficiency, and ultimately what new technology is needed to improve the energy efficiency of transportation as a system (i.e. mobility). A VTO-funded paper shows that connectivity and automation disruptions could result either in a potential 200% increase in baseline energy consumption, or in a 60% decrease in energy use.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: eems000 Presentation Title: Energy-Efficient Mobility Systems Overview Principal Investigator: David Anderson (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer stated that the area was very well covered, including justification for the program by looking at the best and worst case scenarios for energy use by 2050.

Reviewer 2:
The reviewer commented that, yes, there was very good coverage and a high-level overview of Energy-Efficient Mobility Systems (EEMS). The reviewer further appreciated a great job of communicating about how to get further information regarding each specific pillar of EEMS through the week.

Reviewer 3:
The reviewer said that, given the recent initiation of this program, things still appear a bit fuzzy. This may be appropriate at this phase, given the status of planning and other related efforts, but it did make it a bit tough to nail down the full scope of the EEMS activity.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer commented that based off the early stages of this program, the balance was appropriate.

Reviewer 2:
The reviewer remarked that the primary focus is really near-term (with perhaps a little mid-term) for now, looking out only as far as fiscal year (FY) 2020. This appears appropriate given the EEMS charter.

Reviewer 3:
The reviewer stated that there was a clear emphasis on the long term, and to some extent, mid-term R&D. Perhaps due to the early stages of this research and/or the speed at which innovation is occurring, there seemed to be less stated around near-term R&D goals. While there is clearly a lot of near-term activity, the influence of that research tends to all be decades away. Perhaps there is some near-term R&D that also results in near-term wins or stepping stones.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer stated that EEMS is a great addition to the VTO. The presentation was clear in both aspects.

Reviewer 2:
The reviewer remarked that, yes, challenges were identified under the umbrella of maximum mobility and minimum energy. The confluence of all these technological and market forces at the same time leaves significant opportunities and challenges to shape the future very negatively or very positively.

Reviewer 3:
The reviewer noted that overall issues and challenges were identified. Mobility changes are clearly impacting energy consumption, and so this ties in strongly with vehicle technologies.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer commented that the organizational structure and division of topics do seem to address these issues and challenges for now. It will be very important for the team to be able to change as quickly as the landscape is changing by bringing in new partners as needed and de-emphasizing others as their role and expertise becomes less important.

Reviewer 2:

The reviewer stated that efforts to date included a joint National Renewable Energy Laboratory (NREL)/Argonne National Laboratory (ANL)/Oak Ridge National Laboratory (ORNL) study to look at the possible future energy picture, which helps to lay out a path for addressing issues and challenges.

Reviewer 3:

The reviewer noted that at this stage of the program, all issues were addressed appropriately.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

The reviewer noted that this is a new program, which started in January 2017.

Reviewer 2:

The reviewer commented that this was not applicable as it is a new program.

Reviewer 3:

The reviewer did not see a measurement against last year other than, for example, a list of accomplishments over the past year. While this is a big part of answering the question, the reviewer stated that it would be nice to have seen some comparison to last year (e.g., 2015-2016 publications cited X times, 2016-2017 publications cited Y times, or some more meaningful way of measuring relevance and progress).

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer stated that EEMS is really at the heart of the problems and barriers that VTO is trying to solve. While many of the other parts of VTO are very important supporting functions, EEMS is a core function for what VTO is working toward addressing (mobility).

Reviewer 2:

The reviewer remarked that, yes, the projects were addressing the broad problems and barriers. Efforts are focused on addressing problems and barriers at an overall transportation systems level, addressing the interaction of vehicles technologies.

Reviewer 3:

The reviewer noted that EEMS is an excellent addition to VTO at the appropriate time. Technology will need to be deployed in an optimal fashion, and EEMS will provide information to make informed decisions.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

From what the reviewer could tell, the program area seemed very well managed and focused. It might be useful to demonstrate, rather than just state, some measurement of the collaboration outside VTO. For example, many organizations and agencies are mentioned, but one could envision some table, graph, or chart that shows how each organization contributed and why that was valuable.

Reviewer 2:

The reviewer stated that the presenter was very qualified to lead this team and to provide significant value for optimization of mobility.

Reviewer 3:

The reviewer remarked that this program area still seems to be forming. The roadmap is under development. The program does appear to be focused on addressing specific issues and barriers, as best as can be determined at this relatively early stage.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer mentioned that a full assessment of strengths and weaknesses is difficult for at least two reasons: EEMS is very new; and this overview presentation was quite general until the more detailed presentations are given later in the week. One piece the reviewer believed would greatly strengthen the effort is a more robust safety component. Safety was mentioned quickly on Slide 15 along with energy and mobility, but other than that there was not much information. Recognizing that this is DOE-sponsored research, it still is important to bring in the U.S. Department of Transportation (DOT) safety side into the presentation more than was mentioned because safety could very much influence the energy analysis trade-offs. For example, perhaps a perfectly synchronized intersection with connected vehicles (CVs) and/or autonomous vehicles (AVs) could have very high throughput and huge energy savings, but maybe as soon as the safety margins and other related considerations are built in, the savings shift to a deficit somehow where a traditional traffic light or roundabout is actually superior. It might be important to know that.

Reviewer 2:

The reviewer said that much of the program is currently focused around how various transportation technologies interact. This is important and traditionally has not been addressed to this degree in VTO. At the same time, many of these projects are in the formative stage, so it is hard to tell at this point which stand out, ether positively or negatively. The reviewer further noted that a number of projects were to be presented in the individual sessions, but few were highlighted specifically in the overview.

Reviewer 3:

The reviewer noted that the key strength was that the national laboratory consortium provides talent, bandwidth, and resources to do the advanced analytics required for projects of this scale. The key weakness was the potential for silos being formed among the stakeholders. Communication is going to be crucial for EEMS to provide full value. The reviewer concluded that all pillars play key roles in the program.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer was confident that the innovation of the national laboratory consortium would result in a major impact in developing solutions to cities' transportation issues.

Reviewer 2:

The reviewer noted that this program represents a new approach within VTO, though it follows on related efforts within Vehicle Analysis and Deployment.

Reviewer 3:
The reviewer did not observe a great deal of novelty or innovation, but perhaps that will emerge later in the week.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer said that, yes, appropriate partners had been engaged, except to the extent possible it should demonstrate that beyond mentioning the organizations. Even a cursory list of contributions from each partner, highlighting some of the most significant ones, would be very impactful.

Reviewer 2:
The reviewer commented that the program appears to be just starting to engage partners. Partner engagement is really under development, which is to be expected for a program which began only a few months ago.

Reviewer 3:
The reviewer noted that, at this stage, yes, partners were being engaged. It will be important to engage with the transportation industry partners as this program progresses.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer said that, yes, it appeared that effective collaboration was taking place.

Reviewer 2:
The reviewer noted that it was very difficult to gauge collaboration from the presentation. The collaboration group looks excellent, but there was not really a lot of mention of how the collaboration is going and how effective it has been with actual examples (beyond the national laboratories).

Reviewer 3:
The reviewer commented that it is probably too early to tell. The most formal relationship is with the DOT, which assisted DOE in planning a procurement.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer remarked that, as previously mentioned, there was a little bit of development without fully folding in safety concerns at the moment. That is not to say the team is promoting unsafe ideas; it is just saying that if safety had been more thoroughly considered at the outset, some of the projects would have different messages.

Reviewer 2:
The reviewer commented that there needs to be stronger inclusion of alternative fuels, and the needs and solutions they identify for transportation systems-level activities. This will be particularly true if there is a national effort to strengthen U.S. transportation infrastructure, which could provide a significant opportunity in this area.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer noted that at this early stage, it seems all areas are addressed.

Reviewer 2:
The reviewer again identified the gap in safety mentioned previously.

Reviewer 3:

The reviewer pointed out that there could be a stronger description of coordination with other parts of VTO. An example would be the SMART Mobility Framework and Clean Cities coalitions. To be fair, it may simply be too early for some of this detail.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer did not see a lot around developing metrics, or even a definition of mobility. Metrics and definitions such as those will become very important going forward so that uses the same definition, and is measuring something the same way (even if imperfect).

Reviewer 2:

The reviewer reiterated that there should be more explicit inclusion of alternative fuels, particularly as related to overall transportation system planning. This is especially true for alternative fuel infrastructure.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer noted that there needs to be strong stakeholder input on barriers and potential projects. Some has begun related to modeling and data, but the real need is a focus on projects.

Reviewer 2:

The reviewer recommended ensuring that there is connectivity to the many tools being developed from EEMS so that more encompassing and integrated analysis results in the best information for decision making.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer said that this was a very good program with great potential to make a difference.

Reviewer 2:

The reviewer commented that the program could benefit from stronger efforts to validate data and modeling through real-world pilot projects.

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Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 4-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems001	Energy Impact of Connected and Automated Vehicles	Huei Peng (U. of Michigan)	4-11	3.29	3.21	3.36	3.21	**3.25**
eems002	SMART Mobility—Connected and Automated Vehicles	Eric Rask (ANL)	4-16	3.25	3.25	3.33	3.33	**3.27**
eems003	SMART Mobility—Advanced Fueling Infrastructure	John Smart (INL)	4-21	3.42	3.33	3.42	3.17	**3.34**
eems004	SMART Mobility—Multi-Modal	Diane Davidson (ORNL)	4-25	3.29	3.36	3.43	3.50	**3.37**
eems005	SMART Mobility—Mobility Decision Science	Anand Gopal (LBNL)	4-32	3.50	3.17	3.25	3.42	**3.29**
eems006	SMART Mobility—Urban Science	Stan Young (NREL)	4-37	3.20	3.10	3.30	3.10	**3.15**
eems007	SMART Mobility Stakeholders—Curating Urban Data and Models	Joshua Sperling (NREL)	4-44	3.58	3.42	3.83	3.58	**3.53**
eems008	Impact of Population Shift on Energy Use: Detroit Use Case	Josh Auld (ANL)	4-49	3.20	3.10	3.50	3.50	**3.23**
eems009	Energy Assessment of Automated Mobility Districts	Stanley Young (NREL)	4-55	3.30	3.40	3.50	3.20	**3.36**
eems010	Definition of Connected and Automated Vehicle (CAV) Concepts for Evaluation	Steven Shladover (LBNL)	4-59	3.40	3.50	3.00	3.25	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems011	Multimodal Travel Behavior Modeling in Urban Areas using BEAM	Colin Sheppard (LBNL)	4-65	3.30	3.40	3.00	3.50	**3.34**
eems012	Modeling and Analysis of Plug-in Electric Vehicle Charging Infrastructure Supporting Shared Mobility	Yan Zhou (ANL)	4-69	2.40	2.70	2.30	2.60	**2.56**
eems013†	A New System Simulation Framework for SMART Mobility	Phil Sharer (ANL)	4-75	3.20	3.10	2.80	3.10	**3.09**
eems014†	Agent-Based Transportation System Modeling with POLARIS	Josh Auld (ANL)	4-81	3.30	3.30	3.00	3.50	**3.29**
eems015†	Calibration of Activity-Based Transportation System Simulation Tools using High-Performance Computing	Vadim Sokolov (ANL)	4-86	3.30	2.90	3.10	2.90	**3.03**
eems016†	Energy Efficient Connected and Automated Vehicles	Dominik Karbowski (ANL)	4-92	3.40	3.30	3.30	3.30	**3.33**
eems017†	Impact of CAV Technologies on Travel Demand and Energy	Josh Auld (ANL)	4-96	3.20	3.50	3.50	3.30	**3.40**
eems018†	Extended Urban Modeling for Smart Mobility	Budhu Bhaduri (ORNL)	4-102	3.10	3.20	3.10	3.00	**3.14**
eems019†	Smart Urban Signal Infrastructure and Control	H. M. Abdul Aziz (ORNL)	4-107	2.92	3.08	2.83	2.92	**2.99**
eems020†	Energy Impact of Different Penetrations of Connected and Automated Vehicles	Jackeline Rios-Torres (ORNL)	4-113	2.90	3.20	3.00	2.90	**3.06**
eems022†	A Model to Assess Impacts on Fleet-Wide Energy Use from Multi-Modal Opportunities— Freight Fleet-Level Energy Estimation Tool (FFLEET)	Tim LaClair (ORNL)	4-119	3.50	3.50	3.40	3.20	**3.45**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems023†	WholeTraveler Survey on Life Trajectories and Mobility Decisions	Anand Gopal (LBNL)	4-123	3.30	3.10	3.20	3.10	**3.16**
eems024†	MA3T-MobilityChoice: Analyzing the Competition, Synergy and Adoption of Fuel and Mobility Technologies	Zhenhong Lin (ORNL)	4-130	3.30	3.10	3.40	3.30	**3.21**
eems025†	National Scale Multi-Modal Energy and GHG Analysis of Inter-City Freight	Yan Zhou (ANL)	4-133	3.30	3.40	3.20	3.30	**3.34**
eems026†	Expanding Regional Simulations of CAVs to the National Level and Assessing Uncertainties	Tom Stephens (ANL)	4-138	3.40	3.30	3.40	3.20	**3.33**
eems027†	Opportunities for Improving the Energy Efficiency of Multi-Modal Intra-City Freight Movement	Kevin Walkowicz (NREL)	4-142	3.58	3.25	3.42	3.42	**3.38**
Overall Average				**3.27**	**3.24**	**3.24**	**3.22**	**3.24**

†Denotes a poster presentation.

Presentation Number: eems001 Presentation Title: Energy Impact of Connected and Automated VehiclesPrincipal Investigator: Huei Peng (University of Michigan)

Presenter

Huei Peng, University of Michigan

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

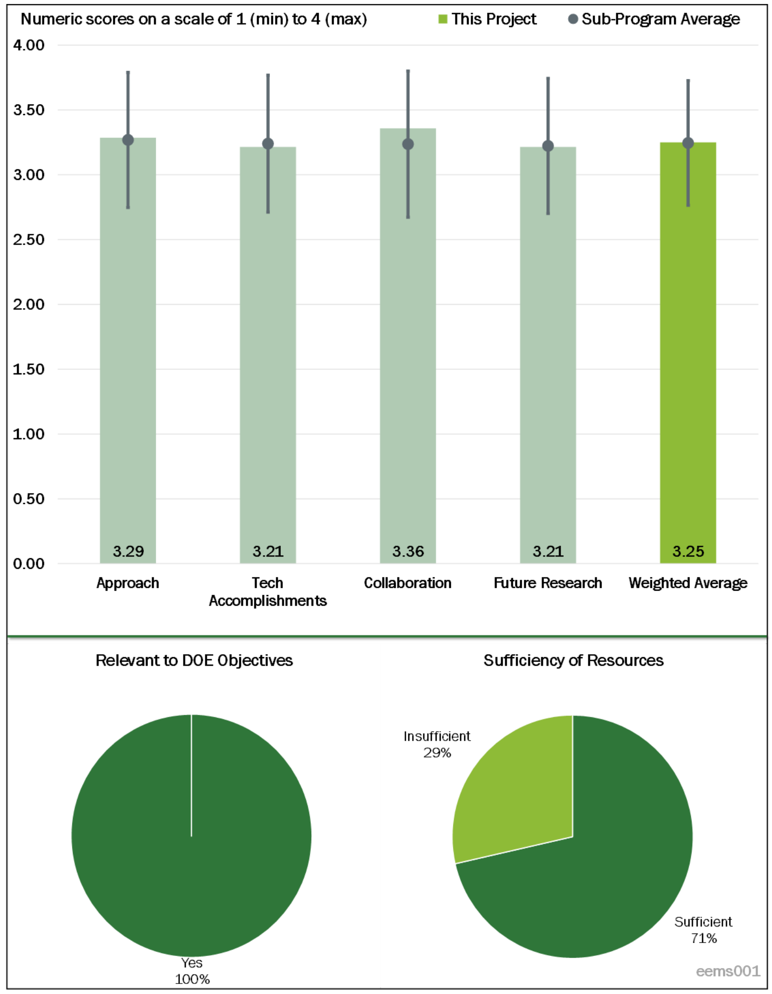

Figure 4-1 - Presentation Number: eems001 Presentation Title: Energy Impact of Connected and Automated Vehicles Principal Investigator: Huei Peng (University of Michigan)

Reviewer 1:

The reviewer said that the approach being pursued should yield valuable data and impactful results that the reviewer looked forward to hearing about.

Reviewer 2:

The reviewer commented that the current approach, which combined user behavior study and data-driven modeling, was good.

Reviewer 3:

The reviewer suggested adding in more fleet data.

Reviewer 4:

The reviewer stated that the approach leverages the capabilities and knowledge bases of the partners to develop data and models that can be used to assess energy impacts of connected and autonomous vehicles (CAVs). The reviewer said that the project is initially focused on gathering field data to characterize the energy consumption characteristics of baseline vehicle populations (pre-CAVs). The reviewer mentioned that data will be used to create models of geo-spatial traffic flow and vehicle energy consumption for the baseline and CAVs vehicle scenarios. The reviewer said that the approach's progression from representing baseline followed by representing advanced CAV technologies is a solid strategy. However, the reviewer said that it is becoming clear that the original project scope may have been too ambitious/optimistic despite the previous experience of the project team members in collecting data and modeling transportation phenomenology. The reviewer concluded by saying that it is critical that the project focus its resources to ensure that priority tasks are accomplished.

Reviewer 5:

While the reviewer thought this work is invaluable, the reviewer said it could be helped by a slightly broader scope involving original equipment manufacturers (OEMs). The reviewer reasoned that in the end, the project will provide a list of benefits for connected vehicles in a fairly broad driving environment in Ann Arbor. The reviewer said it will be based on existing technologies and does not take into account potential enhancements that may be made, such as improved brake systems or enhanced ability for drivelines to take adaptive driving into account. The reviewer added that some offshoot that allows an OEM to consider these things along with the project could be useful. The reviewer also mentioned that these studies had to be geared to providing an incentive to the people building the city infrastructures or vehicles; a basket of knowledge was not good enough. The reviewer said that proof of an off-cycle benefit that can be applied by OEMs per technology will incentivize real work and real energy savings.

Reviewer 6:

The reviewer mentioned that the project scope seemed too large despite the large number of collaborators. The reviewer pointed out that the progress was indicated as 45%, but this did not seem to match the accomplishments of all five tasks. The reviewer said that the slides did not adequately describe the method/approach for each task and separately described the accomplishments, making it difficult to gain an understanding of both. The reviewer added that the various tasks did align with the DOE objective of understanding the energy consumption impact of CAVs, and that each task appeared to be well designed and feasible if sufficient resources and time were provided.

Reviewer 7:

The reviewer said that the design of the project could have improved the methods and data to better verify the baseline situations. The reviewer questioned how well the population of 500 vehicles matched the overall population of the city, the region, the state, etc. The reviewer added that for a given cost, it would have been better to capture 1 hertz (Hz) data on fewer vehicles.

The reviewer added that it would be good to establish the degree of confidence in the baseline measurements before introducing variables or modeling this behavior as “baseline.” The reviewer mentioned that this project could provide better focus on Tasks 1, 2, and 4 to form a hypothesis before embarking on new control algorithms in Tasks 3 and 5. The reviewer stated that definitive driver behavior, travel patterns, and energy usage should be clearly defined and documented before modeling the effects of new driver control (Task 2), ridesharing (Task 3), and adaptive signals (Task 5). The reviewer said that overall it seems very ambitious to do all of this with the amount of available funding. The reviewer added that the barriers or hypothesis could be better outlined. The reviewer questioned the baseline metrics that can be further analyzed, such as the way drivers currently react at intersections, what cooperative adaptive cruise control (CACC) opportunities were available, and how much fuel could theoretically be saved with some of the methods that were being investigated. The reviewer said that similar to the -60 to +200 fuel consumption graph, it would be helpful to frame the issues with some data and current assumptions to justify what, how and why the presenter was embarking on these activities.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project was progressing as planned.

Reviewer 2:

The reviewer noted that the progress was good.

Reviewer 3:

The reviewer mentioned that the presentation described several products that showed considerable work has been done across the five tasks. The reviewer stated that the presenter’s list of lessons learned suggested that the team had initially underestimated the cost and difficulty of implementing the data collection task.

Reviewer 4:
The reviewer said that the technical accomplishments looked significant, and that the progress was not as well along because of earlier hardware issues. The reviewer added that some interaction with or consideration for safety was expected. For example, the reviewer asked did safety considerations ever limit the energy savings potential.

Reviewer 5:
The reviewer stated that this work will accomplish much in terms of proving benefits and providing data for a multitude of operating conditions and scenarios. The reviewer said that it could be improved by showing a statistical study showing the confidence in only 500 vehicles. The reviewer suspected it will be fine, but it should be proven.

Reviewer 6:
The reviewer pointed out that overall it seems like a fair amount of progress has been made. The reviewer stated that some better results should be shown in the AMR slides relative to the 0.5 Hz data collection effort. The reviewer questioned what trends were being seen, how it will be analyzed, and what will be analyzed specifically. The reviewer stated that although the data effort is not complete yet, this will help communicate how the researcher will analyze the data when the entire dataset is available.

Reviewer 7:
The reviewer said that it is difficult to understand exactly what has been accomplished from the presentation. The reviewer mentioned that this is likely due, in part, to the scope being large and the presentation time being limited. The reviewer stated that it was difficult to see how 45% of the work has been completed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the presentation indicates that there is strong participation and contributions by all the partners.

Reviewer 2:
The reviewer remarked that it was a good team.

Reviewer 3:
The reviewer stated that this project leverages the expertise of University of Michigan, Idaho National Laboratory (INL), and ANL. The reviewer remarked that input from OEMs will make it better, although they may hesitate to join this type of project.

Reviewer 4:
The reviewer thought that this presentation demonstrated good partnership and good separation of duties. The reviewer thought that the team members might be expanded to include other partners, such as OEMs and the U.S. Environmental Protection Agency (EPA).

Reviewer 5:
The reviewer stated that there seemed to be a gap in coordinating with the DOT in some capacity to ensure lessons learned are best disseminated and that safety aspects are adequately represented throughout the project rather than as an afterthought.

Reviewer 6:
The reviewer mentioned that the collaboration could be improved by including industry or industry groups, such as the Society of Automotive Engineers (SAE) On-Road Automated Driving (ORAD) committee, at the very least as stakeholders who could help direct the research and ensure that it aligns with industry paths.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the most exciting work is still ahead and should prove to be very valuable.

Reviewer 2:
The reviewer pointed out that more factors should be included in future research.

Reviewer 3:
The reviewer stated that the following response to reviewer comments indicates that project leadership has prioritized its future work, which likely narrows the project scope and reduces overall project risk: "The team agrees that the scope needs to be crystal clear, and we will focus on getting the experimental data from Task 1; "driver behavior" (response to advice and trip behavior) from Tasks 2 and 3; and key CAV function like eco-approach and departure, and eco-routing algorithms into the Planning and Operations Language for Agent-based Regional Integrated Simulation (POLARIS) model as the key outcome of this project."

Reviewer 4:
The reviewer noted that this was clearly defined.

Reviewer 5:
The reviewer said that the future work plan seems to be logical but should ensure that work in this project does not overlap with other similar efforts happening under CAVs.

Reviewer 6:
The reviewer stated that it is not clear how the tasks are related to each other and whether/how delays or issues in one will affect the others. The reviewer added that there is no mitigation strategy mentioned.

Reviewer 7:
The reviewer mentioned that a lot of tasks were listed in the future plan, and some of them are tough. The project needs a solid plan to get them done in time.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that the project is an excellent example of bringing real-world, hardware-based research into the DOE sphere that grounds future models and analyses on actual measured data.

Reviewer 2:
The reviewer commented that this project is going to provide very useful data to enable the informed to act on physics and added that it is perfectly aligned with the DOE's purpose.

Reviewer 3:
The reviewer mentioned that CAVs are going to have a major, but as of yet unknown, impact on petroleum consumption. The reviewer remarked that this project is an important first step for the EEMS program to begin to quantify this impact.

Reviewer 4:
The reviewer agreed that the project supports the overall DOE objectives of petroleum displacement by helping to develop understanding about the potential energy consumption characteristics of CAVs.

Reviewer 5:
The reviewer stated that CAVs do have a great impact on energy consumption in the future transportation industry.

Reviewer 6:
The reviewer said that the project does support the overall DOE objectives of petroleum displacement.

Reviewer 7:
The reviewer wanted the researchers to provide a better and frequent explanation of the opportunities or dangers, relative to petroleum displacement, for the various scenarios that are being investigated.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that this project does appear to have sufficient funds for what was proposed, and seems to be at the appropriate place in the budget based on accomplishments to date.

Reviewer 2:
The reviewer said that the project has a good team of researchers.

Reviewer 3:
The reviewer stated that the resources seem adequate.

Reviewer 4:
The reviewer remarked that the budget is about right.

Reviewer 5:
The reviewer noted that based on the original project resource requirement estimates, the presentation indicates that additional resources above the initial resource estimates are needed to perform the work. The reviewer added that some of the additional resources have been identified as coming from additional contributions from project partners. The reviewer said that the project has also prioritized its tasks to adapt to the realization of resource constraints.

Reviewer 6:
The reviewer said that it is difficult to know if the project’s five tasks can all be completed on time based on the presentation, but that the financial resources appear to be sufficient.

Reviewer 7:
The reviewer remarked that it was mentioned many times in the discussion that more data would be better. The reviewer feared that it may not be enough or may be too coarse due to limitations of the data collection dongles. The reviewer would like to have seen some EPA standpoint on the data about to be collected before finding that it is insufficient for the proof required to provide off-cycle credit for these technologies.

Presentation Number: eems002
Presentation Title: SMART Mobility—Connected and Automated Vehicles
Principal Investigator: Eric Rask (Argonne National Laboratory)

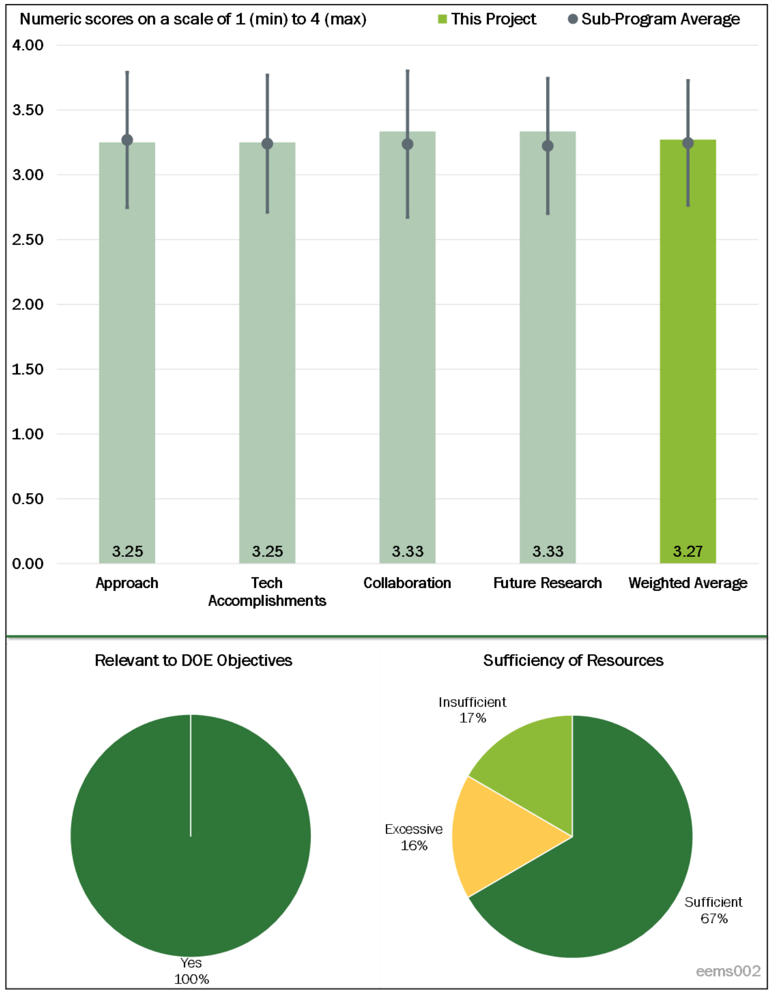

Figure 4-2 - Presentation Number: eems002 Presentation Title: SMART Mobility—Connected and Automated Vehicles Principal Investigator: Eric Rask (Argonne National Laboratory)

Presenter

Eric Rask, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer mentioned that the approach seems quite extensive and possibly quite exhaustive as well. The reviewer remarked that some of the areas of focus, such as platooning of passenger cars (CACC),may face implementation challenges in the U.S. due to consumers' aversion to relinquishing control of certain aspects of their lives (e.g., driving). The reviewer questioned if there are any studies being done to see how some of these technologies will work in the context of the consumer tendencies. The reviewer wondered if that study would belong to another pillar. The reviewer also asked if it is expected that the potential benefits offered by CAVs so far outweigh the negatives that they will eventually be adopted.

Reviewer 2:

The reviewer stated that the approach is good from the standpoint that it has multiple vectors of analysis. The reviewer added that the approach will likely be improved by increased emphasis on concept development and documentation by groups of smart people collaborating together and less emphasis on aggregate simulation.

Reviewer 3:

The reviewer said that although complex and multifaceted, the approach does appear to be sound. The reviewer stated there is a non-zero chance that the components and/or results could become unwieldy if not managed closely. The reviewer opined that, like all teams at all levels, this project team needs to keep the end in mind and have a mission statement to ground any and all decisions/analyses. The reviewer mentioned that perhaps this has already been done and all the parts work together to form a well-oiled machine, but that it was not apparent during the presentation.

Reviewer 4:

The reviewer stated that the four research categories are appropriate. The reviewer remarked that the subject is so broad that it is somewhat difficult to completely assess at this time how effective the approach will be. The reviewer mentioned that this is acknowledged by the proposed feedback loops among the various research activities.

Reviewer 5:

The reviewer observed that this project design, which includes both bottom-up and top-down analyses, is very useful to beginning to quantify the effects of CAVs on the transportation network. The reviewer added that the various tasks appear feasible in the scheduled timeframe, and should result in an advancement in the state of the art. The reviewer said that the “book-ending” of +200% and -60% could perhaps be improved through Intergovernmental Panel on Climate Change-like scenarios in which different configurations and levels of CAV adoption are modeled to provide more insight into CAV impacts on energy usage in the transportation system.

Reviewer 6:

The reviewer said that the presentation was very hard to follow because of the volume of material and the complexities involved. It appeared to the reviewer that the project is something that would be better off being broken into smaller projects or simplified. The reviewer’s concern was that the result of the project will be equally as difficult to parse though and thus come to little value.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer mentioned that the progress is excellent, given the breadth of the project and the October 2016 start date.

Reviewer 2:

The reviewer found the technical accomplishments to be excellent from the perspective that they have produced an initial common set of mobility concepts and definitions.

Reviewer 3:

The reviewer said that these pieces of information will be very useful for future use relative to credit applications. The reviewer said that more detail would have to be understood about each one to utilize the results effectively.

Reviewer 4:

The reviewer stated that the project is quite new, but substantial progress appears to have been made. The reviewer mentioned that the DOE goals of understanding how CAV introduction will impact petroleum consumption are being well met through this project.

Reviewer 5:

The reviewer observed that there is good progress, but it appears that there is so much hard work to be done to make sufficient progress while covering all the relevant areas of focus. The reviewer said that POLARIS, for instance, needs to undergo some improvement for it to be deployed effectively in this project. The reviewer said that this means that further progress may be hampered by extraneous factors that the funding of this project may not have direct control over.

Reviewer 6:

The reviewer said that this is a project in a relatively early stage of execution. The reviewer remarked that the accomplishments seem significant, but it was difficult to process all of that during the presentation. The reviewer added that the presenter often recommended that the audience attend the poster session to learn about the accomplishments, which suggested to the reviewer that the format of this review may not be optimized. The reviewer said that perhaps the expectation for this level of the project should be reconsidered so that the presenter does not feel so much has to be compressed into so little time.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the project work is distributed appropriately among the laboratories. The reviewer remarked that it is nice to have Volvo as a partner at this early stage.

Reviewer 2:
The reviewer noticed that there are a lot of partners on this project, and that there is evidence of collaboration among several of the partners working on separate tasks.

Reviewer 3:
The reviewer acknowledged that Volvo Trucks is involved in the truck platooning work. The reviewer noted that similar work was done by Volvo Trucks and Ricardo in the European Union. The reviewer asked if there was any reason to not include Ricardo as a partner as well.

Reviewer 4:
The reviewer mentioned that the Systems and Modeling for Accelerated Research in Transportation (SMART) Consortium is obviously a strong collaboration, but the industry and academic collaborations are a bit meager. The reviewer added that the SAE, specifically the ORAD committee, should be considered as an additional collaborator.

Reviewer 5:
The reviewer noted that the partner and collaborator list looks very strong. The reviewer allowed that it would be nice to have seen at a high level how or what the collaboration contributions look like, while realizing that this would be challenging to incorporate into a presentation that is already full. The reviewer added that, for example, the DOE-DOT Memorandum of Understanding (MOU) is cited, but the reviewer was not sure exactly which MOU this was; it was not immediately clear what the details of the partnership looking backward have been. The reviewer clarified that the slide does not misrepresent anything; it is more that the reviewer would be guessing a bit as to what the bullet refers.

Reviewer 6:
From the presentation or from the material, the reviewer could not easily tell who is doing what, but noticed that there is a very detailed task list. The reviewer assumed that those details are behind the scenes and that there was just not time to get into it. That being said, the reviewer needed to know where to retrieve the information after it is created and how it is to be used or read.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer mentioned that the work plan is very detailed and appropriate for such a large project.

Reviewer 2:
The reviewer said that the simulation tasks are excellent. The reviewer pointed out that the real-world testing tasks could be expanded to include more use cases. The reviewer added that the planned schedule follows a logical and feasible implementation.

Reviewer 3:
Much of the project is in the future, and the reviewer looked forward to seeing the results. The reviewer thought it is important for the principal investigator (PI) and team to be clear on the audience and the goal, such as increased mobility with decreased energy.

Reviewer 4:
It appeared to the reviewer that there is a tremendous amount of work that has to get done, and the reviewer was not sure that all of that can be covered in the available time. The reviewer questioned if the scope of the work should be narrowed somewhat to ensure that whatever gets accomplished is more complete.

Reviewer 5:
The reviewer said that the highlighted future work outline is deficient in that it does not provide a mapping to how each focus item relates to the study questions that were presented. The reviewer added that the presentation does not provide a justification for why the several previous DOE-sponsored fuel efficiency study results regarding platooning and eco-routing are insufficient to inform the mobility study. The reviewer mentioned that it may be useful to provide a verbose rationale for why it is DOE's mission to answer the question of "How will CAVs be adopted?"

Reviewer 6:
The reviewer found the project to be very complex and impossible to follow in the presentation. The reviewer added that the size of the project could lead to delays and excess spending. The reviewer suggested that if some parts could be independently reviewed or eliminated, it may allow the best value for the higher impact items.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that mobility and CAVs are big topics now and happen to be a focus of both the past administration and the new administration. The reviewer stated that this is clearly highly relevant.

Reviewer 2:
The reviewer said that the project tries to answer the difficult question of how best to maximize the energy efficiency of future transportation systems, which is appropriate for DOE policy setting.

Reviewer 3:
The reviewer noted that the project seeks to develop a knowledge base of potential energy consumption characteristics of new mobility concepts in the transportation sector. The reviewer mentioned that government and industry can use the knowledge developed to inform policy and technology R&D investment decisions with information on potential petroleum displacement impacts.

Reviewer 4:
The reviewer acknowledged that as the presenter showed, the impacts on petroleum displacement are poorly understood but could be quite significant. The reviewer said that this project will help with this understanding and thus supports the DOE's goals.

Reviewer 5:
The reviewer stated that this project has many facets that can help the objective. The reviewer questioned if this project, as scoped, can do this efficiently, if the results can be adequately put out in a quality way, and if it can do this within the budget. These are questions the reviewer still had after seeing and reviewing the presentation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer mentioned that at this point in the project, the resources needed to answer the initial questions are adequate.

Reviewer 2:
The reviewer stated that from what could be gleaned from the presentation, the funding seems to be sufficient, but the reviewer would want to dive more deeply to really see what else could be achieved with more, as compared to what could be cast aside with less funding.

Reviewer 3:
The reviewer referred to previous comments.

Reviewer 4:
The reviewer found project funding to be sufficient from the perspective that the project has a very broad set of objectives that requires a substantial resource investment. The reviewer believed that scaling back some of the project scope and resources (approximately 20%-25%) would likely result in a more streamlined effort with superior effectiveness.

Reviewer 5:
The reviewer said that the resources for three of the four tasks are sufficient. The reviewer stated that the small amount for the fourth task should perhaps be reconsidered because this appears to be an important contribution.

Reviewer 6:
The reviewer feared that the resources will not be enough in the end because of the inefficiency and lack of oversight for such a big undertaking.

Presentation Number: eems003
Presentation Title: SMART Mobility—Advanced Fueling Infrastructure
Principal Investigator: John Smart (Idaho National Laboratory)

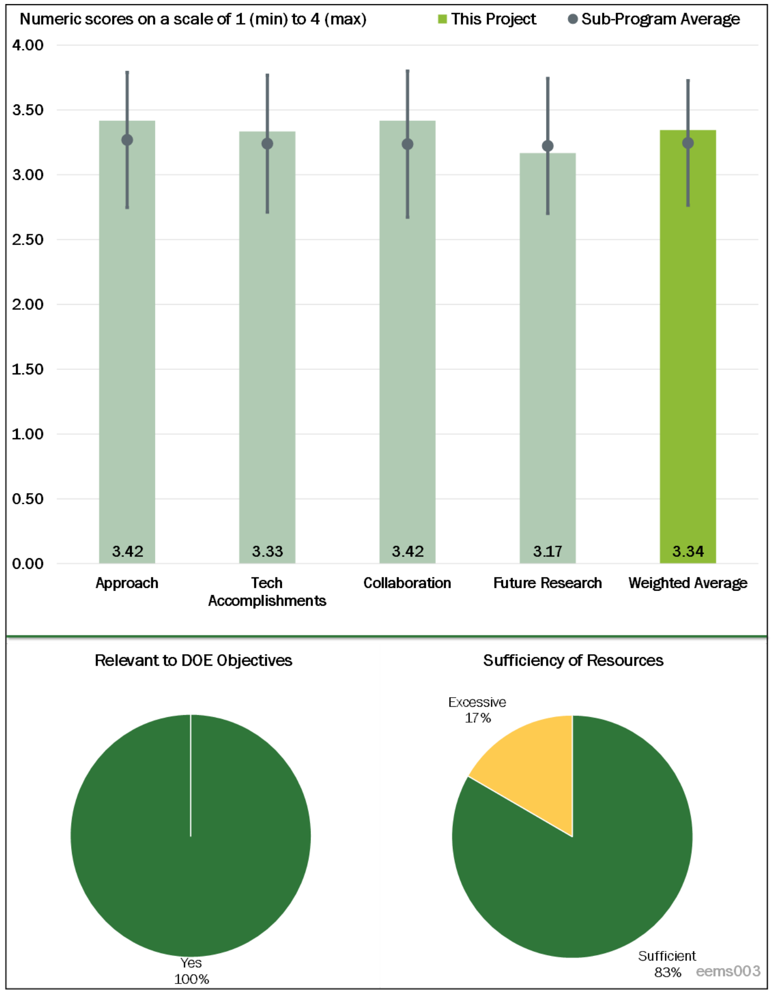

Figure 4-3 – Presentation Number: eems003 Presentation Title: SMART Mobility—Advanced Fueling Infrastructure Principal Investigator: John Smart (Idaho National Laboratory)

Presenter

John Smart, Idaho National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer mentioned that this is a great approach that covered all bases.

Reviewer 2:

The reviewer stated that the approach seems effective as it identifies the problem, objective, and approach of the project. The reviewer said this approach seems to be feasible and is pulling data from prior projects.

Reviewer 3:

The reviewer said that it seems like a good approach with an appropriate scope and plan.

Reviewer 4:

The reviewer commented that this project mainly uses existing modeling tools and develops new tools. The reviewer was not quite sure if the new tool will be developed based on the existing modeling tools or if it is more data-driven.

Reviewer 5:

The reviewer noted that this is going to be a limiting factor in the way of realization of a completely optimized fueling infrastructure and energy result. The reviewer mentioned that this is a good step in determining the best solutions and informing cities and businesses about future planning.

Reviewer 6:

The reviewer pointed out that the approach seems too narrowly focused based on the goals of the project, and the presentation remained very high level. The reviewer added that, for example, it seems that an examination into alternative fuel vehicles (AFVs), alternative fuel infrastructure, and SMART Mobility would have to examine supply chains of all the fuels themselves as well as the hardware that delivers that fuel. The reviewer observed it was unclear if that was part of the presentation. The reviewer also stated that there was no mention of automated stationary refueling that would seem to be obvious to SMART Mobility and AFVs (e.g. wireless power transfer while parked/idling/waiting, robotic fuel delivery, etc.). The reviewer remarked that the answer to the "so what?" question perhaps at the bottom of Slide 7 was not satisfying. The reviewer questioned what part of the private sector was intended, and wondered about considering the public sector, city planners, etc. The reviewer asked what information these customers lack and if the researchers are asking for this information.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that the progress to date looks good. The reviewer looked forward to seeing the results.

Reviewer 2:
The reviewer noted it was early in the process, but well on its way.

Reviewer 3:
The reviewer commented that this project appears to be well thought out and organized. Given that it is early in the project, the reviewer was certain this will develop with time; however the identification of multiple cities to work with helps to diversify the answer. The reviewer mentioned that the method of analysis looks reasonable.

Reviewer 4:
The reviewer did not see much exciting output so far because the project was started late last year.

Reviewer 5:
The reviewer said that progress has been made in the project and the researchers have identified the regions where the work will be focused. The reviewer noted that the plan is to synthesize ride-hailing vehicle data from personal-use vehicle data collected during previous projects. The reviewer said the fact that the team has received a commitment from one shared-mobility service provider to share their data is good, but not having received the data to date is a risk of not getting relevant current data to feed the models.

Reviewer 6:
The reviewer stated that the accomplishment slides looked more like approach slides. The reviewer added that perhaps this was due to the project being in the early stages, but it was difficult to discern what the tangible accomplishments really have been to date.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the project has ANL, INL, Lawrence Berkeley National Laboratory (LBNL), NREL, and ORNL as core laboratories along with Pacific Northwest National Laboratory (PNNL) and Los Alamos National Laboratory as supporting laboratories, and that it shows appropriate collaboration on the subject.

Reviewer 2:
The reviewer said that a good array of expertise is employed to look across the spectrum of tasks required to complete the plan.

Reviewer 3:
The reviewer mentioned that it is a great team, and that the team should add a fleet.

Reviewer 4:
The reviewer pointed out that this project leverages modeling skills of different institutes, and that good coordination and communication among different parties is critical to get meaningful output.

Reviewer 5:
The reviewer saw this to be a fundamentally collaborative project, and that the interaction within DOE is of course excellent, but that the interaction outside of DOE is less so. The reviewer remarked that it appears that the team has made an extensive effort to collaborate when possible, but the nature of the emerging market makes this difficult.

Reviewer 6:
The reviewer found the collaboration slide to be very sparse. The reviewer stated that it appeared that most to all collaboration has been among a subset of national laboratories along with some limited outreach to industry. The reviewer pointed out that more than the other presentations, there seemed to be a large gap here to other federal partners within the AFV community, some of which probably could jumpstart much of this research based on past work, such as Federal Transit Administration (FTA), Federal Highway Administration (FHWA), various alternative fuel working groups, etc.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future research pathway is great.

Reviewer 2:
The reviewer stated that this project has a great long-term plan that seems achievable with low risk.

Reviewer 3:
The reviewer noted that this project was clearly looking at milestones along the timeline and asking questions about future value to proceed. For the moment, and due to the complexity of the issue, the reviewer thought this simple approach is a great start. The reviewer added that it is worth avoiding overcomplication as much as possible and starting to look at the general trends and where they may be leading. The reviewer suggested that some input from the petroleum industry is sought, if they are willing to share, because they may already be considering these questions as a matter of their business planning.

Reviewer 4:
The reviewer mentioned that the proposed future seems planned out on the path that the project will go. The reviewer remarked that the project does not seem to have addressed appropriate decision points, and said that it does not mention what will be an alternative action for acquiring relevant data to feed the models if current planned data are not delivered.

Reviewer 5:
The reviewer said that the future work which is to do the modeling and analysis with the modeling framework being placed, is straightforward. The reviewer cautioned the researchers to be careful in drawing any conclusion with so many different models involved and developed by different institutes. The reviewer reminded researchers that validation is the key.

Reviewer 6:
The reviewer commented that the future research slide was also very sparse, as it only restated the goals of the project without any detail behind where the project is headed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that increasing efficiency and potentially switching to alternative fuels will decrease petroleum usage.

Reviewer 2:
The reviewer stated that this project supports the overall DOE objectives of petroleum displacement because the results of the effort will support shared mobility needs in the future in regards to understanding the value of AFVs and the requirement for fueling infrastructure.

Reviewer 3:
The reviewer commented that if planning is not done for infrastructure, petroleum use will continue until it is convenient. The reviewer said that this project gets at meeting the goal of making alternative fuels more convenient and thereby offsetting petroleum use.

Reviewer 4:
The reviewer suggested that this project may help electrified vehicles prevail.

Reviewer 5:
The reviewer noted that the project supports the overall DOE objectives of petroleum displacement, but that the team should identify areas.

Reviewer 6:
The reviewer observed that the work is highly relevant, though the scope/mission/goal all need to be clarified a bit, perhaps in consultation with the audience or end user, whomever that may be.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the budget seems well matched to the task.

Reviewer 2:
The reviewer said that most of the project tasks are model-based analysis and that the budget is sufficient.

Reviewer 3:
The reviewer remarked that the current resources seem to be sufficient to support the stated milestones in a timely fashion, but that if more funding becomes available it could be used to create more scenarios to support the other DOE SMART Mobility pillars.

Reviewer 4:
The reviewer said that at this point of the project, this budget should obviously be reviewed next year again. The reviewer stated that due to the large amount of collaboration and the size of the study, it is not excessive at this stage in the planning.

Reviewer 5:
The reviewer recommended just adding a fleet.

Reviewer 6:
The reviewer opined that, for being 19% complete, and with a total budget of $4.5 million, the presentation did not align with those numbers. For the reviewer this implies that the budget is excessive given the work that has taken place and presumably for the work going forward, which is also poorly defined.

Presentation Number: eems004
Presentation Title: SMART Mobility—Multi-Modal
Principal Investigator: Diane Davidson (Oak Ridge National Laboratory)

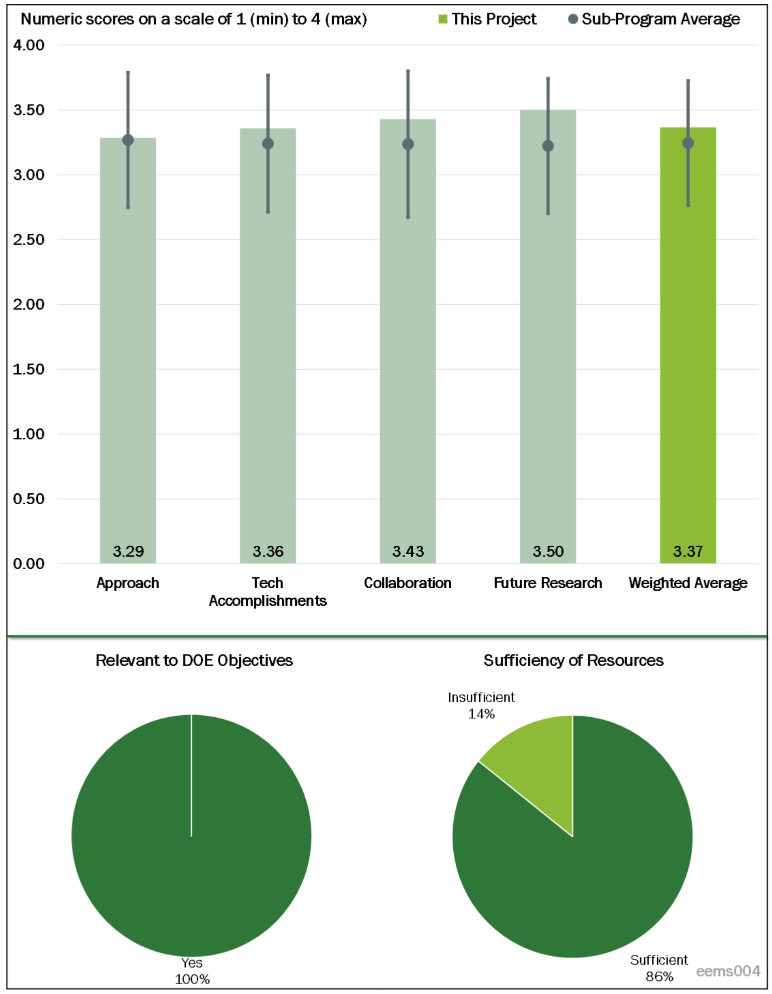

Figure 4-4 – Presentation Number: eems004 Presentation Title: SMART Mobility—Multi-Modal Principal Investigator: Diane Davidson (Oak Ridge National Laboratory)

Presenter

Diane Davidson, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer mentioned that the approach is excellent in that it has an early emphasis on developing a thorough understanding of the status-quo transportation modalities as a set of baselines to be used in future comparative analysis of the new traveler/shipper choices. The reviewer added that the approach is excellent because it contains evidence that the analysis will be using practical real-world decision criteria in its analyses.

Reviewer 2:

The reviewer said that this project is very early in its progress, but that the planning appears to be very well laid out and the technologies involved have been comprehended down to things such as stop/start and upcoming modifications to vehicles for improved efficiency. The reviewer noted that the project is looking at what is happening and building models, and that for this year it is well laid out. The reviewer stated that what is found in these studies with LBNL and ORNL will help solidify future planning.

Reviewer 3:

The reviewer found that the research subtopics address the project objectives and that steps are being taken to acquire appropriate data, which is recognized as a significant barrier. The reviewer questioned if air transport and other planned inter-city pathways, like high-speed rail, will be included and that it was not clear why they were not.

Reviewer 4:

The reviewer remarked that the entire concept of SMART Mobility/EEMS is very complex and interwoven across many sectors, necessitating a well-developed organizational structure delineating the various components into discrete, understandable, and manageable components. The reviewer added that upfront, it is good that the Multi-Model pillar has been delineated into three major areas: intra-city passenger travel; intra-city (urban) freight delivery; and inter-city freight transport. The reviewer said that this helps bound and frame the entire effort and facilitates management.

The reviewer stated that through the three aforementioned areas, the primary thrusts are to collect data, develop models to establish baselines and understand travel modes and behavior, characterize new vehicle choices and modes of passenger and freight delivery, and estimate national energy impacts from technology and model shifts. The reviewer mentioned that research is being conducted on other salient topics to inform and enhance modeling activities and future decision making. The reviewer added that a number of sequential FY 2017-2018 tasks and milestones are identified by quarter, but that there do not appear to be any embedded go/no-go milestones within the project schedule. The reviewer also stated that the presentation provides a good summary of the remaining challenges and barriers, but does not necessarily directly address means to overcome them. The reviewer gave an example of inter-city freight transport needs, and that a challenge mentioned is the need for more accurate energy impacts of partial technology penetration such as CAVs. The reviewer said that partial technology penetration is especially tricky in many aspects, including its potential disruptive aspect on the rest of the conventional vehicular fleet. The reviewer mentioned that the project seems to be integrating well with other efforts including the other four SMART Mobility pillars, Smart City Columbus, and the Advanced Research Projects Agency-Energy (ARPA-E) Transnet projects.

Reviewer 5:

The reviewer said that by and large, the approach looks sound. The reviewer had a few outstanding questions, including clarifying who the customers/end users are of this research and if they were planners or policy makers. The reviewers also asked if their input has been sought as to what would be helpful. The reviewer assumed the goal was how to achieve more freight mobility with lower energy, but that did not jump off the page.

Reviewer 6:

The reviewer mentioned that the aspects that are covered include intra-city passenger travel, inter-city freight, and intra-city freight. The reviewer asked if there is a reason why inter-city passenger travel is not included. The reviewer said that one would think that CAVs could encourage people to live farther out in the middle of nowhere, leading to increased inter-city passenger travel as well. The reviewer added that multi-modal travel has perhaps been more prevalent in Europe and Asia and questioned if there has been enough effort put into learning the lessons these cities/countries have to offer.

Reviewer 7:

The reviewer stated that the approach is a good one with data collection and modeling, then refining. The reviewer added that the model does not appear to capture some relevant data, such as population, housing, business density, type of district (business, light industrial, industrial, residential apartments, housing, etc.), and demographics (i.e., elderly population may embrace the use of shared automated vehicles (AV) more readily as an alternative to walking to a public transit location). The reviewer noted that without these data, there will most likely be substantial variation among the various cities being used for data, which makes it more difficult to predict routes. The reviewer said that the project is well integrated with other efforts, both being populated by data from other projects and being able to support predictions for other projects. The reviewer pointed out that it is a very feasible project and will be a valuable tool for DOE and municipalities performing urban planning/zoning.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that significant progress has been made since the October 2016 start date. The reviewer mentioned that the data being acquired are overcoming one of the main barriers to this project. The reviewer liked the collaboration with AT&T on cellphone location data.

Reviewer 2:
For being only early in the project, it appears to the reviewer that a lot has been done with obtaining the foundation for the rest of the study. The reviewer was impressed by the identification of target cities and obtaining records from AT&T, as well as by the preliminary modeling that has been done.

Reviewer 3:
The reviewer stated that the project is early, but is already able to help predict energy savings from platooning (demonstrated as a tool, validating methods that support DOE's goals). The reviewer said that the project is tracking well.

Reviewer 4:
The reviewer noted that the project is at early stages, but that the progress was good.

Reviewer 5:
The reviewer commented that the presentation touches on what appear to be strong starts in several subtasks to include some national level analytic conclusions regarding the energy impacts of platooning. The reviewer said that it is somewhat difficult to assign a higher rating to the technical accomplishments because the project is new and because of the limited depth of progress descriptions.

Reviewer 6:
The reviewer remarked that 6-9 months into the project, a number of technical accomplishments have been achieved. The reviewer stated that for intra-city passenger travel, data collection and analysis has begun in a number of areas, and progress has been achieved in the development of new models and in some cases in the conversion of existing models to permit greater flexibility with regards to vehicle routes and faster simulations. The reviewer said that for intra-city freight delivery, freight movement and volume data from Columbus have been compiled to characterize freight energy use. Literature reviews have also been conducted, as well as identification of new modes and vehicle efficiency improvements along with analysis of consumer data on household transportation expenditures. The reviewer stated that for inter-city freight transport, preliminary national estimates for platooning have been established. Analysis models have been assessed and developed; data have been acquired on modal distributions, origin-destination, and vehicle operations out of Columbus; and data have been compiled on energy profiles and national freight modes. The reviewer said that being early in the project it is somewhat difficult to fully assess technical accomplishments to this point.

Reviewer 7:
The reviewer mentioned that some interesting results and accomplishments were shown and gave the example of the 5.2% annual energy reduction due to truck platooning as a meaningful outcome. The reviewer remarked that what seemed to be missing is a cost component, and that the 5.2% annual energy savings clearly saves money, but questioned what infrastructure or fleet investment was required to achieve this reduction. The reviewer wondered if the cost/benefit equation was even positive, particularly with freight being so cost sensitive, and said that this needs to be more strongly incorporated somehow. Going one step further, the reviewer suggested that there would be value in not only adding cost or cost/benefit aspects, but also the impact to the economy and/or jobs whether positive or negative.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the partners' list indicates an outstanding effort to create a diverse team that can provide significant unique contributions from each of its members, which include industry, academia, municipal government, and DOE national laboratories.

Reviewer 2:
The reviewer was impressed by the variety of collaborative organizations external to DOE.

Reviewer 3:
The reviewer noted that this project has a very good mix of laboratories, universities, industry and municipalities. The reviewer mentioned that if the project were able to get collaboration from additional groups that are light on information (listed in barriers), it would be an even stronger partnership and would mitigate risk.

Reviewer 4:
The reviewer remarked that this project has a broad array of partners and collaborators, including national laboratories, universities, industry, and metropolitan entities. The reviewer said that it would be good to continue to expand upon this list of partners, especially with regards to metropolitan partnerships. The reviewer added that at the end of the day, entities operating within metropolitan areas—be they transit agencies, airports, shippers, rail authorities, trucking companies, transportation networking companies, schools, medical complexes, large shopping districts, large builders, and so forth — will be instrumental in informing the direction and ultimately facilitating the implementation of smart mobility solutions. The reviewer mentioned that these entities "on the ground" would provide an invaluable perspective and insight into the real-world challenges and ultimately most viable pathways to successful implementation.

Reviewer 5:
The reviewer was curious about the fact that Amazon keeps getting mentioned as the major player in delivery of goods, and how its plans may change the intra- and inter-city freight delivery landscape significantly through the use of drones or other self-driving technology. The reviewer asked if there has been any attempt to reach out to them as a partner.

Reviewer 6:
The reviewer said that although the partners involved are very well coordinated, this project could inform or support further collaboration with OEMs or the EPA. The reviewer stated that the results of this study could provide further useful output by providing incentives through the EPA or informing the OEMs regarding future trends and recommendations.

Reviewer 7:
The reviewer pointed out that multi-modal freight analyses are a specialty within DOT, including mode switch and transloading facilities. The reviewer did not see any DOT link with this work, which is a gap. The reviewer stated that while DOT is charged with enabling a safe transportation system, it is also very involved with enabling an efficient, multi-modal, freight-filled system as well.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found that the proposed future research looked strong and impactful, and that to some extent, some of the prior concerns may be alleviated with this future research plan.

Reviewer 2:

The reviewer said that the future work description indicates that practical criteria are being evaluated in the analyses.

Reviewer 3:

The reviewer noted that after the data are modeled and ready to be reviewed, the step of analyzing those data and then determining how to collaborate on solutions makes sense. The reviewer suggested continuing to look for ways to incentivize the findings researchers get after analysis.

Reviewer 4:

The reviewer stated that this looks very solid, but questioned if the cost of the energy usage figured into the study, as some modalities might be very energy efficient but costly. The reviewer inquired if this should be a part of future work and if not, why not.

Reviewer 5:

The reviewer commented that the future research is laid out in a logical manner with data gathering, modeling, and adding multiple types of transportation to the model (freight, car sharing, etc.). The reviewer stated that there are assessments early in the project, but not many decision points are listed. The reviewer added that there were relevant barriers listed, but that risk mitigation was not described (alternatives if the barriers cannot be overcome). The reviewer said that the research is all very relevant and as the model is refined further, it will become ever more valuable to urban planning and DOE, as it will help at the macro level, not just at the component or micro level.

Reviewer 6:

The reviewer opined that the proposed future research for FY 2018- 2019 covers a lot of ground in all three of the focus areas. The reviewer stated that it is especially good that under intra-city passenger travel there is an emphasis upon analyzing short-term scenarios by mid-FY 2018. The reviewer added that it is especially important to target attractive areas of initial entry that make sense from the end-users' perspective for any variety of reasons including cost, legacy systems, etc. The reviewer said that in this way, some early "wins" could be achieved demonstrating quantifiable benefits. The reviewer mentioned that this would bolster support for the viability of SMART Mobility and provide a springboard for additional actions in the future. The reviewer noted that under intra-city urban freight delivery, it mentions the development of recommendations on adoption methods. The reviewer found this to be especially important and it should be researched in detail. The reviewer said it is likely that many of the same issues, like cost, lack of understanding, resistance to change, risk, existence of legacy systems, etc., that have bedeviled traditional alternative fuels and vehicles (be it compressed natural gas [CNG], electricity, etc.) are also going to challenge SMART Mobility. The reviewer explained that this makes it all the more important to really get down to the local level and thoroughly understand the guiding principles and constraints and what drives the decision making process there. The reviewer remarked that this "feedback loop" from the ground level would be especially beneficial in validating models, grounding future research directions and thrusts, and focusing implementation.

Reviewer 7:

The reviewer mentioned that the nature of this endeavor is so chock-full of uncertainty, that any answer that the researcher may arrive at can neither be proven wrong nor right. Given that, the reviewer said it would be good to lay out the expectations for these analyses, especially with regard to the range of expected uncertainty.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that the economic and energy impact from freight, particularly through the SMART Mobility lens, is extremely important going forward. The reviewer mentioned that this could become one of the most important economic advantages or disadvantages a nation has while competing on the world stage.

Reviewer 2:
The reviewer observed that the project explores optimal means of maximizing transport flexibility at the macro level while also maximizing energy efficiency. The reviewer mentioned that by selecting the most efficient pathways, this should displace petroleum.

Reviewer 3:
The reviewer stated that the project has the potential to help reduce petroleum displacement. The reviewer pointed out that by developing an energy usage model for transportation, it can help city planners see what effect changes in transportation or trends will have on energy usage. The reviewer said that the cities may be motivated by lower energy usage directly or reduced congestion, which leads to reduced energy usage as a secondary effect, but either way it supports the DOE objective of reduced petroleum usage (energy).

Reviewer 4:
The reviewer mentioned that the project description highlights that new business models are changing the way that our society transports people and goods. The reviewer added that the results of this study will help DOE and policy makers to understand how petroleum consumption will change with the adoption of the new transportation methods.

Reviewer 5:
The reviewer was of the opinion that collaborating on the optimized solutions found in the study will meet the goal of petroleum displacement.

Reviewer 6:
The reviewer said that at the high-level, smart mobility technologies have the potential to significantly reduce or increase petroleum usage, especially within the context of urban environments. The reviewer noted that what is intuitively obvious is that some elements are going to provide a positive benefit while others are likely to lead to negative energy impacts. The reviewer's view was that given that there is a steady migration of the population toward urban environments, it is important to identify and work to implement smart mobility strategies to reduce or at least mitigate the currently increasing petroleum and energy demand trends, especially within urban as well as more rural areas. The reviewer said that due to their congested nature, urban areas are not as typically conducive to traditional transportation energy reduction or displacement approaches. The reviewer added that in many cases, entirely new approaches, many of which are not vehicle- based, are needed to truly transform the urban environment.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the level of funding seems reasonable for the work done and the work to do. The reviewer could envision even an increase needed in funding depending on how the research progresses and what gaps are uncovered.

Reviewer 2:
The reviewer mentioned that the resources appear to be sufficient, and that the project is new but tracking according to schedule.

Reviewer 3:
The reviewer found the budget to be sufficient to provide results that begin to address each of the project objectives, and that a modest expansion of the funding may help to reduce project risk.

Reviewer 4:
The reviewer said that the resources appear to be sufficient.

Reviewer 5:

The reviewer commented that the currently identified resources of $4.5 million over 3 years appears sufficient to accomplish the Multi-Modal pillar project objectives. The reviewer stated that the broad team partners should have the technical expertise, equipment, and facilities to conduct the project successfully, but should be continually looking to expand team participation to other relevant entities to expand the base of resources and capabilities.

Reviewer 6:

The reviewer noted that this seems to be a very large sum of $4.5 million, but the amount of analysis and simulation required is also extensive. The reviewer did not think the sum is excessive for the scope defined.

Presentation Number: eems005
Presentation Title: SMART Mobility—Mobility Decision Science
Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory)

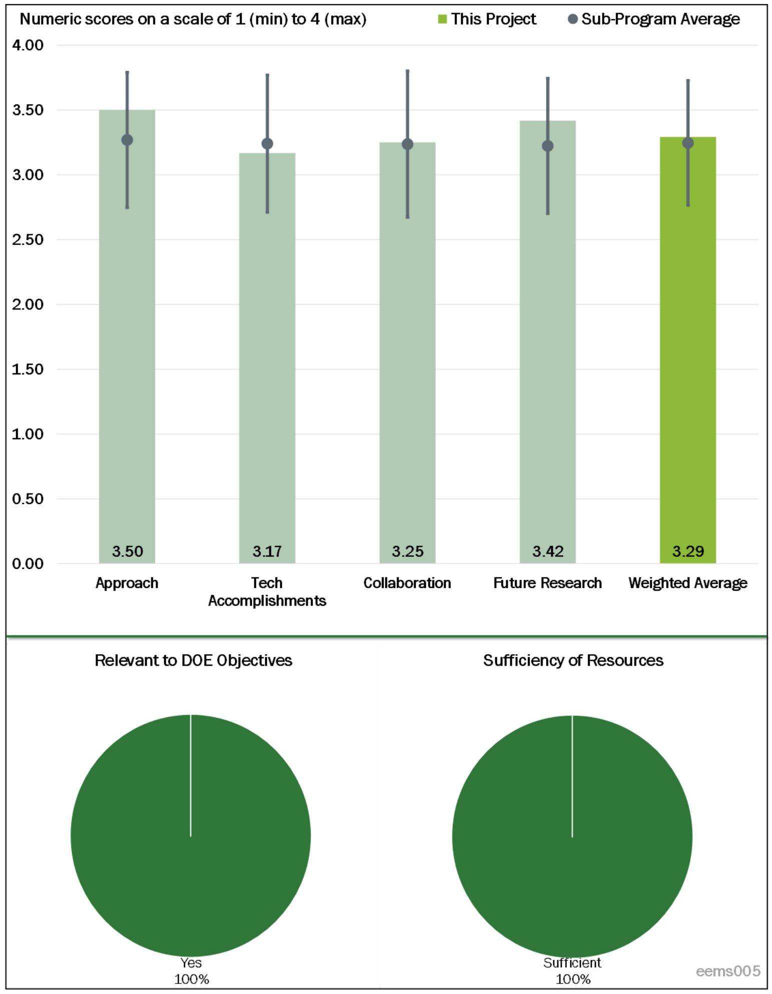

Figure 4-5 - Presentation Number: eems005 Presentation Title: SMART Mobility—Mobility Decision Science Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory)

Presenter
Anand Gopal, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that first, the entire CAV research environment has added an interesting and needed addition to the VTO at DOE. The reviewer said that this project appears to bring an expert academic approach and methodology to the very complex behavioral subject matter through an agent-based model approach. The reviewer said that the "WholeTraveler Project" analysis concept leading to normative behavioral change is a simply amazing analysis potential, and the reviewer looked forward to future progress.

Reviewer 2:
The reviewer said that this project as discussed is apparently a perturbation/response study, which is generally very good at identifying key contributors to energy use, including prevailing societal trends and what causes them. The reviewer hoped that this is able to build something that is predictive as a result and that could be used by the auto industry, municipalities, and the petroleum industry for marketing planning.

Reviewer 3:
The reviewer stated that this project seems to be very well structured and matched to the likely technical barriers.

Reviewer 4:
The reviewer commented that SMART Mobility is a relatively large area for analysis at a national level. The reviewer stated that the project's approach specifically recognizes this, and is therefore focused first on analysis at a regional level (the San Francisco Bay Area). The reviewer added that the project is trying to focus on the long run, rather than primarily short-term. The reviewer mentioned that the project approach explicitly includes processes to address initial results that may dictate changes in directions for future activities. The

reviewer said that this project presented an overview of all Mobility Decision Science projects, including specific ones presented elsewhere in the AMR.

Reviewer 5:

The reviewer found the mobility megatrends to make sense as presented. However, a common vocabulary will be needed, both in this program and DOE-wide, to discuss the topic. The reviewer said that the three questions for descriptive research are all very reasonable. Referencing the second question, the reviewer was unsure how the future vehicle sales increase or decrease is immediately relevant, unless second-order effects are considered (e.g., removal of parking lots, infill, and increased urban density that reduces trip demand and increases building efficiency).

Reviewer 6:

The reviewer noted that it is unclear how effective the life-history survey approach will be in analyzing the costs and benefits involved in new transportation options. The reviewer said that the survey likely can help document the characteristics of conventional transportation choices to include an aversion to accepting the risk of new technologies, but it is unclear how well a history-based model will be able to extrapolate decision constructs that lack historical precedence. The reviewer said that the project may want to supplement the WholeTraveler survey with some system dynamics modeling of the influences affecting traveler decisions.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that as this project is new, progress must be evaluated on how well the work plan is projected and barriers are identified. The reviewer remarked that the approach described in this effort is exceptionally well described for future success.

Reviewer 2:

The reviewer mentioned that the tiered timeframes of the decision model framework are a positive development. It appeared to the reviewer that the upgrades to the decision logic in POLARIS and Behavior Energy Autonomy Mobility (BEAM) are significant improvements to those models.

Reviewer 3:

The reviewer said that although the project is in an initial stage, it seems to be doing well in working toward its goals.

Reviewer 4:

The reviewer remarked that the project only began in fall 2016, and that it therefore seems like much of the effort so far has focused upon structuring activities, as evidenced by completion of the project plan for WholeTraveler. The reviewer said that data collection and analysis plans for estimating value of non-driving travel time have been completed.

Reviewer 5:

The reviewer reported that data collection and analysis through the “life history calendar” WholeTraveler Survey appear to be progressing and are promising for teasing out the medium- and long-term (longitudinal) choices that people make. The reviewer said the survey does not account for type of job, job hours, or job flexibility, which need to be provided by survey taker. The reviewer added that walkscore/transitscore/bikescore of home and job should be considered, as these matter for transport choice. The reviewer wondered how the recommended value of travel time (VOTT) estimates were developed/verified. The reviewer also thought it may be helpful to account for transportation network company (TNC) lease programs where the TNC pays for the vehicle out of the driver’s earnings.

Reviewer 6:

The reviewer commented that the advances already made in creating chronological life events and procuring global positioning system (GPS) data have been good. The reviewer thought it unfortunate that this project is derived from the San Francisco area, because driving behaviors, topography, and vehicle types are very different from most other regions of the United States.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that though the exact relationships within the collaboration group was not expanded upon (impossible in a 20-minute presentation), the collaborative partners appear to be from the highest quality institutions for this subject matter.

Reviewer 2:

The reviewer stated that this is a fundamentally collaborative project, and it seems that the interaction makes sense. The reviewer mentioned that it would be worth talking about collaboration outside of DOE in future presentations.

Reviewer 3:

The reviewer asserted that the project team includes all major laboratories, plus several universities, and that it would not be surprising to have seen additional partners added along the way as needs for these partners arise. The reviewer pointed that in particular, involvement of DOT and state DOTs would be expected to be pursued.

Reviewer 4:

The reviewer wondered how Mobility Decision Science is coordinating with DOT, in particular with the Smart Cities Challenge and with the ARPA-E TRANSNET program. The reviewer mentioned that the latter was mentioned but not in any detail, and because the objective of TRANSNET is normative behavior change through various forms of travel demand management, it would seem critical to coordinate with them for the future work in Mobility Decision Science.

Reviewer 5:

The reviewer remarked that the project team has the potential for strong contributions from several laboratories and universities, and that it is unclear from the presentation materials whether all the partners are coordinated and collaborating.

Reviewer 6:

The reviewer was of the opinion that as results come in from each collaborator, the ability for all participants to work together will be better assessed.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the plan to close the loop and test results is excellent. The reviewer added that in the past, technology changed at a slower pace. The reviewer clarified that with the pace of advancement today and likely in the future, it would be beneficial if results were able to be produced more quickly, and subsequently correlated to predictions.

Reviewer 2:

The reviewer commented that the project seems very well designed to interactively respond to changes in data availability and unexpected developments.

Reviewer 3:
The reviewer looked forward to updates in the future years on this and other EEMS projects. The reviewer said that this type of research can be wide-reaching from informing the needed engineering efforts to transforming our mobility/transportation systems.

Reviewer 4:
The reviewer indicated that most of the project is ahead because it started recently, and that it appears to be focused on doing the data collection, modeling, and analysis leading to obtaining answers to reducing barriers to technology acceptance. The reviewer said that this could well result in identification of new directions, and that the project team and DOE management have specifically taken this possibility into account, setting up a management team and go/no-go points.

Reviewer 5:
The reviewer noted that the mobility decision behavior models flow from the long-, mid-, and short-term choices. The reviewer said that it makes sense that people do not make transportation decisions, but life decisions that lead to transportation choices, as the speaker remarked. The reviewer added that there should be more fleshing out of the behavioral economics application of the normative work. The reviewer stated that even a number of strawman concepts beyond simulation would point to possible field studies. The reviewer mentioned that this would inform the normative work, working from the end backwards, and that coordinating with TRANSNET could inform the shape of the normative work—or even feed into TRANSNET.

Reviewer 6:
The reviewer found the future work descriptions to be logical but too sparse and vague. The reviewer remarked that one strong point of the outline was that it indicates that the project is using a review board to provide feedback on work progress before proceeding with the next steps.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer noted that SMART Mobility has the opportunity to improve efficiency, which will reduce petroleum use.

Reviewer 2:
The reviewer agreed that this project supports the overall DOE objectives of petroleum displacement, given the growing energy consumption share of transportation and the potential to reduce single occupancy vehicles. If decisions at all time scales from daily to decadal can be understood, there is good potential to reduce petroleum through appropriate interventions.

Reviewer 3:
The reviewer said that the project is working on reducing barriers to acceptance of new alternative fuel and higher efficiency vehicle technologies. The reviewer mentioned that this feeds in closely with VTO's objectives. The reviewer added that there is also a funding-constrained scope that has been developed in case the original level of funding is not available. The reviewer mentioned that addressing energy consumption impacts from SMART Mobility is relatively novel, as most projects by others in this area have focused more on the safety and logistical aspects.

Reviewer 4:
The reviewer stated that these forward predictive projects allow the greatest insight to accomplishing more efficient and greater electrified mobility, which will result in energy savings and reduced use of petroleum.

Reviewer 5:
The reviewer observed that the project is developing decision models relevant to new mobility options for travelers and consumers. The reviewer said that these decision models will help DOE understand the possible opportunities for incorporating viable energy consumption reduction mechanisms into future transportation options.

Reviewer 6:
The reviewer suggested that when industry or cities can react to the "marketing weather," then better decisions can be made regarding products to support energy reduction in those new environments. The reviewer stressed that those advances will only be made if there are incentives and clarified that nobody will introduce new product or make extensive changes unless they are free, and they most often are not free.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer brought up that the speaker mentioned a funding-constrained scope. The reviewer stated that it was not fully clear how much of the proposed scope can be done given the $9 million budget currently planned for.

Reviewer 2:
The reviewer commented that if planned funding continues, it should be sufficient. The reviewer stated that this area is currently planned for funding of $9 million.

Reviewer 3:
The reviewer chose "sufficient" because there was no basis for other consideration or concern.

Reviewer 4:
The reviewer noted that the budgeted resource allocation is sufficient to support significant progress in accomplishing the project objectives.

Reviewer 5:
The reviewer said that this was not discussed specifically, but that funding seems appropriate.

Reviewer 6:
The reviewer mentioned that the proposed budget for this project appears to be very large for such a limited geographic region of study. The reviewer questioned if all partners are needed, as sometimes collaboration can be expensive. It was disheartening for the reviewer to hear that the speaker did not believe there was sufficient funding even at $9 million, and said that perhaps there are inefficiencies that can be improved.

Presentation Number: eems006
Presentation Title: SMART Mobility—Urban Science
Principal Investigator: Stan Young (National Renewable Energy Laboratory)

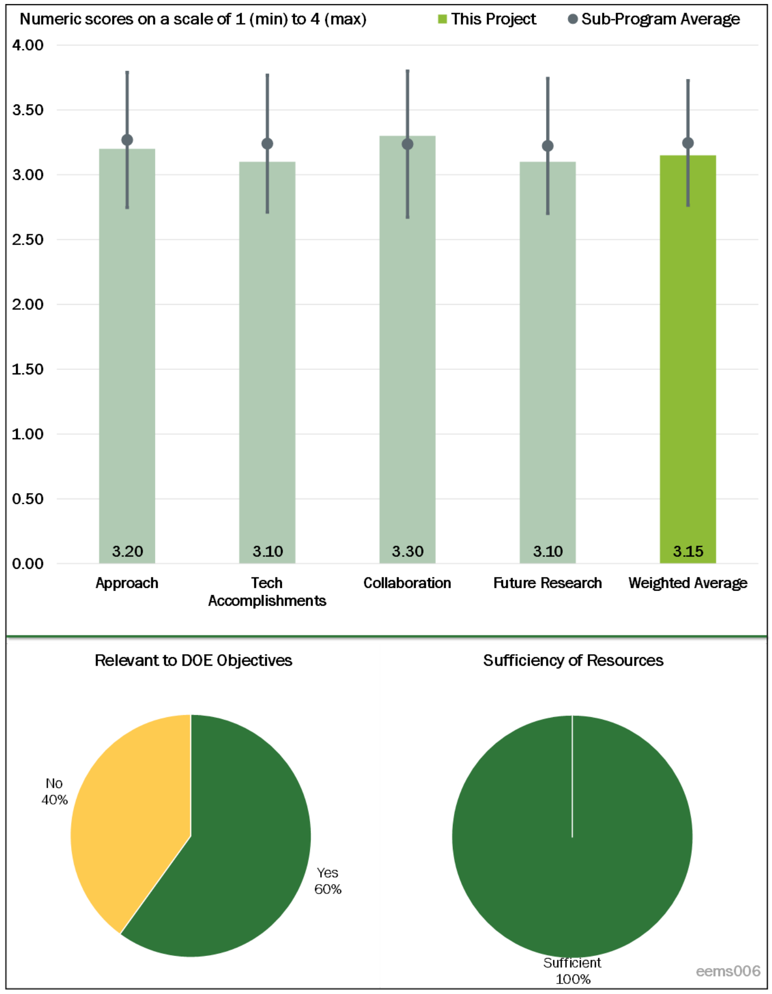

Figure 4-6 – Presentation Number: eems006 Presentation Title: SMART Mobility—Urban Science Principal Investigator: Stan Young (National Renewable Energy Laboratory)

Presenter

Stan Young, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed that the approach appears strong, particularly with the strong connection/engagement with cities that should maintain tight grounding to reality and stakeholder needs. The reviewer said that there are opportunities to improve further by incorporating some of the latest thinking—including high-performance computing (HPC), which was alluded to in the presentation—around model validation and advancement of model maturity.

Reviewer 2:

The reviewer acknowledged that it makes sense to capture all the data, case studies, and lessons learned, and house them in a location that would be accessible to other urban centers that are looking at how they can deal with the challenges. The reviewer remarked that the outline of the approach makes sense, but it was expected that the details will evolve as progress is made and more lessons are learned.

Reviewer 3:

The reviewer understood how computational models, design and simulation methodologies barriers are being addressed, but it was not clear how this project is addressing constant advances in technology.

Reviewer 4:

The reviewer said that this is a new area of investigation that requires new tools and methods to be developed. The reviewer stated that the approach is not yet fully mature and it would be expected to change over time. The reviewer pointed out that some of the elements that will create variation in the predicted outputs need deeper investigation, such as the effects of changes in volume and style of package delivery on traffic and parking in urban areas. The reviewer questioned if schools will become more “virtual” thereby taking the buses off the streets during rush hour. The reviewer added that to tackle the build of a complete enough transportation model environment, it will require future scenarios that must be accommodated in the model.

Reviewer 5:

The reviewer commented that the Urban Science pillar is a critical component of what appears to be a very well-designed and well-integrated five-pillar approach. The reviewer stated that, as an overarching comment, DOE deserves substantial credit and recognition for stepping into this space, as there has been a vacuum of interest and effort in trying to grapple with the challenging longer-term uncertainties involved in the mobility systems of the future. The reviewer said that other agencies and institutions seem to be reluctant to attempt to grapple with the uncertainties facing automation, connectivity, and how they will affect overall system behaviors over the long term.

The reviewer mentioned that the five-pillar framework is not perfect—no framework ever will be—but it is a bold and much-called-for step in an important direction. The reviewer said that the EEMS tagline to achieve "maximum mobility, minimum energy future," is not the best message to send. The reviewer suggested that it would be better to openly acknowledge that the end goal of transportation is not really more mobility in all cases, but is actually to improve "accessibility" of goods, services, and other desired destinations. The reviewer added that it may be the case that the Urban Science pillar is exactly the place to have this conversation—it seems like it might be the best place to raise and address the issue of how to combine the thinking about mobility systems with thinking about land use and the distribution of destinations into a unified macro-system that has a single clear goal of maximum accessibility.

The reviewer questioned if improved understanding of "urban science" can help identify ways to improve mobility without the damaging feedback effects in behavior and land use. The reviewer gave the example of times when improved mobility encourages less efficient travel behaviors, which in turn leads to less efficient land use. The reviewer clarified by asking what urban science can tell us about what needs to happen to enable better mobility (faster, better connectivity, lower travel times, lower cost) without encouraging sprawl. The reviewer explained that another way to think of this is to adopt the energy efficiency approach and ask how people can get access to all the things they need, with minimal movement, and how they can provide "mobility services" without the mobility expenditure. The reviewer mentioned that this is analogous to how the energy efficiency sector talks about providing "energy services"—such as desired temperature and lighting—while consuming minimal or no energy.

The reviewer said that the stated objectives include "methods, models, and data" on impacts and implications of smart mobility, but that there is not very much detail on other current and potential applications resulting from advances in urban science where there may be a lot of other tools and applications enabled by connectivity and better access to data. The reviewer expressed the thought that it would be interesting to take a broader approach to gain a better understanding of the entire flow of goods and people throughout a region, understand what drives those flows, and then examine how data-enabled tools might minimize those flows without impacting access. The reviewer gave an example of having better information about locating public services (hospitals, schools) and alternative "smart" ways to provide services, such as finding other technology solutions to minimize people's need to make trips. The reviewer suggested expanding the scope of this pillar to embrace the full range of everything the public and private sectors do and provide for people, consider the mobility demands related to those services, then do a full analysis of how those mobility demands can be reduced without reducing the ultimate delivery of services. The reviewer asked if there is some role to play for more "delivered" services, or pop-up type locations for a wider range of services. The reviewer remarked that one of the stated goals is to examine "how automation, connectivity, electrification, and shared use might impact the urban network/traveler." The reviewer mentioned that this could be broadened to include data and consider how cities might provide services differently. The reviewer pointed out that if the promises of big data are fulfilled and we can get a much better understanding of exactly where and when people need things, this should enable entirely new and hopefully much more efficient ways of providing goods and services.

The reviewer mentioned that there may also be other Urban Science-type options enabled by new technology worth considering, such as flexible-use road space where "smart-road" technology can make more efficient use of road space by allowing it to dynamically and automatically shift among parking, driving, or changing the direction of flow.

The reviewer said that in terms of models, it would be helpful to have a better description/diagram of the models in this pillar and how they fit together, or some other "taxonomy" of models. The reviewer observed that it looks as if the Urban Science pillar owns the Integrated Urban Mobility model, and this takes inputs from other pillars. The reviewer pointed out that it is not clear if this is a model or a collection of models, and how it relates to other existing models. The reviewer added that there is very little information online about Toolbox for Urban Mobility Simulation (TUMS), what it does, and how it relates to the other modeling efforts.

The reviewer mentioned that another helpful discussion would be to examine what tools exist to understand the nexus of mobility, behavior, and land use. The reviewer added that such tools would be very empowering for municipalities as they plan transportation and infrastructure investments. The reviewer clarified that if good tools exist, it would make sense for DOE to ensure they extend to cover energy consumption; if there is a lack of such tools, it would seem appropriate, then, for DOE to step into this space.

The reviewer indicated that there is also a general challenge facing the broader urban science (or "smart city") and urban planning sector, whereby the terminology sends the false impressiogn that the tools they develop and use are only useful for major cities and dense urban areas. The reviewer acknowledged that this is certainly not the fault of DOE, as this problem is widespread, but that it would be good for DOE to acknowledge and highlight the fact that urban science is about how people live and move and interact with the infrastructure. Urban science focuses on the built environment, but is not limited in its utility to just cities. The reviewer said that the issues in urban science are relevant wherever there are roads, settlements, development, and that they happen to be just a lot more intense and critical with bigger, denser cities.

The reviewer found the approach of spending significant time up front engaging with the seven Smart Cities Challenge finalists to be very strong. The reviewer remarked that it is important to invest the time to fully explore the problem space, and doing so with seven actual cities that have expressed interest and committed resources to achieving "smart city" type goals is a good approach.

The reviewer said that it is a good approach to spend time with the seven Smart City Challenge finalists and fully explore the problem space. The reviewer noted that Task 4.0 focuses on the "role of signal system in smart enabled city," and while this is surely relevant and appropriate, it seems oddly specific. The reviewer remarked that there are so many levers that operations managers can pull, and that signals are just one of them, so it is not clear why that deserves more focus than the others, such as dynamic tolling/congestion pricing, restricted parking/dynamic parking pricing, lane closures/lane-direction changes, etc.

The reviewer suggested that a more thorough explanation for how this pillar interacts with the multi-modal pillar may be called for. The reviewer was interested in knowing if DOE has examined any kind of multi-modal, macro system level, real-time operational concepts to improve efficiency. The reviewer said that based on this, it seems that the matrix of cross-pillar dependencies that is provided should include more interaction with the Multi-Modal pillar.

The reviewer remarked that 3 years is very ambitious, and that it may not be enough time to even fully gain an understanding of the potential role of Urban Science.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said that for an early project, the accomplishments have been notable, and that among successful various modeling workshops, validation of data input like counts, and incorporation of Automated Mobility Districts (AMDs), the project appears to be off to a strong start.

Reviewer 2:
The reviewer stated that the project appears to have made steady progress in each of the subtasks. The reviewer remarked that Slide 3 shows the range of percentage changes in energy consumption for a standard vehicle. The reviewer mentioned that it would be good to have seen this same graphic for an efficient vehicle as a "result" of this work.

Reviewer 3:
The reviewer noted that the project was initiated relatively recently and that in several areas of interest like platooning and vehicle right-sizing, there has been other work that has already been done by DOE-funded projects or other European consortia like the Safe Road Trains for the Environment project, for instance. The reviewer asked the presenter to ensure that the lessons learned from those various projects are carried over.

Reviewer 4:
The reviewer commented that there is not much to score this on as the team is only reporting on about 6 months' worth of effort. The reviewer mentioned that the work in Tasks 2.1 and 2.2 seems to have made solid progress, and that it is very positive that the team has successfully engaged with four of the Smart Cities Challenge finalists. The reviewer said that not much detail is provided for Tasks 2.3.1 and 2.3.3, and that this is understandable as this is an overview of an entire pillar. The reviewer mentioned that strong progress is shown in convening two workshops and establishing a collaborative relationship with the Mid-Ohio Regional Planning Commission. The reviewer said that the work done in Task 2.3.2 appears very strong, relevant, and valuable. It was not clear to the reviewer how this interfaces with the Multi-Modal pillar. The reviewer also remarked that there is not much detail provided for Task 2.4.

Reviewer 5:
The reviewer pointed out that this is a first year of a multi-year project and that it is still in an organizing mode, which should have been done during the proposal stage, hence the low score. The reviewer mentioned that there are therefore few technical accomplishments to discuss. The reviewer remarked that only organizing the project has been done to this point, and that where it does actually support DOE goals is not yet measurable. The reviewer said that the intent to satisfy any particular DOE goal is not stated at all. The reviewer remarked that this presentation does not state the barriers in the DOE strategic plan that were intended to be overcome as is requested in the AMR review instructions, but rather that the project team appeared to make up its own technical barriers.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that unlike some of the other projects where stakeholders were listed out of obligation with only modest actual collaboration, this project truly is collaborating very effectively through workshops and strong connection to the city stakeholders themselves.

Reviewer 2:
The reviewer said that good collaboration seems to be taking place among the laboratories and with the finalist cities. The reviewer questioned if there are other federal collaborations or coordination that should be taking place, for example with DOT.

Reviewer 3:

The reviewer mentioned that collaborations are still in development and that so far a few good ones have been engaged. The reviewer mentioned that this project needs a lot of input and a way to sift out opinion from fact.

Reviewer 4:

The reviewer found that there appear to be many laboratories, cities, and universities that are involved. The reviewer remarked that notably absent is the University of Michigan Transportation Research Institute, which has done a fair amount of research on driving habits going back many years.

Reviewer 5:

The reviewer commented that it is not clear how much collaboration there has been with DOT and what the nature of that collaboration is. The reviewer mentioned that it may be hard to discern, but DOT has extensive expertise on a range of urban science topics with extensive work in overall system safety and environmental impacts. The reviewer stated that the approach of reaching directly to interested and committed cities, such as the Smart Cities finalists, is a great approach. The reviewer said that regarding Task 4, it would have been helpful to know who the potential collaborators were. The reviewer recommended contacting the organizations in Europe that are doing extensive work with low-speed automated shuttles (e.g., Citymobil2).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer brought up one comment completely unrelated to this question, but completely applicable to all the SMART Mobility projects: because this is a relatively new area, and is replete with a large number of acronyms that keep evolving rapidly as well, it makes great sense to include a slide or two describing what all the various acronyms stand for. The reviewer asked if the presenter could elaborate on the type of data that need to be accessed from the Smart City finalists and the winner and how the presenter expects to use them for other aspects of this and other EEMS projects. The reviewer said that all the ideas look good, but there is not a lot of clarity in bullet points, and the devil is in the details.

Reviewer 2:

The reviewer said that future work is clearly planned, but that it would be been nice to have seen the correlation among future work and the remaining challenges and barriers (Slide 18 of 26), each of those future work activities is designed to tackle.

Reviewer 3:

The reviewer stated that the future research slides show a significant amount of important work ahead. The reviewer remarked that the only missing piece to which not much attention was given was on costs as factors or constraints. The reviewer said that these would include implementation/infrastructure costs, as well as the cost/benefit analysis that in the future will increasingly need to be more positive than in prior years. The reviewer remarked that energy savings are clearly an easily tangible benefit, but may be overwhelmed with the infrastructure costs necessary to save that energy. The reviewer added that there may be other benefits that need to be incorporated, such as social costs.

Reviewer 4:

The reviewer praised the approach for future work overall as very strong and well thought out. In particular, the use of scenarios as a way to deal with uncertainty is very promising. The reviewer stated that as discussed earlier, it might be even more valuable to capture some of the indirect effects in those scenarios, such as land use impacts. The reviewer said that as noted earlier, working directly with cities is a good approach, but it might be worthwhile to consider balancing this out by engaging with some other institution less constrained by day-to-day operational concerns, perhaps with more capacity for imagination like an "urban institute," a university, or a quasi-academic institution like the Massachusetts Institute of Technology Media Lab.

Reviewer 5:

The reviewer said that it is still under development and that the overall objective is not fully defined yet. The reviewer said that a general idea of "we want to model smart mobility" is what is currently being worked with, but that by this time one would have assumed that the team would have developed a clearer path to achieve success. The reviewer stated that this one is vague.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer indicated that this work is absolutely relevant and that, if anything, it does not go far enough. The reviewer said that this pillar is beginning to fill a very long-standing and very major gap in DOE's approach. The reviewer mentioned that for too long, there has been no focus at the federal level on how to make entire urban/human-settlement systems more efficient overall. The reviewer recalled that in the past, developing energy efficient vehicles without addressing the way those vehicles are used was somewhat analogous to developing a more efficient furnace without considering how to make the whole building more efficient. The reviewer stated that this is a very welcome solution and is essential to pursue.

Reviewer 2:

The reviewer noted that with cities at the core of population growth and future mobility needs, urban science is clearly a relevant topic.

Reviewer 3:

The reviewer said that the project describes its relevance on Slides 3 and 4, but that the problem with these slides is that there is no quantification of how much petroleum is displaced. The reviewer clarified that there is a quote on Slide 4 that says, "Cities consume close to 2/3 of the world's energy...," but this project does not mention what portion of that is from transportation and how much of that consumption it is trying to reduce. The reviewer stated that the project itself is too broad to provide real metrics. The reviewer remarked that perhaps the individual projects in this pillar (Urban Science) address petroleum displacement in more concrete numbers, but it was not clear how those projects' metrics rolled up into this project.

Reviewer 4:

The reviewer observed that if congestion is reduced, it would reduce petroleum but the current status of the project would not currently be able to claim that. The reviewer mentioned that the estimate of how a smart system would or would not reduce petroleum use is shown to be quite varied from a negative effect to a wildly positive one. The reviewer added that what happens with petroleum use will not be affected by this project, but by what the vehicles themselves may realize, which is excluded as a subject of study in this project. The reviewer said that all this project will do is set up an urban prediction of energy use that may be better or worse than current per capita energy use.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that while the funding is likely sufficient, it leans low. The reviewer mentioned that this activity perhaps could need more funding to ensure the outcomes are best executed.

Reviewer 2:

The reviewer indicated that while the resources appear to be adequate on the surface, this is not an area that should be skimped on, by any means. The reviewer said that minor advances in these macro system-level areas may completely outweigh major improvements at the vehicle level. The reviewer added that one need look no further than the examples of Western Europe and Japan to see that what makes economies there much less energy intensive than ours is not that they all have much more efficient cars (this surely helps, but does not explain the entire disparity), but that their whole mobility systems are more efficient overall. The reviewer mentioned that it is not clear if this will be completed in a "timely fashion" because it is an entire pillar of work. One concern the reviewer had is that the time issue may not be addressed through more resources. The reviewer remarked that getting a better handle on the messy sprawling issues of urban science may take many iterative discussions, revisions, and stakeholder engagement, and that these are all kinds of things that cannot be rushed, regardless of the resources that are provided.

Reviewer 3:

The reviewer said that the resources are sufficient to excessive.

Reviewer 4:

The reviewer said that it is easy to say sufficient for now because it is not clear as to what exact level of effort is required to meet the milestones. The reviewer stated that the answer to this question is always a guess because the review does not address resources specifically.

Presentation Number: eems007
Presentation Title: SMART Mobility Stakeholders—Curating Urban Data and Models
Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory)

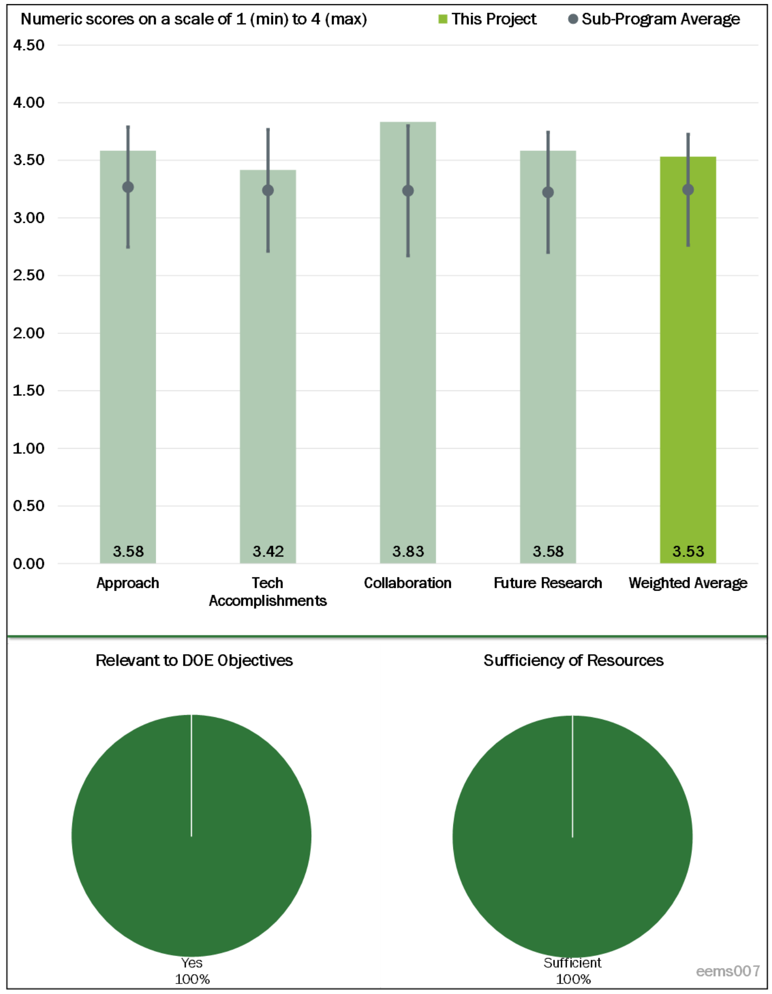

Figure 4-7 - Presentation Number: eems007 Presentation Title: SMART Mobility Stakeholders—Curating Urban Data and Models Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory)

Presenter

Joshua Sperling, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that similar to all of the EEMS projects, this project projects an excellent approach by means of methods and analysis to gain understanding of the urban mobility space. The reviewer stated that actions taken from this analysis could be transformative to the mobility future, resulting in significant environmental impact.

Reviewer 2:

The reviewer stated that this project is early in its progression, but has a very well-defined plan with many collaborators. The reviewer remarked that the risks of making wrong decisions were discussed and the presenter made it clear that this study is required to ensure we have some guidepost to avoid the "nightmare" scenario.

Reviewer 3:

The reviewer commented that the overall project seems to be very well-structured and this specific portion is important in ensuring a useful outcome.

Reviewer 4:

The reviewer indicated that the approach is solid.

Reviewer 5:

The reviewer found the PI to be appropriately focused on barriers in working with multiple external entities and to have a vision of what the project results should be. The reviewer suggested that some specific goals be set for both the curation of data and models and the development of common datasets to be used by the participating cities.

Reviewer 6:
The reviewer pointed out that the workshopping, curating, and convening of city partners and mapping their datasets and decision support systems for planning and policy are an ambitious but necessary task. The reviewer said that the only risk here is being too ambitious in scope and that the researchers may need to focus more narrowly. The reviewer remarked that understanding the nature of existing models and identifying/filling their gaps are clearly something that has not been done before.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer asserted that this is a great project and is moving along well.

Reviewer 2:
The reviewer said that progress to date looks good.

Reviewer 3:
The reviewer stated that for being in its early phases, this project has done some data gathering already and appears to be on track.

Reviewer 4:
The reviewer noted that it is very early in the project development, but that excellent progress has been made in coordinating the participant cities. The reviewer remarked that multiple workshops have been held and a good understanding of methods used by each city is being developed. The reviewer suggested that a more detailed schedule for the balance of the project be developed and/or presented, providing specific milestones and anticipated work products.

Reviewer 5:
The reviewer said that the curation and analysis of existing models of the Denver Regional Council of Governments and other regional transportation models are underway, including Dynamic Traffic Assignment, four-step, and activity-based models. The reviewer explained that there is a framework for analyzing each of the models so their inputs, outputs, and key attributes are being teased apart. The reviewer remarked that some of the early results were shown; initial results shown support benchmarking of cities and segmenting similar cities to understand what determines their per capita vehicle miles traveled (VMT) and parking supply. The reviewer mentioned that reading the Smart Cities Challenge finalists' proposals is a good approach to capture existing datasets and gaps, as are the one-on-one engagements with city agencies. The reviewer was not sure how well success can be measured in this project and suggested that metrics should be crystallized a bit more.

Reviewer 6:
The reviewer saw that, as per all new projects, the accomplishments must be interchanged with plans for success. The reviewer stated that accordingly this project reflects an insight to a very complex set of problems in the space of urban science and mobility while realizing the relationship to behavioral and decision science with urban mobility.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that coordination with multiple cities is an ambitious and difficult effort, and that the PI is to be commended for the dedication to make this happen. The reviewer exclaimed that it is a great effort.

Reviewer 2:

The reviewer remarked that though the concise relationship of "The Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility Lab Consortium" is unclear at this time, a better skilled group of scientists could not be found. The reviewer mentioned that leveraging the national laboratories in a consortium fashion is an incredible accomplishment of DOE and should have great benefits.

Reviewer 3:

The reviewer stated that there appears to be a good planned collaboration with the data gathering entities to pull together the necessary information.

Reviewer 4:

The reviewer said that it is a great team covering all bases.

Reviewer 5:

The reviewer pronounced that this is a fundamentally collaborative project. The reviewer mentioned that in the future it would be useful to spend more time talking about collaboration outside of DOE.

Reviewer 6:

The reviewer indicated that coordination with the Smart Cities Challenge is strong, including the four partner cities and also with the National Institute of Standards and Technology's Global Smart City Transport Event. The reviewer stated that perhaps a collaboration with the World Economic Forum should be considered as well.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer found the overall project to have a well-developed plan and that this project in particular appears to have a clear roadmap.

Reviewer 2:

The reviewer said that it is right on the mark for future research.

Reviewer 3:

The reviewer pointed out that the plan to create future models for the Smart Cities is going to be a learning experience and should result in improved planning for reduced energy usage. The reviewer noted that when this is coupled with potentials for municipal revenue, it should encourage realization of value for this work.

Reviewer 4:

The reviewer stated that the integration of the data models to inform the scenarios for future energy consumption analysis was not discussed at length, but the three scenarios discussed seem like a good starting point. The reviewer said that given the reliance of the project on outside actors beyond the project's control, strong relationships with the cities will be key to develop and maintain. The reviewer mentioned that the project is already considering the available policy levers to influence planning and operations, e.g., airport fees for TNCs that would fund charging stations.

Reviewer 5:

The reviewer reported that the project is observing and quoting an extremely well-defined project plan to do the following: leverage data integration, visualization, and analytical tools to accelerate planning and decision making on urban futures; curate Smart City partners (DOT), transport models, and data to include in a repository for urban mobility science and research; extend data as a basis to exercise/advance urban models; and identify the impacts of SMART technologies on urban travelers.

Reviewer 6:

The reviewer observed that there is recognition by the PI that coordination of the participant cities and development of datasets and, potentially, models that are useful across the city group are an evolving effort. The reviewer remarked that additional milestones and anticipated results should be developed to support project planning and maintain a project focus.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer pointed out that the overall project is intended to facilitate transportation improvements that would improve efficiency and therefore decrease petroleum use.

Reviewer 2:

The reviewer said that this project supports the overall DOE objectives of petroleum displacement.

Reviewer 3:

The reviewer noted that by the very premise of this type of project/analysis, the end result is intended to provide direction in the efficient actions and decisions of future urban mobility, thus realizing a reduction in energy per human and therefore in the use of petroleum.

Reviewer 4:

The reviewer stated that the growing share of energy consumed by transportation in the United States and the strong correlation with urban density (the Marchetti curve) underscore the importance of understanding how city-regional travel models fall short in enabling more efficient land use and zoning that would decrease petroleum consumption.

Reviewer 5:

The reviewer explained that if the cities can prosper and save money because of reduced energy usage, and if they can open up land that previously had to be used for parking or roads, the effort to clean up the mess made by personalized transport will be self-sustaining.

Reviewer 6:

The reviewer remarked that it is not clear that evolving smart mobility systems will reduce or increase fuel consumption. The reviewer stated that it is, however, clear that this is the most significant issue urban planners will face in the coming decade. The reviewer stated that the support of their efforts to create a utopia and not a nightmare is extremely relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that this is very much a level of effort project, and that resources are sufficient at this stage of development. The reviewer remarked that as the project progresses and specific data needs are developed, additional resources may be required.

Reviewer 2:

The reviewer found the funding to be appropriate.

Reviewer 3:
The reviewer stated that resources are good for this project.

Reviewer 4:
The reviewer said that without any basis for differentiation, the resources appear to be sufficient.

Reviewer 5:
The reviewer heard no comment in this presentation about lack of funding.

Reviewer 6:
The reviewer suggested that this is a tall mountain to climb, and that no matter how much funding is thrown at this project, there will probably be more work to do.

Presentation Number: eems008
Presentation Title: Impact of Population Shift on Energy Use: Detroit Use Case
Principal Investigator: Josh Auld (Argonne National Laboratory)

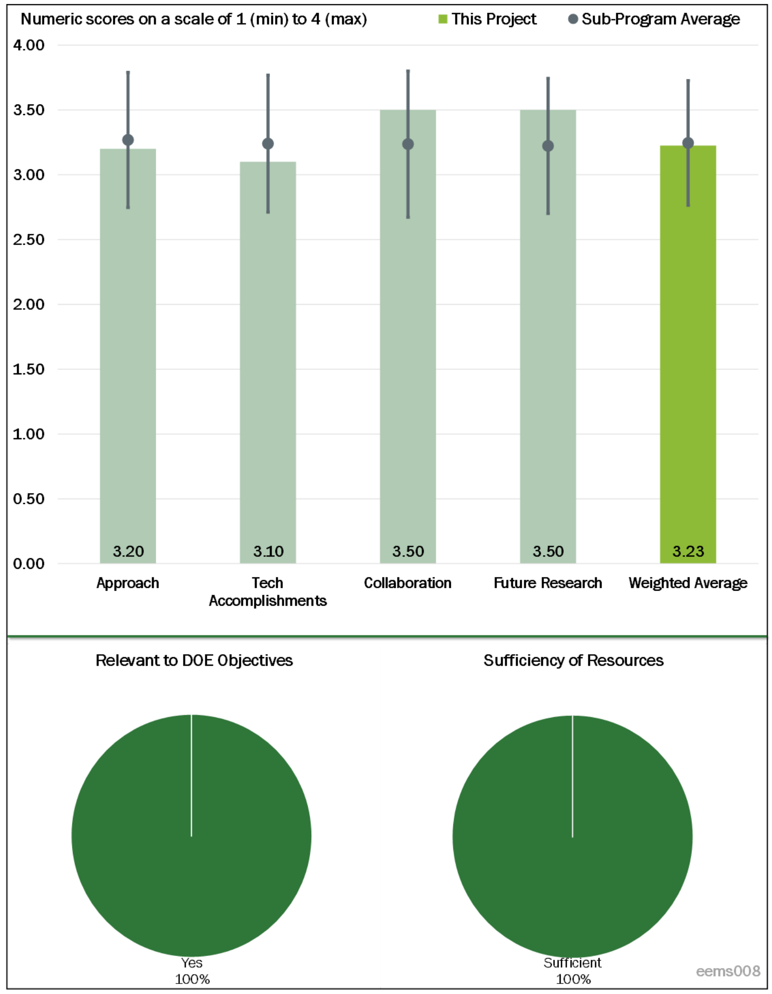

Figure 4-8 - Presentation Number: eems008 Presentation Title: Impact of Population Shift on Energy Use: Detroit Use Case Principal Investigator: Josh Auld (Argonne National Laboratory)

Presenter

Josh Auld, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project's approach appeared to be very robust, adapting POLARIS from Chicago to Detroit, and it did a good job involving stakeholders along the way.

Reviewer 2:

The reviewer thought the approach to the project was well done. The reviewer commented that the technical barriers were addressed and the project was able to adhere to the timeline reported. The reviewer noted that there was not any mention in the presentation of integration of this work with other efforts. The reviewer believed that because this project falls under the EEMS Urban Science pillar, it would be been nice to have seen its relationship to that pillar and the EEMS work on a slide. The reviewer found the work to be a very interesting, stand-alone project.

Reviewer 3:

The reviewer found the approach taken by the project to be a good beginning to extend to other projects and to learn from any mistakes that may have been made. The reviewer noted that routes in Detroit are constantly in flux due to construction, and a comment about that would have been worth including in the presentation. The reviewer hoped that re-routing due to construction would not be a constant in Detroit or anywhere else, but believed it certainly must have skewed the results of this study.

Reviewer 4:

The reviewer pointed out that this was a low-funded project that only used existing datasets and questioned its correlation to the real world. The reviewer was confused as to the way the region was modeled. Specifically, the presentation only shows work for Detroit, Wayne County, and Washtenaw County when, in actuality, the majority of the population in southeast Michigan lives in Macomb and Oakland Counties and their transportation patterns greatly affect what happens in the city of Detroit. The reviewer mentioned that in response to a question during the AMR, the presenter stated that Macomb and Oakland Counties were included in the study. However, the reviewer noted that there is only reference to counties other than these two in the presentation and requested clarification. The reviewer stated that this project appeared to be a low-key application of POLARIS with whatever data were available.

Reviewer 5:

The reviewer noted that land use patterns are set exogenously in the scenarios and believed that that is a major limitation, due to the fact that if feedback is not allowed for between land use and transportation behaviors, the project team may end up with unrealistic scenarios. In other words, there may be inherent tipping points in the system that make certain land use patterns unstable, so leaving them as “fixed” in a scenario and not allowing them to adjust in response to changing behaviors may not be realistic. The reviewer noted that it was understandable, however, that this is a small project, and that this level of modeling may simply have been beyond the scope and capacity of the project. The reviewer stated that if land use is taken as a fixed element, then the outcome is to effectively isolate the question of what these specific land use and population scenarios do to VMT, which the reviewer believed was a valid question, but fairly limited. The reviewer noted that, taken in isolation, the project appears to do a good job of illustrating the one-way causal relationships between land use and population on the one hand, and VMT and employment on the other.

The reviewer stated that POLARIS appears to be an appropriate tool, but the presentation would have benefited from greater discussion of alternatives. Furthermore, it was unclear if other models/approaches were considered.

The reviewer commented that the explanation provided about the relationship among some of the components of the modeling approach was unclear. As an example of this confusion, the reviewer listed the diagram on Slide 5, which seems to indicate that population drives vehicle choice, which drives home and workplace choice, which generates activity demand, which defines traffic flow (which appears to have a feedback effect, where traffic flow is allowed to potentially limit activity demand), which in turn defines vehicle choice. The reviewer is confused as to where mode choice fits into the model, and whether there is any mechanism for traffic flow to influence home and workplace choice directly. The reviewer also noted that it was not clear why traffic flow would be a major input to vehicle choice, and cited the fact that one regularly sees four-wheel drive pickup trucks built for off-road use or heavy cargo hauling, stuck in urban traffic with one occupant and no cargo. The reviewer thought that right-sizing and appropriate vehicle-selection are better addressed separately. In conclusion, the reviewer commented that the relationship between right-sizing and vehicle selection seems like a much less important relationship to understand than the relationship among traffic flow, travel times, and home/workplace choice.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that a significant amount of very useful data was produced and presented. The reviewer further noted that by being able to actually show the regional energy reduction through Detroit Future City’s (DFC) plan contrasted with Southeast Michigan Council of Governments’ (SEMCOG) plan, the output can and did inform Detroit and regional planners in a very tangible way.

Reviewer 2:

The reviewer noted that the results were clear, easy to understand, and well presented. The reviewer commented that the results themselves did show how the trips and VMT could be reduced under certain city planning scenarios. The reviewer stated that there is a citation for a working paper in the reviewer slides that could not be found in a web search and suggested providing the links to any citations in the body of the presentation.

Reviewer 3:
The reviewer commented that this was a very limited scope project that took existing data and attempted to analyze and create conclusions as to how varying future predictions may impact energy use levels. The reviewer noted that the project was done, but was not sure how representative the original datasets are to venture an opinion regarding how well the differences were analyzed and compared.

Reviewer 4:
The reviewer indicated that it was not clear exactly how Detroit used these studies to inform their future; however, the reviewer saw offshoots for use of the data. One potential use listed by the reviewer was real drive traces for the area, which could be used to improve vehicles in those areas.

Reviewer 5:
The reviewer stated that the presenter explained that the project's goal was to better understand why people do what they do. The reviewer noted that if this explanation implies the project is attempting to answer the question of what the one-way causal relationship is between population and land use and people's travel behavior, then it has done a good job of answering that, or beginning to sketch in a piece of an answer. However, the reviewer stated that this is not a truly systemic answer.

The reviewer commented that the logic applied to convert the land use changes into employment and population forecasts appears solid and well thought through; however, there is a nagging thought that the model rests upon a kind of "build it and they will come" projection; if we designate an area for a certain type of land use, it will be done and population and economic activity will adapt accordingly. The reviewer stated that this is an unusual approach, but it does answer the key "what if" question that should be of value to city planners of what the energy impacts from transportation would be if we are able to achieve certain land use scenarios.

The reviewer emphasized that this is a useful tool for thinking about goals for land use and related impacts; however, it should also be made clear at every opportunity that this is only a scenario-based model and has little value as a "predictive" tool for what the future could look like.

The reviewer noted that, on Slide 14, the presenter glossed over the comparison between baseline model results and existing data sources, and the reviewer believed it was unclear how close those outcomes actually are. The reviewer said that from looking at them there are some obvious differences and further noted that there was no discussion of whether there was any iteration or any attempt to re-calibrate.

The reviewer commented that in the changes in mobility indicators on Slide 16, it was unclear why average travel time is the same for SEMCOG 2040 and DFC 2040 when there are substantially fewer auto trips and substantially lower VMT in the latter case. The reviewer found it hard to believe that the difference between a 3.2% increase in VMT and an 8.8% decrease would amount to no difference at all in travel time. The reviewer believed that there must have been some increase in congestion.

The reviewer noted that there is accounting for mode choice; however, there does not appear to be a mechanism for addressing systemic impacts on mode choice. For example, when more people travel by bus, bus revenue increases, more buses are added, and frequency of service improves, which makes the bus a more appealing option, which leads to more ridership, and so on. This creates a virtuous cycle, which, of course, can also emerge as a vicious cycle if ridership drops. The reviewer commented that this effect does not appear to be modeled.

The reviewer noted that on Slide 16, there is a connection drawn between denser land use and increased transit and walking. It was not clear to the reviewer whether feedback effects are accounted for either. For example, increased transit ridership leads to improved levels of service as more buses are added. Increased walking to and from transit is also likely to have a land use impact by increasing foot traffic and potential for retail access. In short, there are a number of "smart growth" factors that tend to reinforce each other, and it does not appear these relationships are fully considered. It is understandable, though, given the size of this project if such considerations are outside of scope.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer opined that this project could be a showcase of the power of DOE, the national laboratories, and how they can collaborate and inform a local area. The reviewer did not think there would have been more enhanced outcomes involving the FHWA, the FTA, or others from the DOT.

Reviewer 2:

The reviewer commented that the project team made the proper connections to get the data needed for this project. The reviewer believed that the project team was resourceful in the areas where the data needed were lacking.

Reviewer 3:

The reviewer stated that there was good collaboration with the city of Detroit and good collaboration with those doing the modeling, leading to completion of this project. The reviewer noted that outreach of this project to the industry and the EPA would be useful.

Reviewer 4:

The reviewer remarked that given the size and scope of the project, the collaborations seemed appropriate. The reviewer noted that it was essential that the project collaborated with SEMCOG, and the additional collaboration with DFC was a little illustrative icing on the cake to develop one scenario. However, the reviewer believed that other inputs may have been more interesting and illustrative and suggested finding an extreme scenario for Detroit, especially considering that the city, given its staggering collapse in population in the latter half of the 20th century, has the land and the flexibility to take many different paths in the future. The reviewer suggested sketching out an extremely efficient, transit-oriented-development focused future. Lastly, the reviewer stated that there was not much discussion of integration with other efforts, but this was understandable as the project precedes the five SMART Mobility pillars.

Reviewer 5:

The reviewer indicated that only government partners were involved to provide data and thought the collaborations as presented were limited.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the project is complete and noted that any proposed future research that was presented is not related to this funding as it has been completely exhausted.

Reviewer 2:

The reviewer said that because this project is finished, there is no further work and it will begin with the other pillars doing similar work.

Reviewer 3:

The reviewer commented that while the Q-line was only mentioned in the question and answer portion of the presentation, studying the Q-line data as well as working with planners to possibly address the other corridor that would benefit from a similar system, the Interstate 94 corridor would be very valuable to all involved.

Reviewer 4:

The reviewer stated that while this project has ended, it had identified some good examples for how to use the model and its approach. The reviewer believed that examining the energy impacts of future smart mobility strategies was of special value. The reviewer noted that related future efforts would suffer from the weaknesses pointed out earlier, and noted there did not appear to be a good accounting for feedback effects.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that Detroit has been informed about ways that their infrastructure may be improved and potentially how to respond to changes in population load and that these takeaways may have already resulted in new public transport methods that were mentioned by other reviewers.

Reviewer 2:

The reviewer mentioned that Slide 3 shows one of the objectives of the project is to evaluate energy and mobility impacts of various cases. The reviewer noted that the results demonstrated on Slides 16 and 17 show how energy and petroleum can be reduced. The reviewer stated that this project provided the data needed for the city planners to be informed when taking action. The reviewer believed that if the planners were to execute per the model, the petroleum displacement would be realized.

Reviewer 3:

The reviewer pointed out that there was no way to say for sure, as there was no understanding as to which of the two models may be realized. The reviewer said that the analysis shown could spur actions toward energy use reduction policies.

Reviewer 4:

The reviewer observed that the project does an adequate job of emphasizing the importance of understanding the energy implications of changes in land use and population, which is a very critical question and one that demands far more attention than it has gotten in the past. The reviewer noted, however, there is something lacking in the connection to the other work of the VTO. The reviewer stated that it could be made more explicit that population and land use are key drivers of VMT, which in turn drives the overall impact of VTO's other efforts.

Reviewer 5:

The reviewer said that the project is highly relevant to the Detroit region, but questioned how easily transferable the work would be to other cities. The reviewer stated that while this was addressed in the presentation, it was unclear which cities already have the necessary input data, or even what inputs are required so that a similar project could be ported to other areas.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that, because the project is complete and is out of funding, the funding appears to have been sufficient.

Reviewer 2:

The reviewer found the funding to be sufficient as the project is complete.

Reviewer 3:

The reviewer noted that the overall cost of this project seemed to be low for the accomplishments made and was satisfied that this was money well spent to benefit a single city. The reviewer hoped the experience here will result in improved methods in analysis of other cities.

Reviewer 4:

The reviewer remarked that the resources were appropriate for this limited scope project. The reviewer noted that it would be nice to have had a few additional resources to roll this analysis out to additional cities or create awareness at other cities of this capability and have them exercise this model and team in their future planning efforts.

Presentation Number: eems009
Presentation Title: Energy Assessment of Automated Mobility Districts
Principal Investigator: Stanley Young (National Renewable Energy Laboratory)

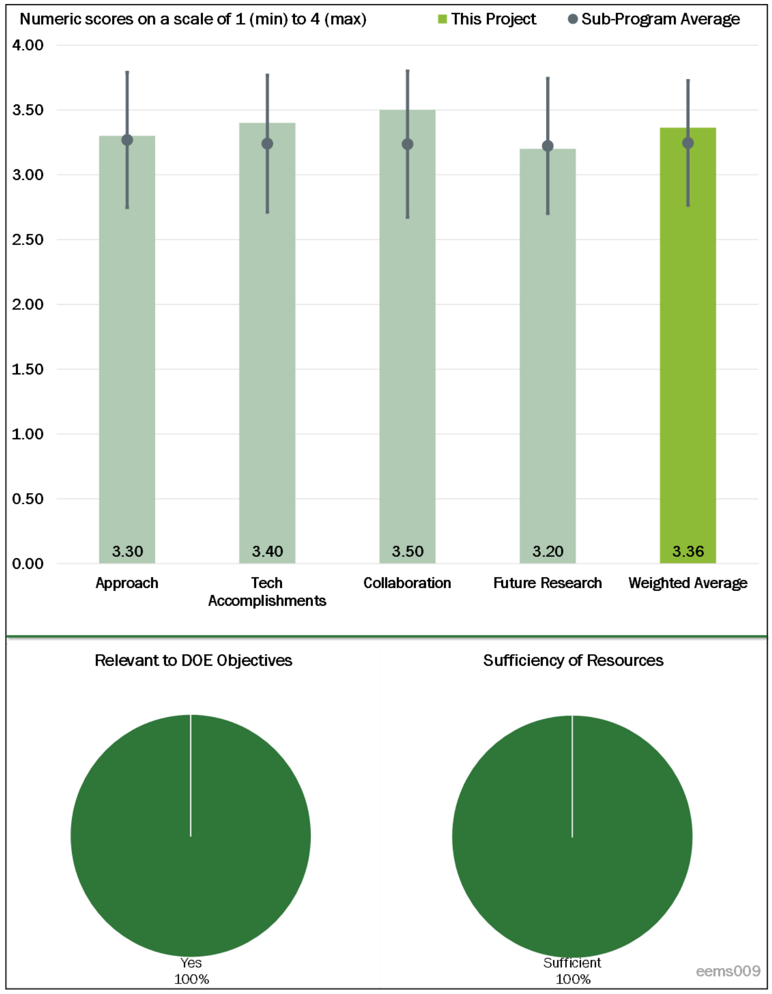

Figure 4-9 - Presentation Number: eems009 Presentation Title: Energy Assessment of Automated Mobility Districts Principal Investigator: Stanley Young (National Renewable Energy Laboratory)

Presenter

Yuche Chen, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer asserted that the project took a great approach.

Reviewer 2:

The reviewer noted that the elements of the project—a white paper, stakeholder identification, and developing a modeling architecture—seem like the right way to approach the work this year. The reviewer commented that the four dimensions being considered for energy impacts of AMDs are reasonable, though it was not quite clear how “traveler attitudes” are an input. The reviewer was unsure if this referred to acceptance, valuation of travel time, or something else. The reviewer stated that exercising the model with local government either implementing or planning an AMD will be important to validate the model and cautioned against relying too heavily on fixed guideway personal rapid transit (PRT) studies from the 1970s and 1980s as there are good reasons that PRT never materialized as a viable transport system.

Reviewer 3:

The reviewer commented that by use of highly controlled boundaries, the AMD study approach offers a high potential of “practical” data to validate models in a reduced timeframe. The reviewer stated that this method, and others like it, are necessary first learning steps before widespread automated mobility adaptation.

Reviewer 4:

The reviewer said that the overall project is great and this project seems good, but it is not clear how it fits into the overall project and will coordinate with the other elements.

Reviewer 5:
The reviewer acknowledged that the approach depends on finding a proposed AMD to model and obtain data from, and noted that this is a tenuous dependency that should be addressed to firm up the collaboration partner and remove this significant barrier.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the project is still at an initial stage, but seems to be on the way toward producing useful results.

Reviewer 2:
The reviewer said that the project is right on plan.

Reviewer 3:
The reviewer noted that the foundational work on the energy analysis of smoother drive cycles on automated vehicles (as would happen in an AMD) is similar to the DOT's Intelligent Transportation System Joint Program Office (ITS-JPO) Applications for the Environment: Real-Time Information Systems program, and the reviewer noted that it would be helpful to cross reference and validate against DOT's program.

The reviewer stated that the project's current work is surveying and identifying AMD planning and early implementation efforts, including the types of campuses and service models. The reviewer noted that the project also surveyed trip generation models.

The reviewer remarked that the role of parking in these AMDs is unclear between being a park- and-ride type of concept or for storage of AVs during off-hours. The reviewer said that the major challenge is that little AMD data exist from actual implementation, and stated that the project will need to determine which model inputs to fix and which ones to keep refining and validating as data from new implementations trickle in. The reviewer also noted that infrastructure within an AMD could be different from the general transport network, including better integration of pedestrian, bike, transit, and other modes and challenged the project to reflect these inputs in the model.

Reviewer 4:
The reviewer commented that this is a new project and the "accomplishments" are perhaps blended with the "planning," but stated that the project has a clear and rational objective that appears to be well scoped and underway.

Reviewer 5:
The reviewer stated that the project is in its early stages and to date little progress on modeling is evident. The reviewer suggested developing a detailed scope and schedule for work beyond September 2017, the last date on the milestone slide, to better focus modeling work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that this is a fundamentally collaborative project.

Reviewer 2:
The reviewer observed that there is a good team assembled.

Reviewer 3:
The reviewer commented that two DOE laboratories and two universities are project partners, but no city partner that is planning to implement AMDs has been identified. The reviewer noted that the DOT's Smart Cities is cited as a possible beneficiary, but was also an input, for example, by reviewing the Smart Cities applications for how AMDs were proposed to be implemented. The reviewer stated that the future collaborators are promising, including Columbus and Jacksonville.

Reviewer 4:
The reviewer noted that as it appears for all EEMS projects, the SMART Consortium along with the two universities have an excellent combined skill set, though the relationship of the collaboration is unclear.

Reviewer 5:
The reviewer mentioned that several potential partners have been identified and believed that a committed partner should be secured as soon as possible.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that there seems to be a good plan for future work. The reviewer looks forward to seeing how the project develops.

Reviewer 2:
The reviewer stated that this was a very important project with a good research plan.

Reviewer 3:
The reviewer commented that future work includes setting model requirements and identifying/collecting necessary data and noted there is a challenge here in collecting sparse data to build this model. The reviewer stated the project may need many bounds or a scenario-based approach to understand the uncertainty of AMD energy impact, similar to how general AV energy impacts have been bounded, but hopefully with much less uncertainty. The reviewer said that military base collaboration is promising, and stated that there is a program underway with Major Brandon Newell that should be considered. The reviewer pointed out that the emphasis on performance over cost for the U.S. Department of Defense is going to be a different situation from private sector driven city districts, so exploring both could help bound the energy impacts of AMDs.

Reviewer 4:
The reviewer noted that the future described in the summary is the project itself, as expected with a new project, and stated that the future scope beyond the project may become clearer in the next 18 months.

Reviewer 5:
The reviewer said that a vision for future work exists, but so do barriers, including a lack of an identified AMD facility partner. The reviewer commented that no specific plans are presented for dealing with barriers or for developing the model that is the objective of the project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed that by enabling efficiency improvements this project will decrease petroleum usage.

Reviewer 2:
The reviewer stated that everyone will benefit from this research.

Reviewer 3:
The reviewer mentioned that AMDs are not necessarily going to be pervasive and therefore highly impactful on petroleum displacement for a while, but if they grow rapidly, it is important to understand the factors that determine whether they increase or decrease energy use. Therefore, modeling their impacts, validating them with pilot deployments, and then ensuring policy recommendation outputs will be key to shaping AMDs as they grow in size and fraction of all trips in the United States.

Reviewer 4:
The reviewer noted that this project, as per all of the EEMS projects, is very relevant to support the fundamental objective of DOE, energy savings, and petroleum reliance displacement.

Reviewer 5:
The reviewer commented that in anticipation that an AMD partner can be identified, the project has relevance. If no partner is identified, the relevance is lost as there will be no implementation to support.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that this project seems to be appropriately funded.

Reviewer 2:
The reviewer commented that the project has proper resources.

Reviewer 3:
The reviewer said that the project has sufficient resources, assuming the data acquisition and continual refinement do not drain the resources more than expected.

Reviewer 4:
The reviewer stated that until and unless an AMD partner is committed, the resources are sufficient and believed that once a partner is committed, the resources should be re-assessed.

Reviewer 5:
The reviewer acknowledged having no basis to confirm nor critique the budget necessary for this type of program.

Presentation Number: eems010
Presentation Title: Definition of Connected and Automated Vehicle (CAV) Concepts for Evaluation
Principal Investigator: Steven Shladover (Lawrence Berkeley National Laboratory)

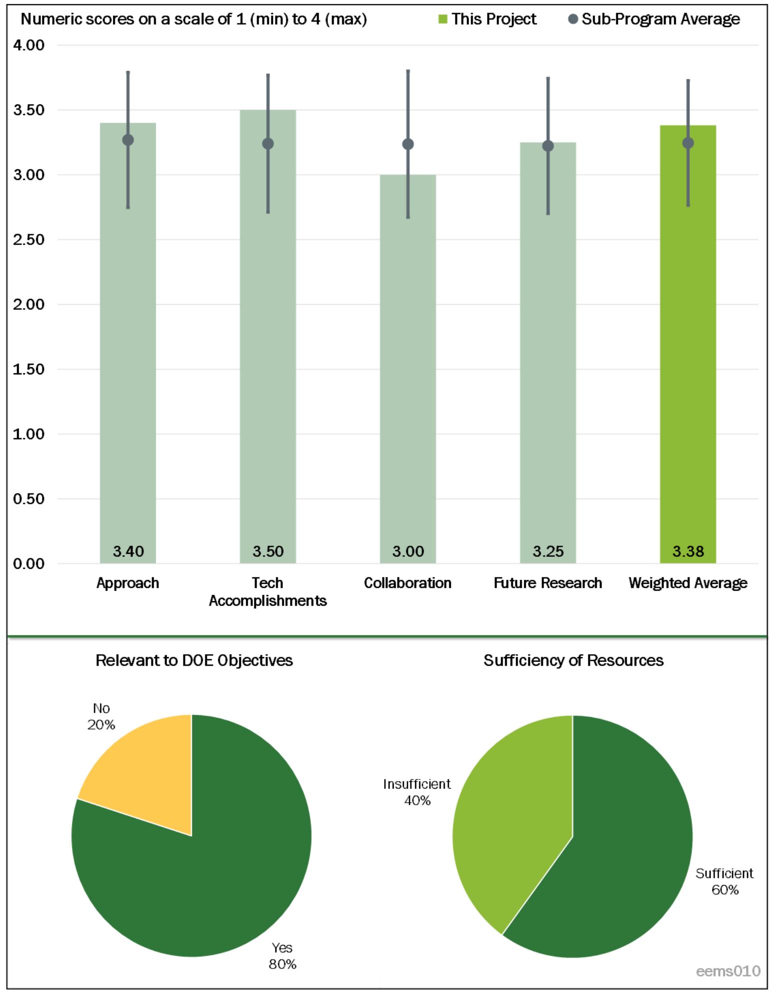

Figure 4-10 - Presentation Number: eems010 Presentation Title: Definition of Connected and Automated Vehicle (CAV) Concepts for Evaluation Principal Investigator: Steven Shladover (Lawrence Berkeley National Laboratory)

Presenter

Steven Shladover, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that given the size of the budget, yet the importance of the work, the approach has been excellent.

Reviewer 2:

The reviewer commented that the approach taken is very good as it limits the scope of CAVs by practical considerations instead of taking a blue-sky approach by assuming technologies that may never materialize.

Reviewer 3:

The reviewer remarked that the project takes the confusing aspects of CAV and tries to standardize the meanings and terminology. The reviewer hoped that this work may create a standardized way of defining CAVs.

Reviewer 4:

The reviewer commented that the work here is necessary to ensure that all of the pillar projects and other related projects are using the same terminology and noted that without this, there could very easily be a translation problem. The reviewer said that the SAE paper mentioned contains most of what is necessary, however.

Reviewer 5:

The reviewer mentioned that a key shortcoming in the approach is that the project's outreach was limited to national laboratories. While they can be expected to have substantial expertise and knowledge base, the reviewer opined that it would have cost fairly little in terms of time and effort to reach out to major stakeholders—for example, DOT, automakers, the American Association of Highway Transportation Officials, ITS America, and the American Public Transportation Association—to help frame the issue more completely.

The reviewer indicated that the approach identifies the key dimensions, but appears to be essentially an internal thought exercise. The reviewer was unclear whether or how much iteration and feedback was involved in developing and fleshing out these dimensions, and believed some of them appear lacking or a bit limited. The reviewer stated that casting a wider net would have avoided this and defined a broader field, one more likely to capture a fuller range of applications.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that given the budget, the accomplishments have been excellent. The scope seems reasonably constrained and the pieces of the definitions are all there to be combined in hopefully thoughtful ways.

Reviewer 2:
The reviewer said that the project has made excellent progress and noted that the work is essentially complete.

Reviewer 3:
The reviewer stated that the project took all of the various definitions of these vehicles and clarified the definitions. The reviewer asserted that the work was definitely needed.

Reviewer 4:
The reviewer affirmed that having someone who is responsible for setting SAE definitions be also responsible for the DOE project definitions could hardly be better. The reviewer noted that this was demonstrated in the conversation; however, there are always grey areas.

Reviewer 5:
The reviewer indicated that given the resources and time spent thus far, the technical progress is good. The initial fleshing out of the various dimensions appears solid and logical.

The reviewer noted that CV systems are well defined at a high level. The broad categories capture the key functionality. However, the list is neither a full catalog of CV applications, nor does it span the full range of possible (and proposed) CV applications.

The reviewer stated that one key challenge, which the project did not really address, is that CV applications are hard to predict, as in, there is no telling exactly what applications may emerge. The applications can include essentially anything that a developer can do with data from the infrastructure or the vehicle. The reviewer commented that while it would be impossible to catalog them all now, a broader scan may have revealed more categories that would more fully span the space, for example, to include applications for operations, maintenance, efficiency improvements, etc.

The reviewer remarked that the presenter explained that Level 5 automation is not considered in the definitions, as the presenter's belief is that full driverless operation, unconstrained by the operational design domain (ODD), will not happen by 2050. The reviewer commented that while this may be true and the presenter appears to have the credentials to suggest this is a well-informed expert opinion, the absence of this explanation from the original slide deck was a bit glaring. The reviewer stated that it was not until a reviewer asked about it that this point was clarified. In summary, the reviewer believed that given that the audience for this work could be fairly broad and spanning a wide range of expertise, it would be a welcome addition to include at least a passing explanation for why Level 5 is not currently considered.

The reviewer noted that it is not clear why there is a brief, single slide discussion of the "importance of connectivity to performance." While this is certainly a very important issue, and one that demands more attention, it is not clear how this fits into the discussion of "defining CV and AV concepts." The reviewer believed that it seems like a separate discussion. The reviewer further opined that the example cited showing improvements with CACC over automated cruise control (ACC) appears to be just one study by a single national laboratory. The reviewer commented that it would also be worth mentioning work done by the Crash Avoidance Metrics Partnership in their cooperative-agreement efforts with the FHWA. The reviewer stated that those groups have done extensive work in modeling CACC and also show improvements over ACC.

The reviewer commented that in the area of vehicle classes and business models, the examples provided do a good job of spanning what currently exists and what may exist in the near future. However, there are a number of additional use cases that one can easily imagine, and that have already been sketched out by a number of companies and researchers, for vehicle architectures and business models that fall outside the framework this project has created. The reviewer pointed out that, even today, there are a number of demonstration vehicles in operation that are not clearly captured here. The reviewer provided the example of slow-speed automated shuttles, which the reviewer believed deserve to be in a different class from general "medium-duty," highway-capable vehicles. The reviewer noted that the size, weight, operating characteristics, and overall architectures of such vehicles are radically different from what is consider to be conventional "medium-duty" passenger vehicles, and believed they would seem to deserve a separate category. In addition, the reviewer remarked that the category of "ultralight" seems to be a bit vague and undefined as this could also span a very wide range of current vehicles; for example, this category seems broad enough to include automated low-speed tricycles currently under development as well as two-seat highway-capable automobiles. The reviewer further thought that taking this forward several years, one can imagine a much broader range of vehicle architectures. Removing the need for a human driver or even a human occupant opens up a tremendous range of new possibilities for vehicle architectures, including both much smaller and much larger vehicles. The reviewer cited a 2015 DOT survey of potential "novel modes" of transportation (https://www.rita.dot.gov/sites/default/files/NovelSurfTranspModes-web.pdf) as a potential useful resource. The reviewer commented that, in terms of business models, it may be helpful to ask a broader question about what potential business opportunities are presented by automated vehicles when there is no longer a requirement for a driver or human occupant.

The reviewer noted that the presenter explained that these alternative architectures and business models were not included, as such speculation is more suited to other SMART Mobility pillars. The reviewer stated that if that is the case, then it seems that this project should at least make passing reference to the significant uncertainty in this area, and perhaps define a few additional broad categories to acknowledge and capture some of the potential alternatives. Furthermore, the reviewer believed that this project presents precisely the right opportunity to make sure that all the pillars are thinking as broadly and openly as possible about new architectures and business models, as leaving this issue up to the individual pillars to address independently does not seem like the best approach. The reviewer suggested that it may be appropriate to hold some kind of workshop among the pillars, and include outside stakeholders, focused on the potential new business models and vehicle architectures and when can we expect to see them. The reviewer believed that such a thorough survey of current thinking and expectations would seem very valuable and relevant.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the project had very good collaborations. The reviewer noted that the presenter cited participation in SAE and connections with industry as an indirect source of input, which may be appropriate to indicate in the material.

Reviewer 2:

The reviewer said that the scope of this project is very small and limited and believed extensive collaboration was not required. The reviewer commented that SAE is de facto included. The point about inviting safety input was also taken, and the reviewer was satisfied on this point.

Reviewer 3:

The reviewer remarked that given the size and scope of the project, the collaboration is probably adequate; however, it seemed a bit narrow to only consider national laboratory representatives. The reviewer added that if funding would have allowed, it would have been better to reach out to the DOT to ensure definitions are fully harmonized.

Reviewer 4:

The reviewer commented that only collaborations within DOE are listed and that the work needs to be vetted within the automobile industry and with the standards makers in North America, Europe, and Asia.

Reviewer 5:

The reviewer realized that the collaboration is purposely limited to a DOE definition among the pillars. The reviewer believed not synchronizing with DOT (National Highway Traffic Safety Administration, ITS-JPO, Federal Motor Carrier Safety Association, etc.) may come back to haunt this project as well as the other projects that use the definitions that are the outputs of this project. The reviewer pointed out that this feedback was provided during the question and answer session, and the presenter did assure the audience that the team is very plugged into the DOT space.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the future work seems fine within the scope and budget of this project.

Reviewer 2:

The reviewer said that the list of future tasks is reasonable and appears manageable.

Reviewer 3:

The reviewer commented that the project is essentially complete, but it should be brought to the attention of industry, standards groups, and regulators.

Reviewer 4:

The reviewer opined that this project could be improved by including some method to allow for future developments and gray areas. The reviewer suggested that the difference in steering types or even longitudinal control could be sub-categorized. The reviewer noted there actually is z-axis control being considered with drones on another project, and was not certain that vertical should be out of scope on this project.

Reviewer 5:

The reviewer indicated that given the work done to date and the overall work plan, the proposed future research is appropriate and adequate. The reviewer noted that estimating timing of availability of emerging technologies is a valid and relevant aspect of this project, but given that the study years reach out to 2050, it seems like there is a very strong justification for including more business models and vehicle architectures. The reviewer believed that there is already so much inherent uncertainty in looking out to 2050 that it does not seem at all out of place to cast a wider net, embrace more uncertainty, and consider more business models and architectures. The reviewer said that any such predictions are going to be wrong to some degree, and there is very little we “know” about how things will turn out; however, we can probably be fairly certain that in 2050 the vehicles and business models are likely to look very different from how they do today.

The reviewer offered one cautionary point, specifically that “historical data from prior vehicle technology changes” can provide a good starting point, but the applicability of historical cases can vary widely. The reviewer pointed out that there can be powerful feedback effects that drive very rapid adoption of a new technology, in some cases by rendering the old technology unusable in very short order. The transition from the horse and buggy to the automobile is a good example of why typical “vehicle turnover rates” cannot be relied upon as people did not wait for their horses to die before buying a car. The reviewer provided an additional example that, in the last decade, people did not wait for their old cell phones to die before switching to a smartphone. The reviewer noted that there were powerful motivating factors other than just “upgrading to the latest technology” including the fact that society, behavior, and expectations all change with major new technologies; it is not simply a matter of convenience that drives people to buy the latest thing. The reviewer offered a final example: it may become expected that one can work during a commute and those who do not have an automated vehicle will lose precious work time during the day.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that it is clearly very important to bring everyone working in this space toward common definitions.

Reviewer 2:
The reviewer remarked that the project supports analysis to determine energy savings by way of fuel displacement of various CAV-penetration scenarios. This understanding will contribute to the DOE goal of reducing petroleum usage by allowing DOE to more effectively shape policies that contribute to that goal.

Reviewer 3:
The reviewer said that in supporting the projects needing consistency and translation of message, this certainly supports the goal.

Reviewer 4:
The reviewer stated that the project is relevant to DOE goals and has an important role to play. The reviewer noted that getting everyone on the same page, using the same terminology, will definitely pay dividends as the work of the five SMART Mobility pillars proceeds. The reviewer further observed that this is especially true, given the broad scope and wide range of efforts involved in those pillars. The reviewer stated that given that the five pillars may have a tremendous long-term effect on displacing petroleum use, this enabling effort may have a significant indirect impact.

Reviewer 5:
The reviewer saw no real connection to petroleum reduction from this work. CAVs may or may not achieve reductions overall.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that $50,000 may have been a little too small. The reviewer noted that it would be interesting to have seen the outcome if this project had had sufficient funds to pull together a workshop or two to make this a more lasting, comprehensive effort, especially if it could have been an interagency workshop to make the point of getting all relevant federal agencies on the same page.

Reviewer 2:
The reviewer indicated that this project is barely one person’s wages for the year. The reviewer thought it was not enough funding to perform the necessary cross communication, publication, or extension of message outside of the DOE.

Reviewer 3:

The reviewer found that the resources to be sufficient.

Reviewer 4:

The reviewer stated that this was a small project that completed what was defined as the objective and thought the resources were sufficiently employed.

Reviewer 5:

The reviewer commented that the budget is small and while the task is important, it is not resource intensive so the reviewer believed the funding is sufficient.

Presentation Number: eems011
Presentation Title: Multimodal Travel Behavior Modeling in Urban Areas using BEAM
Principal Investigator: Colin Sheppard (Lawrence Berkeley National Laboratory)

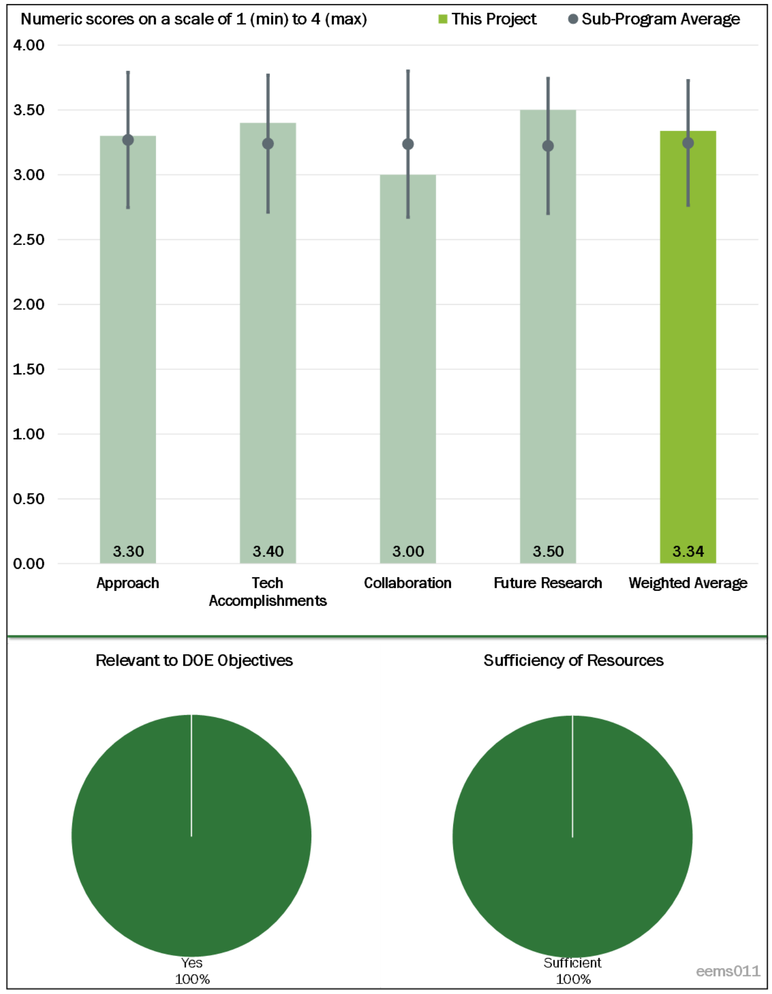

Figure 4-11 - Presentation Number: eems011 Presentation Title: Multimodal Travel Behavior Modeling in Urban Areas using BEAM Principal Investigator: Colin Sheppard (Lawrence Berkeley National Laboratory)

Presenter

Colin Sheppard, Lawrence Berkeley National Laboratory)

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that this project as presented is one of, if not the best, multi-disciplined approach to bring into model analysis agent-based behavioral decision making, technical options, and urban mobility optimization criteria. Though the reviewer acknowledged not being familiar with BEAM, it appears to have excellent potential to expand Multi-Agent Transport Simulation (MATSim) tools.

Reviewer 2:

The reviewer commented that the approach makes sense and noted that the milestones as described in Slide 4 show how this project is integrated with the different pillars in EEMS.

Reviewer 3:

The reviewer stated that the narrowly focused approach seems solid and specifically targeted to fixing the model, validating it, and then conducting analysis.

Reviewer 4:

The reviewer remarked that making the model framework accessible and extensible is important for it to be used and to be improved by others in the future, and thought that it is important that the project focuses on this. The reviewer noted that it makes sense to gut the MATSim structure and replace it with something scalable in BEAM that can be parallel computed and can calculate large geographic areas. The reviewer suggested considering including additional validation of the model as it is refined based on actual before-and-after events in a city, such as inclusion of a bike corridor or bus rapid transit or a bridge outage event.

Reviewer 5:

The reviewer mentioned that overall the approach looks good, but there are specific aspects that need clarification, specifically, the scheduler apparently is allowed to relax strict chronology in order to achieve higher computation speeds. The reviewer noted that it is not clear if this will result in an agent missing the bus or the plane. The reviewer also wondered if the scheduler will also ensure that the agent does not miss a plane by delaying the plane. However unlikely, it was not clear from the explanation how this aspect is addressed.

The reviewer also indicated that it is not clear that the reliance on Open Trip Planner as a router is necessarily good. While it is open source, it does not have vital information on the road grade, the knowledge of which is critical to energy consumption calculations and route optimization to ensure minimum energy consumption.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that it is early in the project and that reasonable progress appears to be made.

Reviewer 2:

The reviewer commented that given how little time has passed since the start of this project, the project has made good progress thus far.

Reviewer 3:

The reviewer said that the project had only recently begun last fall, but appears to be making significant progress as planned. The reviewer mentioned that the efforts to date are already pointing to some very useful tools for use by the overall program. The reviewer also noted that the work completed to date was described by the project lead as being the most complicated part of the effort.

Reviewer 4:

The reviewer stated that at this early phase of the program the project appears to be quite well focused and poised for a successful project.

Reviewer 5:

The reviewer commented that the model architecture has been developed, including the three principal components. The reviewer found that the chronological relaxation to allow massively more parallel computation to be a great solution; however, the reviewer wanted to see this space explored in greater detail. The reviewer stated that it would be good to understand the computation benefit versus cost to fidelity curve, generally speaking, to optimize this strategy. The reviewer added that it is helpful to integrate the OTC as well as the Uber open source portal. The reviewer commented that proprietary filtering in the Uber model may limit its utility. The reviewer stated that there is still work to make the model more robust and understand accessibility for each choice agent, but the preliminary implementation is highly encouraging.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that collaboration with the SMART Consortium like all EEMS projects aligns excellent talent; however, the reviewer thought that there is no indication that Berkeley cannot run this quite independently.

Reviewer 2:

The reviewer commented that it may be worth exploring further collaboration with ANL and their approach so that synergies may be exploited and unnecessary repetition of work avoided. The reviewer noted that this is easier said than done.

Reviewer 3:

The reviewer remarked that there would seem to be room for additional collaboration with not only DOT Smart Cities but also state and local DOTs during the project. The reviewer noted that ultimately to be a tool for informing interventions for improving accessibility and reducing energy usage, it will need to be accessible to local DOTs in cities so some validation of before-and-after simulations for a transit change, bridge closure, and dynamic pricing may be helpful as the model is refined.

Reviewer 4:

The reviewer said that the model seems to be in the hands of a few niche people and those are all part of this work currently. The reviewer suggested that later in the project it might make sense to get a person who represents the cities of San Francisco and Chicago when doing the simulations for those cities.

Reviewer 5:

The reviewer observed that the list of partners includes all the DOE national laboratories plus a few other entities. The reviewer stated that it would be good to see the DOT added, along with several state DOTs. These entities will ultimately serve as implementers of the modeling developed so it would be good to get their input sooner rather than later, and the reviewer thought this might have made sense from the point of project initiation. The reviewer noted that the project lead indicated that the project team has considered this, but feels the project is not yet ready for adding these partners. The reviewer stated that at some point, however, it will be important to add those partners. The reviewer noted that the project also appears to be collaborating with the Smart Cities Research Center and proposed that this may turn out to be a way to pull in some of these entities.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer expected to see more progress by next the AMR and requested that the project team keep previous comments in mind as they proceed—especially the lack of grade information to compute accurate energy information. The reviewer suggested referring to the work done by NREL in support of their Transportation Secure Data Center (TSDC) database, which indicates the limitations of the U.S. Geological Survey data, in case the team plans to utilize that for grade and elevation calculations.

Reviewer 2:

The reviewer commented that for future application and accessibility of this model, the model will need to be capable of being run by others and be of high enough fidelity to be trustworthy and reliable. The reviewer noted that the model will be run over cloud services. The reviewer suggested the model should be graphical user interface driven.

Reviewer 3:

The reviewer said that the proposed future work is well thought out and planned logically and methodically.

Reviewer 4:

The reviewer stated that the future work identified appears to focus on achieving the overall project milestones as laid out in the approach and noted that this work includes completing model enhancements, conducting calibration, and then performing analyses.

Reviewer 5:

The reviewer indicated that the proposed forward progress of the program is well described and ambitious and noted that it will be interesting to see the BEAM analysis in future years.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer mentioned that this, like all of the EEMS projects, supports the fundamental objective of DOE in supporting energy efficiency and reduced petroleum dependence.

Reviewer 2:

The reviewer remarked that the large-scale introduction of CAVs appears to have the ability to either result in decreased energy consumption or increased energy consumption. The reviewer hoped that these projects will ensure that irrespective of whether the VMT goes up or down, the overall system efficiency can still be maximized about that operating point.

Reviewer 3:

The reviewer believed that this project supports petroleum displacement by its modeling efforts but that this is not well described in the presentation. The reviewer noted it would be good to have made a more explicit connection between the project and petroleum displacement in future presentations.

Reviewer 4:

The reviewer commented that the project focuses on the concept that mobility choices impact efficiency of the overall transportation system, determining petroleum consumption. The reviewer said that the better the idea as to where things are headed and what choices are possible, the easier it will be to determine and model overall energy consumption for the future.

Reviewer 5:

The reviewer noted that understanding the adaptive nature of the transportation system, for example, TNC supply-demand matching, and modeling not just individuals, will support intelligent interventions once the model is robust enough and accessible enough to use locally.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that resources seem consistent with the scope and schedule.

Reviewer 2:

The reviewer stated that the resources appear to be sufficient for the work at hand.

Reviewer 3:

The reviewer commented that funding appears sufficient.

Reviewer 4:

The reviewer could not determine if funding levels were necessary to accomplish this project.

Presentation Number: eems012
Presentation Title: Modeling and Analysis of Plug-in Electric Vehicle Charging Infrastructure Supporting Shared Mobility
Principal Investigator: Yan Zhou (Argonne National Laboraotry)

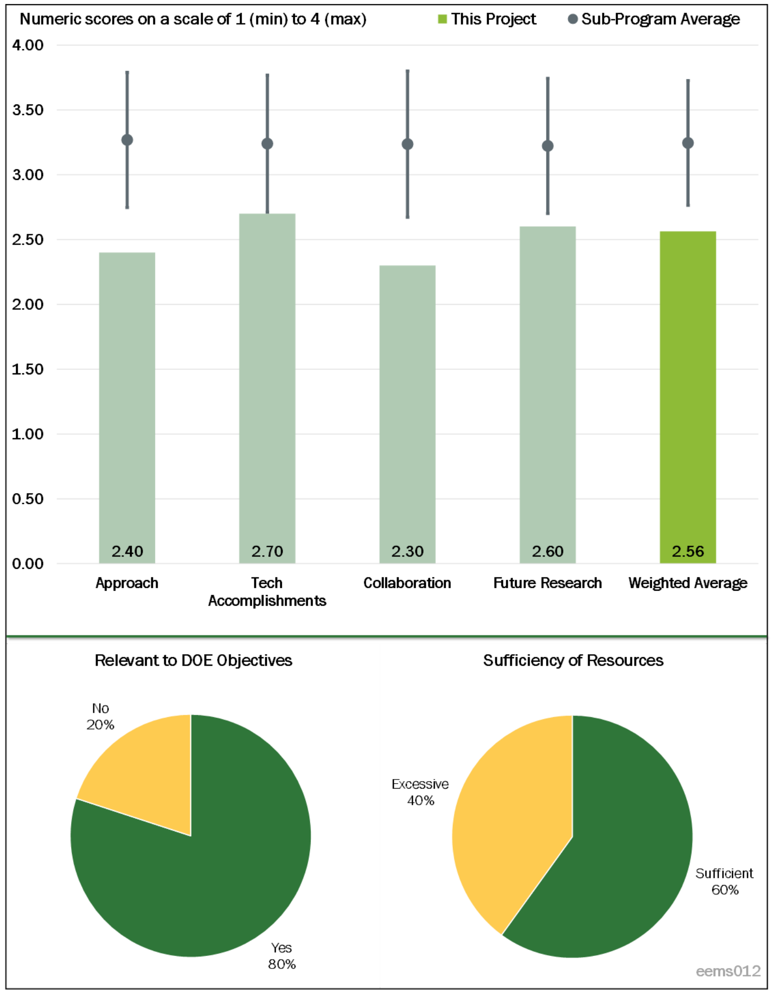

Figure 4-12 - Presentation Number: eems012 Presentation Title: Modeling and Analysis of Plug-in Electric Vehicle Charging Infrastructure Supporting Shared Mobility Principal Investigator: Yan Zhou (Argonne National Laboraotry)

Presenter
Yan Zhou, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer noted that the approach seems mostly fine; however, the reviewer was confused about the connection between Task 1, which states, "impacts of near-term AFV infrastructure," yet the research seems to be 100% electric vehicles (EVs). The reviewer stated that if the task was not fully fulfilled, it should change to only include EVs. AFVs are considered to be hydrogen fuel cells, biodiesel, propane, CNG, etc. The reviewer said that some might even categorize EVs as something other than AFVs because they would not consider electricity a "fuel."

The reviewer expected to see more of a pursuit toward actual cost-benefit analysis and noted that all of the elements are in the project including installation cost, revenue scenarios, and operating cost. The reviewer commented that the results could become very useful and interesting if costs and benefits are directly compared in some meaningful way. For example, the lowest cost option may not end up with the best cost-benefit ratio.

Reviewer 2:
The reviewer said that the approach includes mostly a bottom-up approach of electric vehicle supply equipment (EVSE) return on investment (ROI) and travel survey data. The reviewer commented that this could be supplemented with some more top-down analysis. The reviewer noted that overall, the five-step approach is infrastructure driven by how many chargers there are and where, how many opportunities there are to charge, what this does for range extension, what vehicles are sold, and how much energy they consume. The reviewer stated that a possibly missed opportunity in considering the electrification and shared mobility interaction is

the third leg of the automated-shared-electric (ASE) triangle, automation. The reviewer noted that automated shared EVs are distinct from non-automated shared EVs in how efficiently they use EVSE and their range.

Reviewer 3:

The reviewer commented that existing charger use data show an aversion to charging away from home both from a convenience perspective and one of cost, and noted that this approach seems to ignore this fact by focusing exclusively on away from home DC fast charging. The reviewer commented that the use of home charging to support home and work trips for ridesharing should have greater consideration in this model.

Reviewer 4:

The reviewer pointed out that the approach to this project is flawed and that it makes the overriding assumption that the charging (not "fueling") infrastructure is the primary deterrent to EV adoption. The reviewer commented that it has been seen multiple times that vehicle range is the primary deterrent because it is a major departure from the range of a liquid fueled vehicle. The reviewer noted that in an urban environment, very few, if any, drivers would have to "fuel" their car daily. EV owners with short range must do so, especially in extreme weather conditions. The reviewer stated that as EV offerings hit the market with real 200-plus mile range, this deterrent to adoption is removed. The reviewer said there is still a need for urban fast charging infrastructure, but it would not be designed using these datasets as they are described in this project.

Reviewer 5:

The reviewer stressed that difficulty with available data and unpredictability for analysis tools with a maturing industry, such as shared transportation companies, will likely lead to projections errors, which in this case may damage the support of future EVSE infrastructure deployments. The reviewer noted that the project may need to focus on clear data accumulations and standard7ized first level analysis so that there would be something for the model to validate against prior to projecting for multiple deployments and varied market penetrations of technology.

The reviewer said that a misstep in locations for infrastructure investment could drastically reduce future support for EVs in general, calling to memory the news stories when first generation EVSE were removed from various cities after years of non-use.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that for the early stage of the project, a great deal of work has been completed identifying model inputs.

Reviewer 2:

The reviewer said that the technical accomplishments to date look great, though it is clear there is a lot still to do. The reviewer also found it important to define, and then keep sharp focus on, the customer of this work along with the intended influence this work might have. The reviewer suggested that maintaining a strong connection to "more mobility for less energy" is important.

Reviewer 3:

The reviewer stated that the project developed methods and modeling framework for estimating infrastructure impacts on EV market share and energy use, segmenting these by three types of sharing. The reviewer found it helpful that the infrastructure-to- charging opportunity link has been modeled and that high-level impacts of these three sharing types have been qualitatively characterized based on industry research, for example, ride-hailing drivers sometime driving far to get to a denser market, increasing energy usage.

The reviewer noted that looking at national trip purpose segmentation may not reflect urban trip segmentation and suggested that this should be validated. The reviewer also found it unclear whether the model accounted for all trips, or only trips made by car. The reviewer added that home charging and corporate charging would be important to include somehow in this analysis; workplace and home charging account for a significant fraction of EV charging, and might account for shared vehicle charging when a driveway is rented out to an electric Zipcar, for example.

Reviewer 4:

The reviewer remarked that there is a limited understanding about energy impacts of shared mobility applications. The reviewer noted that although the presenter claims to have identified three types of shared mobility, each of these represents a maturing business model that requires more substantial investigation in the various deployment scenarios for each type of shared system before models for any of these three systems would appear to be validated. For instance, the reviewer stated that in order to claim that ride-hailing has a decreasing impact on VMT, it would be appropriate to show the fleet data on vehicles meeting rider demands that indicate those vehicles have a lower VMT than the sum of VMT for vehicles they displace, which would have been in the hand of the riders as operators. The reviewer stated that any taxi or Uber used by a good percentage of travelers shows high VMT.

Reviewer 5:

The reviewer said that making progress on a flawed approach is not of value, and noted that it is hard to understand from the presentation what was being accomplished. The reviewer found one of the most glaring flaws in the SMART Mobility projects is the reliance on incomplete and poorly designed experiments that create dubious datasets that industry does not see as being validated. The reviewer further stated that the data used are what is available and are not agreed upon by significant stakeholders as being appropriate to the purpose it is being applied to.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer believed that coordination with other laboratories and with shared mobility implementations like Hertz, Car2Go, and Zipcar provides an excellent foundation for the modeling.

Reviewer 2:

The reviewer noted that the SMART Mobility inter lab arrangement will yield benefits to EERE by reducing technology overlap and stated that the continued validation of the various models from each laboratory or other transportation partner is required as is the need to ensure that data can be transferred among tools effectively.

Reviewer 3:

The reviewer acknowledged that there is collaboration among the laboratories, but it also appears siloed within DOE and VTO. The reviewer stated that the team is developing industry partnerships, but said this seems insufficient to really create a robust and useful deliverable in the end.

Reviewer 4:

The reviewer commented that working with a city initiative like New York City's electric charger initiative would be a useful collaboration to gain data on EVSE usage by actual shared vehicles. The reviewer further suggested working with a shared vehicle provider like Car2Go, which has EVs in some markets, such as San Diego.

Reviewer 5:

The reviewer noted that collaboration for this project needs to be with all of the stakeholders that are a part of the urban transportation segment that is being studied. The reviewer found this project to be limited to the academic elements within the DOE laboratory system using requested data from a city and charge system operator. The reviewer said that this is extremely limited and will lead to extremely limited conclusions.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that aside from previously supplied suggestions, the bullets listed on the slide seem great and reasonable.

Reviewer 2:
The reviewer commented that the range and uptake of shared EVs must still be modeled, and observed that there are important assumptions about whether trips are replaced in kind or decrease as shared vehicles displace private vehicles. The reviewer stated that evidence shows that shared vehicles reduce trips per household because the marginal cost of trips becomes explicit and changes traveler behavior.

Reviewer 3:
The reviewer said that there is a good plan for future research in this area, but some of the project difficulties and tool immaturity need to be cleaned up first. The reviewer also stated that as the technologies, such as direct current fast-charging (DCFC) and energy storage systems (ESS), and the EV market change there will be occasion to investigate the accuracy of the Market Acceptance of Advanced Automotive Technologies (MA3T) model as a market prediction tool. The reviewer commented that the new administration may reduce incentives for EVs, the low price of fuel may reach out 3 years, and growth regions with large population densities may also have additional difficulties to deploy DCFC. The reviewer stated that this cost needs to be better understood prior to next level of predictions.

Reviewer 4:
The reviewer stated that the project team expressed concern that the EVI-Pro model has "home dominant charging preference for simulated consumers with economically efficient behavior." The reviewer said that this is viewed as a challenge when it is more a reality than recognized in the approach. The reviewer noted that the use of home charging should be an integral part of the modeling.

The reviewer suggested that the Car2Go EV car sharing project in San Diego be used to understand the issues with EV car sharing. The reviewer cited the white papers from the EV Project, which discussed the difficulties in charging vehicles in the field and the efforts put in place by Car2Go to retrieve the vehicles and charge them at a central location. The reviewer pointed out that this is contrary to any of the models proposed for use in the project.

Reviewer 5:
The reviewer remarked that the slides on project progress were simply a collection of slides stating many things that are clearly apparent in the current EV use world. The reviewer noted that the fact that car sharing would reduce energy is a "known," and it does not matter whether it is an EV or a fossil-fueled vehicle and believed that studying these things is a wasted effort. The reviewer stated that modeling that does not take into account the changes to technology in future EV fleets is a real waste of effort and said that this project lacks attachment to the real world. The reviewer stated that the project will simply use a different set of tools to give the same general predictions that have been previously reported.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project has good relevance as it will build EEMS understanding of where and how to focus on areas of interest for electric mobility technology advancement. The reviewer believed the project will be critical in urban centers to offer competitive electric mobility options, to obtain maximum oil

displacement, and to improve air quality. Maturing the tools used for these predictions is a valuable part of EEMS.

Reviewer 2:
The reviewer found a potential for petroleum displacement, but it is unclear whether the project will increase EV penetration.

Reviewer 3:
The reviewer remarked that in the long term, modeling charge infrastructure to support shared mobility is relevant in providing a guide to car sharing operators and support to operators of charging infrastructure intent on supporting ride-hailing services. However, the reviewer noted that from data gathered in the project, it appears that ridesharing would be supported by home charging and by workplace charging, approximately 55% of VMT. The reviewer stated that home charging does not require modeling and workplace charging is already covered by the Workplace Charging Challenge.

In the short term, the large uncertainty of every model input makes the relevance of this effort questionable.

Reviewer 4:
The reviewer noted that the project is relevant, but nonetheless believed the dots need to be connected to the audience to show why it is relevant. The reviewer wanted to know that this work can impact the world.

Reviewer 5:
The reviewer said that the project does not support DOE objectives as it is simply reaffirming old understandings and does not take into account how the EV fleet will change over the next five years. The reviewer stated that the market has spoken and to get widespread EV adoption, the vehicle must perform and be as convenient to use as a fossil fuel car. The reviewer noted that this is why DOE funded battery and fuel cell research to drive down costs and increase power density to extend range.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer allowed that the funds are probably sufficient, but suggested that the data hunt could be a huge effort and data are clearly scarce here. The reviewer stated that it is hard to determine whether resources are in fact sufficient.

Reviewer 2:
The reviewer believed that with data currently unavailable, the resources seem sufficient to sort out inconsistencies in models to be incorporated into the analysis.

Reviewer 3:
The reviewer commented that the resources are sufficient, but there should be additional support available from the national laboratory's modeling community as a whole. The reviewer saw an opportunity to engage an academic branch to help with some of the possible data transfer.

The reviewer observed that for the EEMS project to be successful, there needs to be a concentrated effort to validate the transportation system level predictions of this type of project. This would be no small feat and not the responsibility of this project on its own.

Reviewer 4:
The reviewer appreciated the relevance and the outcomes to date. However, the reviewer noted that this does seems like a lot of funding in total for this work unless the scope is expanded or the outcomes are connected to

a more significant effect, such as providing vital data being asked for from planners and industry to build out the shared AFV mobility space.

Reviewer 5:

The reviewer characterized using valuable technical minds on a project that started with a flawed approach as excessive, especially when, after some time, all that can be reported are a number of well-known things that did not need to be studied again.

Presentation Number: eems013
Presentation Title: A New System Simulation Framework for SMART Mobility
Principal Investigator: Phil Sharer (Argonne National Laboratory)

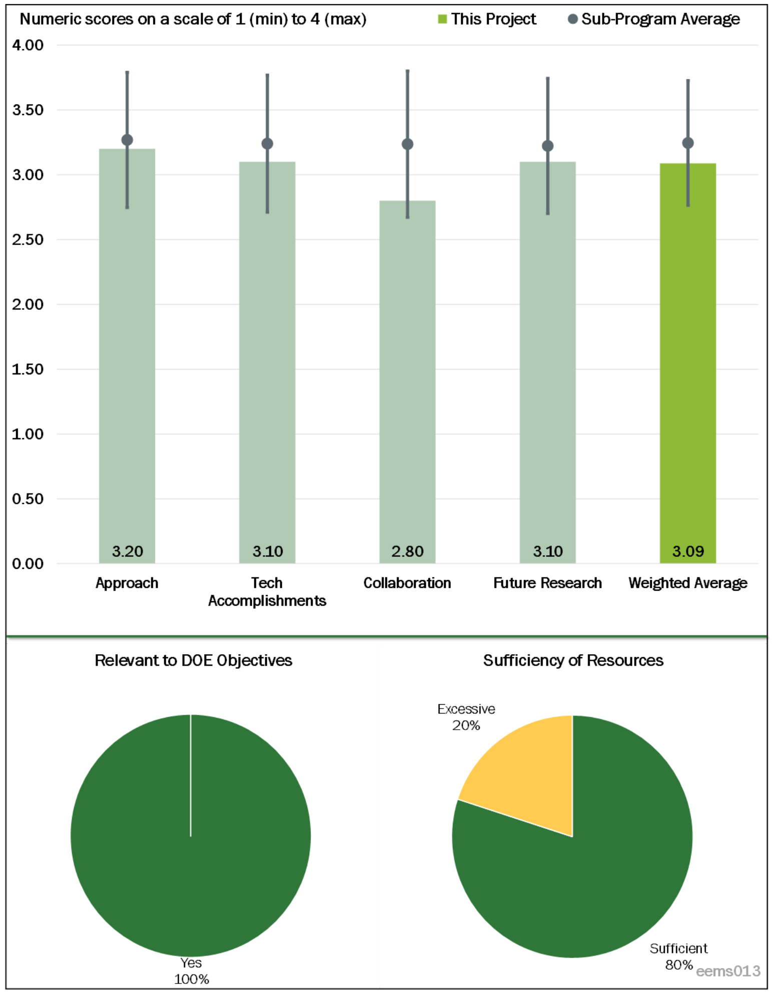

Figure 4-13 – Presentation Number: eems013 Presentation Title: A New System Simulation Framework for SMART Mobility Principal Investigator: Phil Sharer (Argonne National Laboratory)

Presenter
Phil Sharer, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that in response to VTO's new program for EEMS, ANL has developed a new simulation tool, the Advanced Model Based Engineering Resource (AMBER), that builds upon the vehicle level simulation model, Autonomie; integrates other national laboratory models like POLARIS (multi-vehicle simulation); and plans to develop new EEMS supporting processes. Given the shift in VTO focus from component level and vehicle systems R&D to the transportation system level, it is appropriate to have an HPC-enabled, multi-workflow model that would help quantify the potential benefits of VTO EEMS activities.

Reviewer 2:
The reviewer pointed out that, as with some of the other posters/projects related to simulation of large interconnected systems, this project does a good job of recognizing not only the need to simulate on a large-scale system and but also that current tools will need changes to more accurately predict the best way to shift mobility toward more efficient technologies. However, the reviewer believed that this project does not attempt to take lessons learned from prior urban and anthropological planning tools in the progression from Autonomie to AMBER other than the future use of MA3T. The reviewer noted that going from Autonomie to multi-vehicle Autonomie simulations will require human factors and reaction interface data unless the project only considers high-level autonomous vehicles with very high market penetration rates or the projections even regarding traffic flow simulation and energy calculations may be in error. The reviewer stated that it would be good to have seen some projections from the POLARIS tool versus real-world data to validate the agent-based models.

Reviewer 3:

The reviewer said that the project approach addresses the barrier of "bringing technologies to market faster" by developing a simulation framework that will speed up the analysis process for new transportation paradigms. The reviewer explained that the project increases the portability and potentially expands the user population for a suite of DOE tools by enabling users to employ precompiled Autonomie vehicle representations that can be run on a free version of MATLAB. The reviewer said that this will allow scientists and engineers to leverage validated vehicle models in their analysis of proposed new mobility solutions.

Reviewer 4:

The reviewer acknowledged that the AMBER project is a much-needed modeling framework that can be applied to a transportation network that still has the granular capabilities of the underlying modeling platforms of Autonomie and POLARIS. The reviewer stated that the project design is feasible and the integration with the underlying modeling platforms is solid. The reviewer said that the only missing element appears to be future plans once this project is complete.

Reviewer 5:

The reviewer commented that the approach to the development of AMBER is not clearly defined, presented, or defended and believed if the barrier being addressed is bringing technologies to market faster or accelerating technology evaluation, then it is unclear how this new tool will help overcome these barriers. The reviewer observed that if the barrier being addressed is simply integrating a diverse set of simulation tools, then someone has to ask why this is necessary, and if it is, why it needs to be done with these specific tools at this level of fidelity and to achieve exactly what goals. The reviewer noted it is not at all clear from the poster whether the goal is to simulate or predict traffic flows, energy use, accident frequency, or any one of a vast array of useful pieces of information.

It was unclear to the reviewer what level of predicted information is being sought and, what technologies would be brought to market faster, including new powertrain concepts, new powertrain components, new vehicle safety systems, new traffic flow measures, and new road designs. The reviewer mentioned that there are better ways to site charging stations, parking structures, or passenger pick-up points, and it was not clear if AMBER is meant to address any or all of such questions or issues. The reviewer noted that the poster implies that AMBER will provide a framework over other tools, such as Autonomie or POLARIS, but how and why are not at all clear. The reviewer stated that understanding the impact of different vehicle populations on energy use in a city does not require knowledge of every detail of every vehicle, such as which alternator or what tires it uses; rather, the information required is something about its energy use over various drive cycles. The reviewer said that including complete models of every vehicle inside a model of fleets or groups of fleets seems like gross overkill for most practical purposes.

In summary, the reviewer believed the barriers this project is addressing are not well defined, and therefore did not think the project is well designed or feasible. As for being integrated with other efforts, the reviewer found little evidence that the work is coordinated with others at ANL or with major potential users, much less with other researchers in the field who are modeling large systems or mining large datasets or trying to optimize vehicle populations for one purpose or another.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the project's technical accomplishments and progress toward the overall project and DOE goals are outstanding in the sense that they have focused on addressing the requirements of OEMs that are motivated to explore the feasibility and viability of advanced mobility solutions technologies.

Reviewer 2:
The reviewer commented that given the charge to develop the simulation tools for smart mobility, technical accomplishments are in line with the proposed project milestones and noted the milestones are focused on integration of existing and development of new workflows for AMBER. The reviewer stated the project seems on track with the annual milestone of first public release of the model at the end of the fourth quarter of 2017. The reviewer noted that this is a multi-layer approach, with a diverse set of workflows, and a new user interface to run large studies with Autonomie.

Reviewer 3:
The reviewer remarked that the project has made good progress toward its milestones of simplifying workflow modification and basic framework development, but seems to be working outside of the rest of the SMART Mobility team. The reviewer added that it may be appropriate to have an outside evaluation of the best current tools in the industry, then allow the focus to be on datasets that work across tools rather than improving a tool if there is something out in the market better for that portion of workflow.

Reviewer 4:
The reviewer noted that there appears to be significant progress toward the project goals already accomplished. The completed workflows are already enabling useful analyses.

Reviewer 5:
The reviewer stated that the poster indicates that progress has been made and about 60% of the funds have been expended, but there are no specifics provided as to what other tools have been incorporated successfully and how many other tools, or types of tools, need still to be incorporated to make AMBER functional and productive. The reviewer opined that there are no examples provided of a specific problem that AMBER would help address, so it is impossible to say if the project is on the way to meeting its goals. The reviewer mentioned that charts are provided that reference other tools and talk about the vision to generalize any workflow, but the need for this capability and the reasons for mentioning these specific tools, and some discussion of the differences among their inputs and user interfaces and how AMBER is addressing this, are all lacking. The reviewer said that there are no well-defined goals so there is no way to measure progress against those goals. The reviewer noted that the poster says that “customizing workflows is easy,” but wondered who was customizing the workflows. The reviewer recommended that the project principals identify the target market for this software, show that they are getting input and direction from that target market, define one or more clear goals, and show progress toward meeting those goals. If any of that currently exists, the poster provided little evidence.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the decision to replace the previous vehicle system simulation framework (Autonomie) with something that can model a variety of vehicles in a much larger transportation system network was driven by the user community of more than 200. The requirements were developed with the user community and validated by interactions with a couple of domestics OEMs.

Reviewer 2:
The reviewer noted that the project is validating its technical progress by issuing beta versions of the software to potential users. This collaboration improves the likelihood that the tool will meet the evolving requirements of the user community.

Reviewer 3:
The reviewer stated that the use of feedback from Autonomie users is positive, but advocated for receiving feedback from users of other platforms, such as POLARIS. The reviewer noted that there is mention of “specific discussion” with OEMs, but extensive discussions should be the goal and suggested that an academic partner could be helpful as well.

Reviewer 4:

The reviewer noticed that this effort appeared to be ANL- and Autonomie-user centric with partners and input. The reviewer commented that though stated OEM discussions have been taken into consideration, there was a simple statement that "the tool structure was consistent with the requirements." There was no mention that as complex traffic simulation technology matures, and with the impact of driver information and options on travel and choices, there is no standard way to define interactions or responses to information available. The reviewer stated that this type of supplemental research is required, in particular for agent-based models to have credible predictions.

Reviewer 5:

The reviewer commented that the poster provided very little evidence of collaboration or coordination with any other researchers or institutions that are either involved in similar work or might be users of the product of this work. The reviewer noted that there is some brief mention of meetings with General Motors and Ford, but no names are provided of the people involved and there is no record of the outcome or result of the meetings. The reviewer reported that many other software tools are mentioned, but there is no evidence provided of contact with the developers or users of these other tools. The reviewer also noted that the references that are provided at the end of the poster include only prior work by these same researchers, which shows no effort to connect with others in this field. The reviewer was aware that there is substantial competing or complementary work going on at places like Georgia Institute of Technology (Georgia Tech) by Professor Dmitri Mavris and colleagues. The reviewer stated that if AMBER is being designed to interface with large databases of vehicle information, then this reviewer expected coordination with companies like SAS Institute, who are experts in large data. The reviewer pointed out that even companies such as Ricardo and AVL have developed and used their own vehicle simulation tools and are attempting to model systems of vehicles, yet the poster offered no evidence of connecting with such companies or with other national laboratories for the purpose of making the work relevant to potential users.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer asserted that the future work is outstanding in that it represents a logical, stepped introduction of new capabilities that are critical to accomplishing the overall project objectives. The future work appropriately addresses development of new functionality and validation of the capabilities via analytic exercises that are useful to DOE.

Reviewer 2:

The reviewer commented that the proposed future research is well described and focused. The deliverables are sound and the schedule appears feasible.

Reviewer 3:

The reviewer noted that there are a good set of tasks that will allow the progression of the system framework and workflow and believed that there are real opportunities in this project that would have important progress in HPC applications if they are successful. The reviewer added that a task that highlights a validation with real-world supporting data of a smaller scale prediction would be of significant value.

Reviewer 4:

The reviewer found the future work to be focused on first launching the public version of AMBER and then developing use cases to support current and future VTO technologies with a focus on smart mobility and very large simulations. The reviewer remarked that while developing a simulation tool that can model the potential benefits of the future mobility systems is appropriate, the transportation system being modeled is very complex and uncertain, making one question the accuracy of results because there will not be any means to validate the outcomes for years to come.

Reviewer 5:

The reviewer observed that the project has identified a number of tasks that appear logical and may be worthwhile, but it has not shown how these future tasks fit into an overall strategy or help to reach important goals. The reviewer stated that the goals appear to be just a random set of additional tasks that involve adding new cases, new vehicles, and incorporating additional workflows. The reviewer believed that no decision points are incorporated and that there appears to be no attempt to evaluate the success or utility or benefits of the future tasks. The reviewer did not see any identification of alternative development pathways, and there is no discussion of risk or risk mitigation, perhaps because when no target is identified there is no chance of missing it. The reviewer commented that the problem with the future research goes back to the problems identified initially: a lack of clear focus and a lack of clearly identified goals and the benefits of reaching them.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer acknowledged that while this project will not directly impact petroleum displacement, it is developing a model that will enable quantification of potential benefits of a variety of smart mobility activities. Its future use is envisioned as one of the analysis tools for VTO.

Reviewer 2:

The reviewer indicated that this project enables the evaluation of transportation energy consumption of existing and emerging technologies on a scale of hundreds or thousands of vehicles. This type of analysis is useful for assessing the potential petroleum displacement impacts of the new technologies. The analyses will help commercial and governmental organizations identify technology strategies that minimize petroleum consumption.

Reviewer 3:

The reviewer commented that the impact of CAVs on petroleum displacement must be considered via modeling of the transportation network as a whole, and that the AMBER project provides the tool for these analyses.

Reviewer 4:

Although the project is very relevant to oil displacement, the reviewer was not completely convinced that it would have significant impact on technology or quicken market strategies unless the following occur: there is significant work aligning a customer impact model like MA3T, which was promised by the project team; and there are supporting incentives from the government, which is uncertain.

Reviewer 5:

The reviewer remarked that the answer to this question with respect to this project is not completely straightforward and suggested it would be better if another answer were allowed, such as “maybe” or “possibly.” The reviewer commented that this project could support DOE’s objective of displacing petroleum if it were properly structured and integrated with other DOE research and if it included more collaboration with stakeholders and other non-DOE research. A software tool like AMBER might help identify how future vehicles, including automated vehicles, might affect traffic flow in a city or might affect energy consumption in a region. It might help guide fueling options and help locate charging stations; help select between mass transit vehicle and route options; and help vehicle designers and urban planners devise better systems. However, it needs to focus on a small number of applications and uses and demonstrate its utility on those specific problems before it tries to be all things for all potential users. The reviewer commented that a program like AMBER could support DOE’s objectives, but it needs much better direction and coordination with other projects before it will do so.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer allowed that $600,000 per year over three years seems like an appropriate investment for building this multi-workflow framework.

Reviewer 2:
The reviewer commented that the resources are sufficient to introduce critical functionality to the AMBER framework.

Reviewer 3:
The reviewer suggested that additional outside input should be considered to focus resources on portions of the project with the most promise, but funding may cover all proposed future tasks if funded to planned amounts.

Reviewer 4:
The reviewer noted that the modest budget appears to leverage existing ANL resources and is cost effective for the significant deliverables.

Reviewer 5:
The reviewer remarked that because the project does not seem to have identified any milestones (at least not meaningful and measurable milestones), then the resources available per milestone are, by definition, excessive. The reviewer brought up that it was not sufficient to simply put other tools into the AMBER workflow and say that it is an accomplishment. The reviewer stated that it seems to be what is happening and it would seem to have minimal utility. The reviewer proposed that rather than put more money into a generalized workflow enabler like AMBER, it would be better for the researchers, with DOE input, to identify a specific problem or limitation that cannot be overcome or addressed by current simulation tools, then define a tool that satisfies that specific need, and next identify the resources needed to develop that specific tool, with goals and milestones along the way. The reviewer said that putting more money into something as ill-defined as the current AMBER project seems like a mistake. The reviewer commented that there are projects and proposals to model a fleet of vehicles, a municipal transportation system, a city’s vehicle population, an Army base, or a regional transportation and energy system, but this poster does not communicate how this project or the AMBER software simulation tool will apply to any of these and certainly not in a timely fashion.

Presentation Number: eems014
Presentation Title: Agent-Based Transportation System Modeling with POLARIS
Principal Investigator: Josh Auld (Argonne National Laboratory)

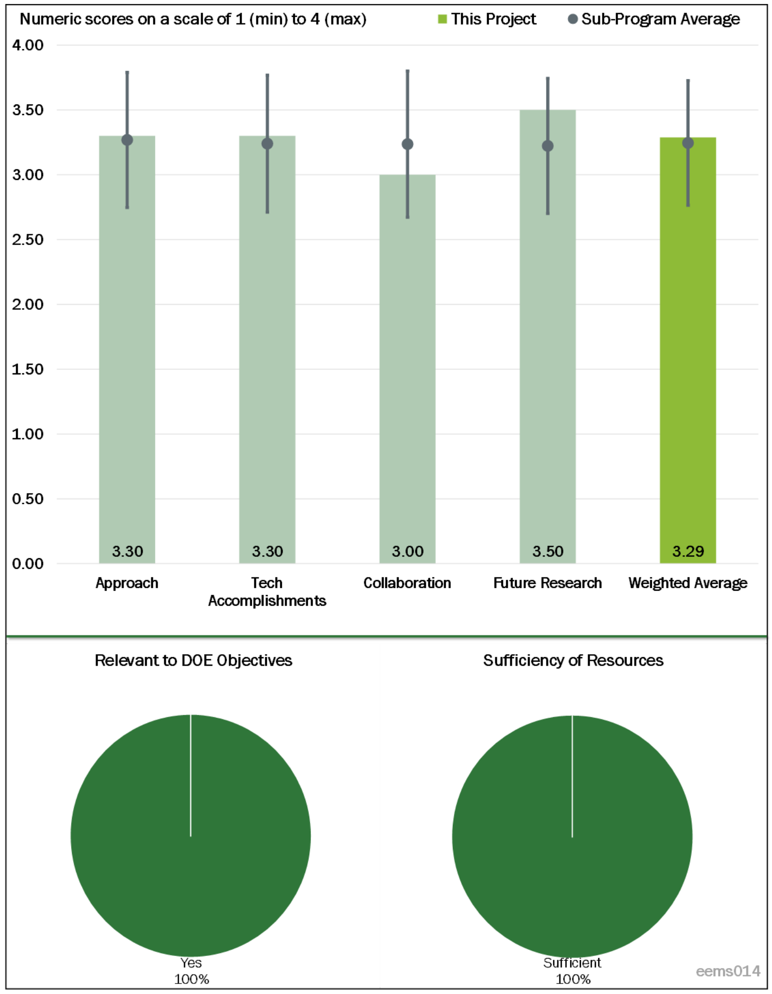

Figure 4-14 - Presentation Number: eems014 Presentation Title: Agent-Based Transportation System Modeling with POLARIS Principal Investigator: Josh Auld (Argonne National Laboratory)

Presenter
Josh Auld, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer pointed out that POLARIS is an open source model designed for large-scale studies modeling the transportation system of a metro area. The reviewer noted that the model takes into account traveler, mode, and energy use when coupled with Autonomie. The reviewer stated that the model is well suited for EEMS modeling, supports four out of five DOE SMART Consortium pillars, and is well integrated with other EEMS modeling efforts.

Reviewer 2:
The reviewer remarked that this a major task with many variables in a rapidly changing world. The reviewer noted that the approach is realistic considering the current environment.

Reviewer 3:
The reviewer outlined that the project focus is to further develop the POLARIS model for evaluating the energy impacts of CAV technology implementation and effects of changing travel behavior and modes on a community or metropolitan level basis. The reviewer added that POLARIS is a good platform for this type of modeling given its efficient computing capabilities for large datasets. The reviewer stated that the approach includes five primary milestones: Vehicle Assignment Models; Travel Behavior Models; CAV Traffic Flow Model; Multi-Modal and Transit Model; and POLARIS Core Development. The reviewer commented that the outlined approach is well constructed to result in improved functionality of POLARIS regarding future EEMS technology modeling efforts and fits within the broader context of important POLARIS model development. The reviewer noted that the project is leveraging off several ongoing and complementary modeling efforts and case studies supported by other organizations including DOT.

Reviewer 4:

The reviewer stated that the project has a good approach. However, this reviewer noted that barriers highlighted by the presentation include difficulty transferring models to multiple cities and the need for expensive traffic data, which are not fully sorted as components of initial project barriers.

The reviewer also said that if we understand our models are not accurate in energy estimations given new modes or technologies, we should identify the work that is being done to better understand the agents and validate those foundational components of this approach.

Reviewer 5:

The reviewer commented that it appears that there are data sources from FHWA that may be overlooked.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that vehicle assignment, travel activities, and enhanced traffic flow models have been completed to date, and the core POLARIS and multi-modal transit models are under development. The reviewer stated the project is well on the way to meeting project objectives and milestones.

Reviewer 2:

The reviewer stated that it was very good to see groundwork laid for a computation effort to be placed into the HPC realm and the recognition of the need for critical simulation capability of human interaction and decision science. However, POLARIS seems light on the availability of information and driver response.

The reviewer commented that successes with this project could guide the future focus for EEMS projects and relationships for dense population planning, including charging and parcel drop spot location forecasting. The reviewer noted that the model needs elements of historical data, which can validate model projections.

Reviewer 3:

The reviewer stated that it was very early in the project and that things were very good at this stage.

Reviewer 4:

The reviewer said that the accomplishments appear to be moving toward achieving the goals.

Reviewer 5:

The reviewer indicated that the researchers stated that the project is 15% complete as of development of their presentation, which seems reasonable given an October 2016 start-up. The reviewer noted that the presentation stated that the project should be 25%-30% complete by the end of the fiscal year. The reviewer said that the project has pursued a new approach to vehicle assignment models, initiating work on a new framework for a dynamic vehicle transaction model based on data from R.L Polk and ORNL’s MA3T market penetration model.

The reviewer noted that the project also reported progress on travel activity and choice models for representing future mobility modes and options by focusing on new enhancement to POLARIS’ traffic flow model to better represent travel times and vehicle speeds due to CAVs. The reviewer commented that the enhancements incorporate road features, traffic conditions, and number of CAVs in the link, and leverage traffic flow micro-simulator work done by Texas A&M University. The reviewer stated that the project has begun work on multi-modal travel with a public transit model, with design and testing of a fast multi-modal router, and prototype development for the Chicago metropolitan area as an initial incorporation into POLARIS. The reviewer also indicated that researchers have also started POLARIS core development activities, including new interface and visualization tools and software enhancements for automated build and test. However, researchers did not intimate that available datasets has been and will be a limiting factor toward progress.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer found there to be good collaboration with four universities and two other national laboratories.

Reviewer 2:
The reviewer commented that collaboration partners represent all but one capability, fleet logistics. The reviewer emphasized that the model is good with recognition of human decision, but wondered what travel information will impact large fleet services, say for changing routes for drivers or even going to semi-live routing based on truck inventory and stem versus branch routing options. The reviewer stressed that the project needs a partner with a stake in the game to see how they are learning and predicting.

Reviewer 3:
The reviewer said that collaboration and coordination with the other laboratories in the consortium is most crucial.

Reviewer 4:
The reviewer suggested that there appears to be an opportunity to reach out to the DOT and FHWA for data sources and technical expertise

Reviewer 5:
The reviewer applauded that the researchers cited significant current and planned collaboration with outside organizations. To date, this includes SMART Mobility Consortium members and Texas A&M University. The reviewer noted the team has also utilized ORNL's MA3T model and outside data sources for supporting progress to date. Lastly, the reviewer complimented the team on its leveraging of over half of the available funding from non-DOE SMART Mobility sources, including FTA, DOE-VTO, DOE funding opportunity announcements, and ANL laboratory directed R&D.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that proposed future research, new data sources, and automation are well aligned with addressing the remaining barriers.

Reviewer 2:
The reviewer said that there is a lot of potential for POLARIS to play a major role is mobility decisions.

Reviewer 3:
The reviewer found it encouraging that the researchers are taking advantage of the investment made by the DOT and Columbus on the Smart City challenge. The reviewer was hopeful that this can be extended to other cities that proposed or are otherwise participating in some way.

Reviewer 4:
The reviewer noted that the research team has laid out a well-thought out research plan and has made reasonable progress to date that currently funded FY 2018/2019 research activities that appear to support overall project objectives of enhancing POLARIS capabilities for effective future mobility modeling, including development of travel behavior and CAV traffic flow models, and continued development of POLARIS core

capabilities. The reviewer remarked that the researcher recognizes that availability of data, especially travel behavior data, will be a continuing challenge to future work under the project, but the proposed investigation of big data sources from commercial, public, and metropolitan planning organizations should help address some of these deficiencies. The reviewer stated that key attributes of future research will be the development model externalization and leveraging of an HPC environment to allow for large-scale POLARIS EEMS research. The reviewer commented that the researchers also offered interesting post-project research opportunities, pending additional funding (including additional travel modes and refueling and recharging infrastructure), and links to land use and energy and grid models.

Reviewer 5:

The reviewer said that behavioral and traffic flow should be a focus as this category should be able to help identify policies that may truly influence traveler's choices. The reviewer noted this may be the only way to truly validate with cause and effect for future projections.

The reviewer indicated that the automated process for validation of POLARIS seems like it may be an expansion of scope of the project. The reviewer added that it is understood that the ability of the models to transfer to other regions is of great importance, but improving the accuracy of the projections, highlighted as an initial barrier, should trump the focus of spreading to new locations or incorporating new datasets until various models can be evaluated for their performance and downselected.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said that while this project does not directly impact petroleum displacement, it is developing a transportation modeling tool to quantify the energy impacts of future mobility trends and identify technologies and policies that can be leveraged for a more energy efficient transportation system.

Reviewer 2:

The reviewer affirmed that there is no doubt that the project has impact on the mission to reduce oil consumption, but until projection accuracy improvements can be quantified, there is a question as to the decisions that can be made from this initial work. The reviewer noted that building a stable foundation model that accurately accounts for behavior and impact of new technologies (CAVs) or sharing modes is no small task; this effort is both relevant and should build understanding of critical characteristics relating to model performance in each of the partners.

Reviewer 3:

The reviewer commented that understanding mobility is key to optimizing the technology created through VTO's vehicle investments.

Reviewer 4:

The reviewer stated that the objective appears to be more about efficiency of freight movement rather than petroleum displacement, but the two go hand-in-hand.

Reviewer 5:

The reviewer agreed that this project has significant relevance to DOE objectives for petroleum displacement by investigating model approaches for estimating the energy impacts of future smart mobility technology. The project leverages the existing capabilities of the POLARIS model for providing a common modeling framework for future CAV implementation and travel mode and behavior. The project also looks to expand POLARIS capabilities in performing large-scale modeling in an HPC environment.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer acknowledged that for FY 2017 the $300,000 of DOE funding is being leveraged with another three times that amount provided by other organizations, showing the importance of this work.

Reviewer 2:
The reviewer commented that the research appears to have sufficient resources to complete the proposed activities and that the researchers have done a nice job of leveraging several funding sources, both DOE and non-DOE, to achieve overall stated research objectives.

Reviewer 3:
The reviewer observed that the partnerships described provides confidence that the project will achieve its goals.

Reviewer 4:
The reviewer stated that leveraging the laboratory consortium will be very important to optimize resources.

Reviewer 5:
The reviewer said that it can be difficult to understand the source funding and project scope or partner efforts when Slide 2 discusses multiple streams and possibly projects related to the efforts and their funding.

Presentation Number: eems015
Presentation Title: Calibration of Activity-Based Transportation System Simulation Tools using High-Performance Computing
Principal Investigator: Vadim Sokolov (Argonne National Laboratory)

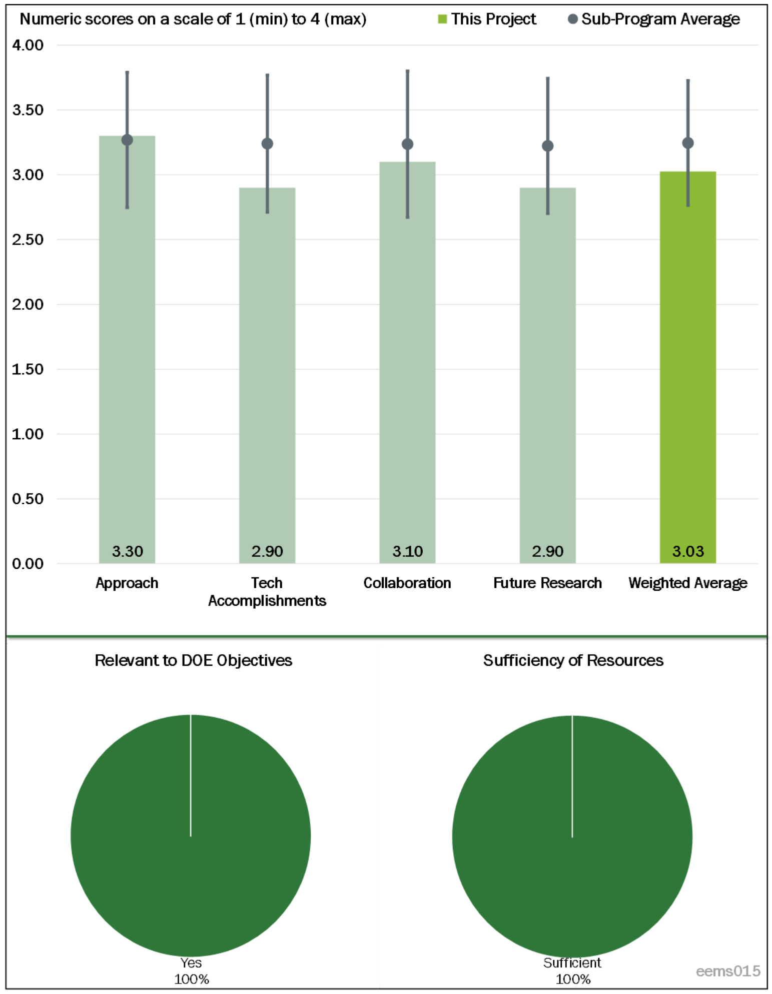

Figure 4-15 - Presentation Number: eems015 Presentation Title: Calibration of Activity-Based Transportation System Simulation Tools using High-Performance Computing Principal Investigator: Vadim Sokolov (Argonne National Laboratory)

Presenter

Vadim Sokolov, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project took a good approach focused on combining big data, simulation, and HPC. The reviewer noted that new types of mobility datasets are being considered for integration into POLARIS.

Reviewer 2:

The reviewer remarked that while it was early on in the project, the poster presenter had a good handle on the task at hand and the difficulty in truly paring down parameters of interest as well as the importance of sensitivity studies and analysis. The reviewer stated that a basic plan and milestones were in place, but the reviewer also recognized that the project interlaced with other SMART Mobility projects, which the reviewer believed should be able to keep the project in focus and not creep into other areas.

The reviewer suggested that the Bayesian optimization and transfer from other industries would be the importance of the similarity of agents and noted that other industries listed are typically profit focused where transportation is activity focused.

Reviewer 3:

The reviewer noted that the project adopts a proven method for minimizing errors to estimate model parameters and said that if datasets of input and output variables were available, the calibration computations are feasible using the method proposed. The reviewer commented that the calibration task is integrated into a multiple step approach for performing EEMS analysis.

Reviewer 4:
The reviewer stressed that calibration of models is crucial to making the models applicable to new locations and stated that this project addresses the calibration needs for a transportation system model and usefully employs POLARIS for the framework.

Reviewer 5:
The reviewer remarked that the poster identifies the technical barriers as “Transportation models are complex” and “Calibrating [them] is costly and inaccurate” and suggested that the team describe the barriers differently. The reviewer, however, believed that this research is addressing important issues and doing so in a relatively logical and well-designed manner. The reviewer noted the research is trying to incorporate new sources of data regarding vehicles and traffic flow while also taking steps to simplify the problem through dimensionality reduction, Bayesian optimization, and Gaussian process emulation. The reviewer said that these methods have been applied to other technical problems and believed their use here makes for a sound approach. The reviewer stated that the project is addressing important technical barriers in a feasible manner and the chance of producing useful results is reasonable. The reviewer was concerned with the lack of more and better integration of this work with other efforts. The reviewer indicated that the poster mentions sources of data and the difficulties in getting good data, but the reviewer would like to have seen evidence that the researchers considered and pursued additional potential sources, such as those that deal with traffic flow in specific cities such as Google Maps and Waze, not to mention other potential data sources, such as Lyft, Uber, and taxi companies. The reviewer suggested attempting to access data from these sources. The reviewer also brought up that other companies such as SAS are involved with mining huge datasets and stated there are others, such as Georgia Tech, who are doing research on modeling of large complex systems. The reviewer said that there is no evidence that the researchers are connecting with other similar research. In summary, the reviewer suggested that the project team could do more to integrate the work with others in the field outside of their current collaborators.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the project is only 15% complete as it was a new start in FY 2017. The reviewer noted the project has completed a literature review on calibration of complex models, identified three distinct approaches, and prototyped a computational framework for calibration using HPC.

Reviewer 2:
The reviewer found the project to be in its early stages, but stated that it seems to be keeping on pace. The reviewer said it was significant to find early sensitivity, but it was also as significant to recognize early success with calibration of systems regarding input variation, as it may also mean there are more scenarios to examine prior to calling a model calibrated. The reviewer called out the cell phone activity pattern relationship to activity patterning as needing some validation.

Reviewer 3:
The reviewer noted that the preliminary analysis of high-sensitivity results shows that significant challenges remain in the software infrastructure and said that the plan to overcome these challenges appears sound. The reviewer stated the resulting framework will support DOE goals for modeling transportation networks.

Reviewer 4:
The reviewer observed that evidence of the work performed to date was sparse in the presentation and suggested it would be helpful to have seen more complete explanation of results of the sample data exercise that was mentioned in the presentation.

Reviewer 5:

The reviewer said that while the poster talks about some of the progress that has been made in selecting the approach, identifying data sources, reducing dimensionality, and performing a sensitivity analysis, there is no clear evidence of measurable progress against quantifiable milestones because the milestones are not well defined or measurable. The reviewer stated that the milestones should be reconsidered and recast to define a quantifiable level of performance or progress. The reviewer suggested establishing a milestone that could say that the model has been developed to a point where it handles X-number or Y-types of vehicles, or that it has reduced the dimensionality from A to B, or that a certain amount of data has been gathered and analyzed. The reviewer cited the current milestones as offering no way to measure progress or providing any performance indicators. The reviewer noted that despite the technical progress made, no real evidence is provided. The reviewer suggested having more quantifiable milestones will become even more important as the project starts to deal with the issue of calibrating the model against data and found it critical that the DOE project managers demand that all the milestones be redefined in terms that are meaningful and measurable.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that there was good collaboration on calibration framework for POLARIS with George Mason University (GMU), with LBNL on large-scale travel activity data, and with the Colorado Department of Transportation (CDOT) for transportation data exchange.

Reviewer 2:

The reviewer stated that the project is making a good attempt to cover bases with players who can assist in input date and modeling theory, but in looking at the available funding, the reviewer found that a delivery fleet logistics coordinator would go a long way to allow driver agent validation; such a person should have large datasets of traffic flow for analysis with specific traffic inputs and the actual traffic response data. The reviewer suggested such an organization would be a valued partner in this type of analysis.

Reviewer 3:

The reviewer noted that because this work is connected with other researchers at GMU and LBNL, it merits a satisfactory grade for collaboration and coordination. However, the project could do much more in this area, and the reviewer believed it would make the project so much better if the researchers widened the scope of their collaboration activities. The reviewer earlier mentioned collaboration opportunities with companies and organizations that are active in similar areas such as Georgia Tech, SAS, IBM, and CISCO as well as others that could be sources of data such as Uber, Lyft, Waze, taxi companies, and taxi and limousine commissions. The reviewer stated that there is other relevant work at the national laboratories that could also be sources for collaboration. The reviewer suggested that the researchers should do more to collaborate with others if they want to increase their score above the “Satisfactory” level.

Reviewer 4:

The reviewer called the coordination and collaboration among the partners as appearing strong and noted the presentation was specific in naming potential sources for the data sources that the project plans to use.

Reviewer 5:

The reviewer remarked that the collaboration among academia, ANL, and CDOT is strong. The reviewer suggested that additional DOTs could be added as the software framework is developed in order to test it in different locations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that proposed future work is appropriate and focuses on implementation and simulation in FY 2017, mathematical models in FY 2018, and application using cell phone data and origin-destination flows in FY 2019.

Reviewer 2:
The reviewer looked forward to seeing if the future effort changes as the project progresses and noted that completing the process of inputting a large dataset would be valuable for many projects if the datasets are standardized and suggested that this could be useful across multiple EEMS projects.

The reviewer stated that continued work on sensitivity is key and noted that an automated calibration technique was also noted in EEMS014; the reviewer wanted clarification about which activity is funding that specific effort.

Reviewer 3:
The reviewer commented that the future work outline provided in the presentation indicates that the near-term work will focus on process automation and that key datasets such as cell phone data and estimated origin-destination flows will not be incorporated until FY 2019. The reviewer suggested that significant efforts should be made to introduce the key data much earlier in the project timeline as a way to lower project risk. The performers should consider obtaining limited scope, sample data sets of the key data that address small geographic areas from the sources they plan to use for larger studies.

Reviewer 4:
The reviewer indicated that the significant challenges remaining do not have clear paths to success and suggested more milestones should be developed in order to ensure that interim goals are met and the project is progressing at the scheduled pace.

Reviewer 5:
The reviewer saw that the project clearly has plans for the future work and these plans may be logical and useful; however, the reviewer believed they are not expressed in a quantifiable form so it will be impossible to evaluate progress. The reviewer stated that because the researchers have set no measurable goals, they have also not identified any risks in achieving their goals; as a result, there is no discussion of risk or risk mitigation. Because of this, there seems to be no consideration of alternative development pathways. The reviewer proposed that the project needs to lay out a clear path to an endpoint and define milestones along the way that can be evaluated. The reviewer also suggested that the likelihood of meeting the milestones should be estimated and the barriers and risks should be identified for each one so that the DOE program managers can assess whether the project is on track or not. The reviewer stated that the researchers have some fairly clear ideas of what needs to be done, but have not clearly defined the steps along the way and have given no consideration to alternative paths or how to identify and deal with risks and barriers.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that this project is developing an automated calibration process for large datasets to be used in POLARIS and is therefore an enabler for modeling energy use, including petroleum impacts of future mobility systems.

Reviewer 2:

If it were not for the fact that this reviewer had reviewed multiple EEMS projects, it might be easy to overvalue the importance of this project. The reviewer told AMR organizers that it was good to have multiple related projects so that comparisons could be made.

The reviewer mentioned that the focus should remain on highly variable inputs and the effect of final predictions and sensitivities with an eye on validating against other industry models, given agent differences. The reviewer noted that this would mean the project could home in on first blush research projections with a less detailed effort than some other projects.

Reviewer 3:

The reviewer said that models of the transportation networks will require calibration in order for them to be flexible in their location application and that understanding the impacts of CAVs on petroleum consumption within the transportation system is very much aligned with DOE goals.

Reviewer 4:

The reviewer pointed out that at this early stage of the EEMS project, the reviewer's response is based on optimism and giving the benefit of the doubt to the analytic team's vision. The reviewer noted that this calibration task is one of several tasks that work together to provide a simulation framework that will be used to perform analysis on mobility concepts that have potential to both increase and/or decrease petroleum consumption.

Reviewer 5:

The reviewer asserted that the results of this project should be improvements in the calibration of transportation models, which should help make them more accurate and more useful. The reviewer stated that with more accurate transportation models, we should be able to evaluate a host of variables in transportation systems: vehicle population make-up, traffic patterns, and public policy decisions. All of these things could have a significant impact on petroleum use and displacement. The reviewer said that the project is focused on a useful topic, but needs to have clearer goals and better milestones along the way to meeting those goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that $500,000 over 3 years is a relatively small project, but it is providing an important pathway for including new kinds of large datasets into transportation systems models.

Reviewer 2:

The reviewer acknowledged that multiple EEMS projects have some common efforts listed and it is hard to address specific funding to specific efforts. The reviewer noted the main effort seems both unique to the program and also important to the foundation of modeling theory for transportation as a whole. The reviewer stated that this was a good project.

Reviewer 3:

The reviewer said that the resources appear to be sufficient for this project.

Reviewer 4:

The reviewer commented that the budget is sufficient based on the assumption that the costs of obtaining the required datasets are low or are funded through another task. The reviewer pointed out that the presentation does not address the costs of the HPC resources and the reviewer assumed that the HPC resources are free to the project.

Reviewer 5:

The reviewer believed the resources are sufficient for making progress in improving the calibration of transportation models, but believed the project might benefit from more interaction with industry, which could bring its own resources through a cooperative research and development agreement or similar arrangement in order to share data and results.

Presentation Number: eems016
Presentation Title: Energy Efficient Connected and Automated Vehicles
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

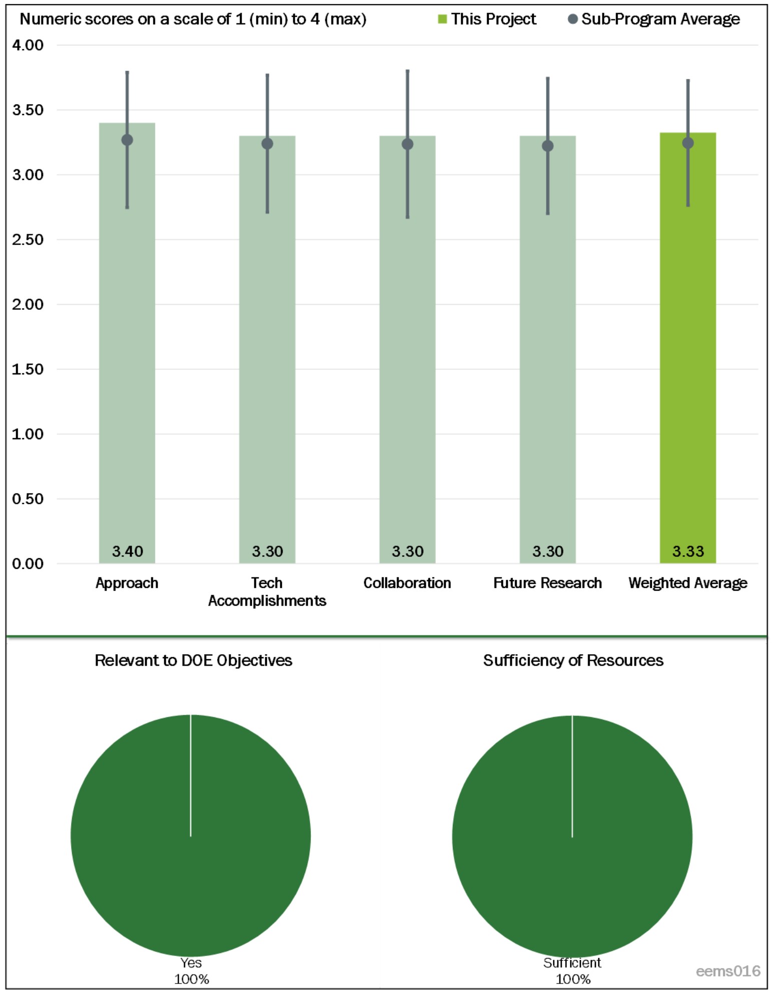

Figure 4-16 - Presentation Number: eems016 Presentation Title: Energy Efficient Connected and Automated Vehicles Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach is a very good way to leverage existing modeling infrastructure and adapt it to the needs of the CAV pillar as it utilizes expertise from other sources to achieve some of the goals and looks like a very practical approach without getting too deeply into the OEM engineering design space.

Reviewer 2:

The reviewer commented that the project makes excellent use of previously developed DOE tools. These are cleverly integrated to achieve the project objectives.

Reviewer 3:

The reviewer said that at this point in the project the approach is appropriate.

Reviewer 4:

The reviewer pointed out that this research addresses several outstanding barriers to future CAV technology, including the role of advanced powertrains in CAV implementation and associated energy impacts. The project objective is to perform control-based simulation focused on powertrain and velocity parameters to assess the energy impacts of advanced powertrains for various CAV strategies. The approach involved CAV modeling framework development, optimal control strategy development, and analysis of a case study on CAV strategy. The project relies on framework development by pairing with an existing ANL powertrain model, Autonomie, for use in evaluating future CAV strategies, and will result in functional CAV libraries that other researchers will be able to utilize in Autonomie. The scope is laid out well, and utilizes existing data and results from other SMART Mobility Consortium members. The reviewer believed project efforts were vehicle-centric, focused on single or small groups of vehicles, but the reviewer suggested project results could eventually support wide-scale CAV simulations through existing models like POLARIS.

Reviewer 5:

The reviewer commented that the project is a dive into a couple of applications for CAVs from a broad swath of potential applications. The reviewer noted these methods are present in the literature, but have not been scaled to include both powertrain control and vehicle dynamics control parameters. The reviewer suggested adopting the ARPA-e differentiation between vehicle dynamic and powertrain controls, which would be more useful in understanding which methods are valuable where.

The reviewer was unsure how the results would be taken to practice and who the target audience was for the work and thought that policy makers would make sense because the methods are far removed from what is practiced in automotive industry.

The reviewer said that there was no mention of methods of prediction and uncertainty in prediction discussed in the presentation.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that accomplishments are helping to answer the questions posed by the CAV pillar and that progress has been excellent thus far. The reviewer was looking forward to further updates.

Reviewer 2:

The reviewer commented that it is very early in the development of this project; however, a detailed plan of work and schedule has been developed and progress to the plan is on target, with the framework development underway.

Reviewer 3:

The reviewer stated that accomplishments were appropriate for this early stage in the project.

Reviewer 4:

The reviewer commented that to date, the researchers claim to be 10% complete with the proposed research plan. However, the PI also verbally stated that the project team expects to have about 25% of the plan completed by the end of FY 2017. The reviewer noted that the research has made meaningful accomplishments including initial development of the simulation framework with early integration of the human driver model, powertrain (Autonomie) model, and CAV model; identification of CAV velocity control parameters; development of optimal control theory for powertrain-velocity combinations including Pontryagin's Minimum Principle (PMP) results; and early results for model-predictive control (MPC) scenarios.

Reviewer 5:

The reviewer was interested in feedback from OEM industry partners on the potential for vehicle integration, if that is the goal/audience.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer acknowledged that the project team did an excellent job of leveraging contributions from universities and other government agencies and laboratories.

Reviewer 2:

The reviewer said that collaboration with other laboratories is excellent within the SMART Mobility Consortium and noted that several partnerships, including universities and the FHWA, have been implemented to obtain data for validation.

Reviewer 3:
The reviewer said that the collaboration and coordination with other laboratory partners are crucial for optimization.

Reviewer 4:
The reviewer commented that researchers have stablished significant collaborative partners with other federal agencies for framework development, national laboratories for testing relevant program data, universities for control theory and human driver and CAV models, and roadway digital map data vendors for roadway conditions for a better understanding of the terrain. The reviewer indicated that as the research proceeds, there should be significant collaborative research opportunities with other organizations concerning human driving and CAV models and translation of results to large-scale CAV simulation using models such as POLARIS.

Reviewer 5:
The reviewer stated that the project team should expand the description of their collaboration and coordination in future AMRs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the future work consists of logical next steps and extends modeling capability.

Reviewer 2:
The reviewer noted that the project plan and schedule have been developed and fully support the project objectives. The reviewer stated that the plan for development of the framework, case studies, and predictive control is well thought out.

Reviewer 3:
The reviewer indicated that the proposed future research logically flows from what has already been accomplished on the project. The reviewer noted that activities in FY 2017 and FY 2018 will include a continuing the CAV simulation framework, developing and running specific case studies, and working on optimal control theory including PMP and MPC. Future framework development will focus on human driver models, better integration of Autonomie, and use of real-world driving databases. The optimal control work will start with conventional vehicles and then proceed to hybrids and EVs. The researchers understand the challenges to their controls research that lie ahead and will rely on "optimization-based" heuristic control in case optimal control becomes too complex.

Reviewer 4:
The reviewer stated that an expanded emphasis not only on verification and validation of aerodynamics as proposed, but also of the Autonomie models, would be important to the project. The reviewer was unsure what the levers that the optimization will be turning in Autonomie to be able to achieve optimal fuel economy control, but cautioned it may be outside of the drivability constraints or actuation abilities of real-world powertrains.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the project provides an excellent tool for CAV developers to optimize vehicle design as it relates to energy use.

Reviewer 2:
The reviewer said that the success of this project can have a significant impact on petroleum displacement and improved mobility.

Reviewer 3:
The reviewer commented that this project supports DOE program objectives by studying the energy and operational relationships of future CAV and advanced powertrains, investigating potential CAV control theories for a variety of operational scenarios and providing a simulation framework for vehicle-specific and wide-scale CAV implementation. The reviewer noted that output of this effort will establish CAV-related libraries and modules for Autonomie that can be used by other researchers in estimating future fuel consumption benefits from CAV technology.

Reviewer 4:
The reviewer indicated that the project is critical to providing analytical results to understand how much efficiency (and hence fuel savings) can be gained from the new transportation modes implied by CAV capability, a key question for the SMART Mobility work.

Reviewer 5:
The reviewer said that the project is fine in regard to this question.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the research appears to have sufficient resources to complete the proposed activities, both for the current fiscal year as well as future years, based on the planned activities and period of performance.

Reviewer 2:
The reviewer stated that the project plan incorporates the necessary outside resources to accomplish its objectives and noted that there is effective use of existing DOE-developed tools.

Reviewer 3:
The reviewer suggested leveraging all laboratory partners.

Reviewer 4:
The reviewer stated that funding is adequate for FY 2017. The reviewer was unable to judge the FY 2018 funding based upon the presentation.

Presentation Number: eems017
Presentation Title: Impact of CAV Technologies on Travel Demand and Energy
Principal Investigator: Josh Auld (Argonne National Laboratory)

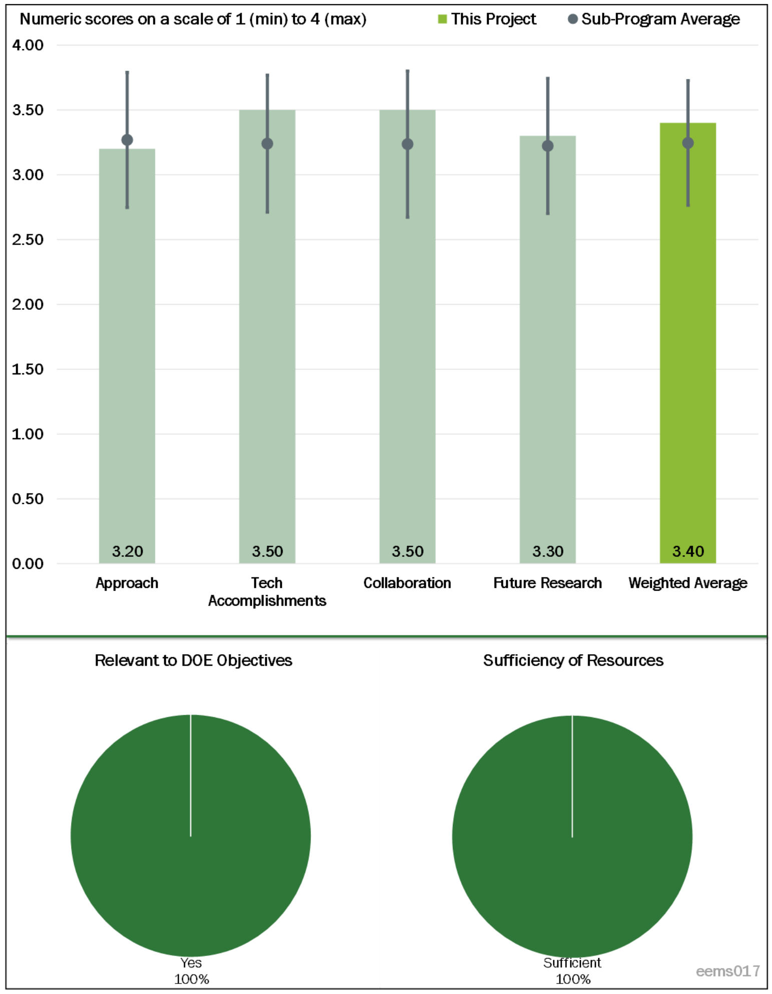

Figure 4-17 - Presentation Number: eems017 Presentation Title: Impact of CAV Technologies on Travel Demand and Energy Principal Investigator: Josh Auld (Argonne National Laboratory)

Presenter
Josh Auld, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the approach recognizes that the objective of this effort is to build a framework that becomes a foundation for future evaluation of the effects of CAV use on travel demand and energy use. The reviewer also noted that while some data are available to validate the framework, it is insufficient at this point in CAV development to quantify either the impact on travel demand or energy use. However, the reviewer elaborated, best efforts are planned to utilize available data to bound CAV effects.

Reviewer 2:
The reviewer stated that the approach is sound, given all the uncertainties involved in trying to answer the question posed.

Reviewer 3:
The reviewer observed that this project begins the necessary quantification of CAVs energy consumption prediction using survey data. The reviewer said that such data are notoriously inaccurate so the approach of using multiple surveys is sound. The reviewer noted that efforts could be made to either conduct additional surveys for the project itself, but, at least, the literature needs to be continuously monitored for additional survey studies to serve as rationale for updating the inputs to the modeling framework developed by the project. The reviewer pointed out that there is also no model validation mentioned that is to occur after the case studies have been run so efforts should be made to develop validation methodology.

Reviewer 4:
The reviewer remarked that the approach is good in that it considers quantified decision parameters (i.e., VOTT) and CAV penetration characteristics to quantify impact of regional CAV deployment. However, the

reviewer noted, the validity of the case study conclusions are brittle due to the overly simplistic utility function used for the case study (primarily VOTT). For instance, there does not seem to be a fuel or service charge cost penalty for traveling further distances. The reviewer said that the project as a whole could be improved by generalizing the utility function used for decision making; more complete decision functions could be represented and used for analysis. The reviewer added that the project may want to consider making the model capable of having the decision utility function specified via a list of input parameters. This approach would enable the project tools to be flexible to address a wider range of impact studies.

Reviewer 5:

The reviewer observed that generally, the approach appears to be well thought out and logical and is a good start to addressing a very tricky, complex question. However, the reviewer noted that the project should be clear about its limitations and that it is tackling a subset of a larger question.

The reviewer said that, in terms of project design, the project addresses the impact of Level 4 CAVs, but appears to be specifically constrained to Level 4 private passenger vehicles. In other words, there is a wide range of other types of Level 4 CAVs, and these can introduce many different behaviors and impacts on VMT and energy use. For example, Level 4 includes completely driverless (and even unoccupied) vehicles, as long as they are within an appropriate ODD.

POLARIS and Autonomie appear to be strong models and very appropriate for this research. The reviewer said that it is helpful that the project acknowledges that the case study is only a "preliminary assessment" and that outcomes will be richer and more meaningful as information is fed in from other SMART Mobility efforts.

The reviewer remarked that the approach identifies two key impacts: congestion may go down if VMT stays the same, and VMT may increase because drivers can repurpose driving time. The reviewer noted that another key impact not mentioned is that CACC can increase highway capacity, which may induce additional demand (and resulting VMT).

The reviewer noted that another factor not mentioned is that a significant percentage of highway congestion is caused by crashes and hard-braking due to near misses, and full adoption of Level 4 CAVs is likely to dramatically reduce (or virtually eliminate) that major source of congestion. The reviewer offered an interesting question for this research to address: how much energy is saved by avoiding crashes and related slowdowns/inefficient driving and how much additional energy will be used because the effective road capacity is increased by eliminating crashes and therefore more demand is induced. The reviewer stressed that this is not an insignificant question as longer inter-city trips are likely to encounter one or more incident-related slowdowns over a several-hour journey. As a result, travelers will typically adjust their expected times accordingly, and if they get used to shorter travel times without crashes or incidents, they will be more likely to take the trip.

The reviewer noted that the approach outlined on Slide 7 for integrating inputs from other pillars with POLARIS and Autonomie appears reasonable and effective. Of particular value, the reviewer said, is the fact that they clearly identify the current and future inputs so it is clear how this project is integrated with other pillars and how it will evolve as it gains their inputs.

The reviewer brought up that a weakness is that the approach does not clearly illustrate how mode choice is addressed. Similarly, the project does not make it clear how impacts of Level 4 automation on mobility options (including multi-modal trips, shared mobility, etc.) could affect VMT. It seems somewhat narrowly focused on private vehicle ownership and use. However, the reviewer said, given the size and complexity of this question, it is understandable that the scope is somewhat constrained.

The reviewer acknowledged that the scope of this project appears to keep land use and work/residence choices fixed. The reviewer noted that these are major considerations, probably demanding an entire study of their own so it is understandable if they are not included here. However, it would be helpful for the project to clearly define its scope as not including such factors and to acknowledge those limitations up front.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the technical achievements and progress to date are excellent in that the case study work was completed. The reviewer said that the case study presentation allowed the reviewer to have a clear picture of the project's approach, assumptions, and initial results. The reviewer noted that the case study results show that the tool is already capable of producing results and also can readily evolve to provide maximum utility to the exploration of energy characteristics of CAV-enabled transportation.

Reviewer 2:
The reviewer said that the progress has been very good and that the early results are interesting and reflect the wide range of possible outcomes.

Reviewer 3:
The reviewer opined that it is too early in the development of this project to measure results. However, the overall plan that has been developed is solid and clearly recognizes the limitations of model results at this point in CAV development.

Reviewer 4:
The reviewer noted that the VOTT and willingness-to-pay (WTP) literature reviews appear sound as is the implementation of the WTP model in CAV adoption and the vehicle selection model. The reviewer said that the proposed future research goals are well developed and the major challenges appear to have been identified. The reviewer indicated that the project appears on track to deliver on DOE's goal of quantifying the impact of CAV energy consumption.

Reviewer 5:
The reviewer indicated that the project team appears to have done a fairly thorough job consulting existing literature on how CAVs will affect VOTT. The reviewer noted that the presenter was very aware of the limitations of current predictions and analysis in this area—in particular, the presenter acknowledged the major uncertainty around VOTT that arises when new vehicle architectures and new forms of activity are introduced for the occupants of CAVs. For example, old VOTT estimates did not take into account the wide range of activities that are possible in a vehicle now due to mobile devices and improved connectivity. In other words, the reviewer explained, if a commuter can be connected remotely to his/her desktop, with access to videoconferencing, he/she may be able to perform a significant majority of work tasks, thereby causing VOTT to drop precipitously.

The reviewer said that the methodology and initial results for consumer adoption appear to be sound based on existing literature. However, the reviewer noted, given the extreme uncertainty around such adoption models, it almost seems like those efforts could be better spent elsewhere. In other words, the reviewer explained, this seems like an area where ROIs diminish very rapidly—one could spend a fortune on trying to perfect these predictions and still be very far off. The reviewer commented that a scenario-based approach might be more appropriate—aiming to identify the energy impacts of CAVs at a wide range of market penetration (e.g., 5%, 10%, 20%, etc.). The reviewer stated that such outputs would still be very useful for policymakers, and would disentangle the discussion from all the potential disagreements about assumptions involved in making a prediction.

The reviewer found the CACC traffic flow simulation results to be interesting, but said that it would be helpful to see how these compare with other results in the literature. In particular, it would be good to know whether the project team consulted with work in this area done by the DOT's ITS-JPO.

The reviewer said that in the "impact on mobility" discussion, it is observed that travelers are likely to take longer trips. However, the reviewer noted, there is no discussion about potentially more trips being taken, as well as entirely new kinds of trips/destinations that could result from Level 4 CAV technology.

The reviewer stated that the outcomes, in terms of potential increases in energy use (while highly qualified and not likely to be "predictive" in any precise sense), are very valuable in that they clearly highlight a potential for substantial increases in energy use. The reviewer stressed that this topic has generally been under-addressed by the transportation community so even though it is far from perfect, by initiating this discussion and highlighting these issues, this project has added a lot of value to the broader conversation. The reviewer noted that it will be very interesting to see what its outputs are as inputs come in from other SMART Mobility pillars.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that the coordination among laboratories to utilize available, DOE-developed tools as part of the SMART Mobility Consortium is outstanding. Additionally, the reviewer noted that two university partners have been incorporated to provide data for the model.

Reviewer 2:

The reviewer stated that the collaboration and coordination were assessed as good because it appeared that only two of the five partners had contributed significantly to the case study results. The reviewer said that the future work indicates that the other partners may have opportunities to make contributions to the efforts.

Reviewer 3:

The reviewer said that the project requires data from a variety of sources and that the proper connections appear to be in place and working.

Reviewer 4:

The reviewer remarked that the collaboration partners listed appear to provide a good background for the inputs used to date. However, the reviewer noted, as more inputs to the model transition over to direct inputs from other SMART pillars, it is unclear what these relationships will continue to provide.

The reviewer commented that one suggestion would be to engage with additional partners, not just for external inputs to the model but also for a deeper discussion of ways to structure the model and possibly examine different versions of the model that could be developed. As noted earlier, this model is somewhat limited in its scope. The reviewer said it might be worthwhile to engage with other experts—perhaps through the DOT's "University Transportation Centers"—to consider alternative approaches for the model and how subsequent versions/variations of the model might address more issues. For example, the issue of mode choice and addressing new mobility options could be a focus of a future version.

Reviewer 5:

The reviewer said that the collaborations with other national laboratories and academia appear sound and that the PI should ensure that the project is broadcast within the SMART Consortium to ensure input from stakeholders that informs the model inputs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that they project is well planned and fully recognizes the limitations of developing models this early in CAV development and deployment.

Reviewer 2:

The reviewer noted that the future task list addresses the current known modeling gaps.

Reviewer 3:

The reviewer commented that the future work can be improved by limiting the scope to regional studies. The reviewer stated that it is important that this project nail the modeling of CAVs concepts at a regional scale before trying to expand the scope. The reviewer said that the case study exposes a need for significant work to develop more complete decision utility functions and that the future activities outlined also indicate the need to develop additional CAVs representations/functionalities for the model.

Reviewer 4:

The reviewer suggested deemphasizing the importance of "vehicle choice models" and market penetration models, given the extreme uncertainty. The reviewer said that this might be a case where scenarios spanning a wide range of outcomes are just as good (or better) than attempts at precise prediction.

The reviewer remarked that the plan to integrate data from surveys, while useful, is clearly somewhat limited. The reviewer noted that the Whole Traveler survey seems to be doing an admirable job considering its limitations but one would hope that there are other data sources being considered as inputs to better address attitudes toward CAVs.

The reviewer noted that there is no mention of addressing changes to work/residential choices in the near- to mid-term and longer term changes in land use; those should at least be on the radar for future research.

Reviewer 5:

The reviewer commented that the project has extensive future research plans that appear to follow a feasible and logical schedule and to meet the DOE goals for the project. The reviewer said that mitigation risk analysis is missing in case alternative pathways to the deliverables could be more extensive.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer acknowledged that the project absolutely supports the overall DOE objectives of petroleum displacement. The reviewer noted that any attempt to understand future transportation energy use and to displace the use of petroleum will have to understand and address the impacts of CAVs on travel demand and energy use. The reviewer said that while this project has significant room for improvement, it is also making significant progress in a very important area, with very clear, direct implications for future energy use.

Reviewer 2:

The reviewer said that the project will provide useful analysis of CAV impact on petroleum displacement and will be used in real-world traffic networks; this aligns well with DOE objectives.

Reviewer 3:

The reviewer commented that given the modeled CAV capabilities, the project tries to determine how they might be used on a large scale, which is necessary for determining the transportation-system level fuel displacement implied by CAV deployment.

Reviewer 4:

The reviewer mentioned that the models developed will provide important tools to support and guide the development and deployment of CAVs.

Reviewer 5:

The reviewer observed that if the project is successful in modeling CAV energy impacts, it will be a useful tool for understanding opportunities for petroleum displacement. The reviewer said that the project may also identify the need for additional strategies necessary to encourage petroleum displacement by CAVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources are adequate for FY 2017 and that there is no indication of future funding, though the project extends beyond that period.

Reviewer 2:

The reviewer stated that the laboratory and university resources applied appear sufficient to achieve the project objectives.

Reviewer 3:

The reviewer noted that the resources appear to be sufficient to achieve the stated objectives.

Reviewer 4:

The reviewer remarked that assuming that national level analysis is removed from the project scope, the project resources are sufficient to meet the majority of the milestones outlined by the project. The reviewer noted that this portion of the overall energy EEMS analysis process/framework appears most likely to quickly produce tangible analytical results and therefore warrants priority to maintain its funding (in the event of possible reduced funding for EEMS).

Reviewer 5:

The reviewer found the funding level to be sufficient, perhaps a little higher than necessary but by no means excessive.

Presentation Number: eems018
Presentation Title: Extended Urban Modeling for Smart Mobility
Principal Investigator: Budhu Bhaduri (Oak Ridge National Laboratory)

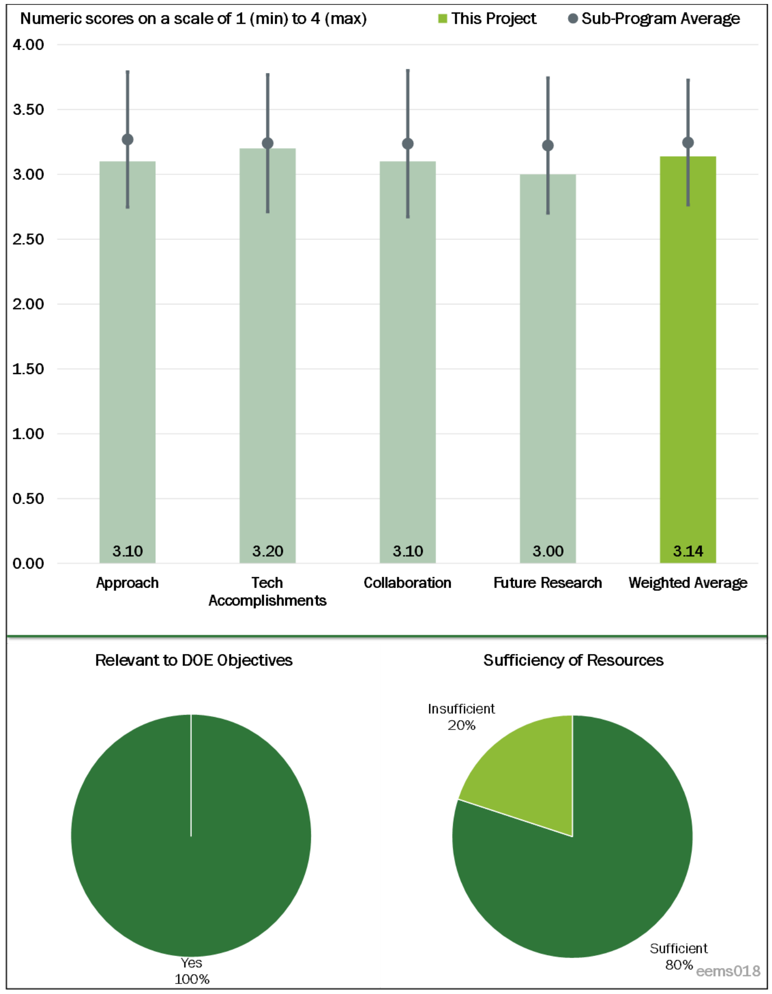

Figure 4-18 – Presentation Number: eems018 Presentation Title: Extended Urban Modeling for Smart Mobility Principal Investigator: Budhu Bhaduri (Oak Ridge National Laboratory)

Presenter
Budhu Bhaduri, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the approach is great and that this is a very important project

Reviewer 2:
The reviewer stated that the approach is feasible and that it is an integration effort so it is closely tied to other efforts.

Reviewer 3:
The reviewer noted that the overall approach seems reasonable and that the researchers propose to use existing simulation tools and calibrate them to a target city for demonstration and then apply them to multiple cities and a mix of fleets. However, according to the reviewer, it is unclear how the simulation will be compared to actual data. The reviewer said that it would be very helpful to list the metrics for evaluation of the simulation and judge the quality/validity of the simulation. The reviewer remarked that it could be validated against traffic patterns based on specific scenarios (normal traffic, rush hour, major events, construction, major accidents, etc.) to see if the simulation can model the traffic patterns that emerge in real-world situations.

Reviewer 4:
The reviewer observed that the approach is ambitious; however, there are data sources the researchers should consider, especially from FHWA and the second Strategic Highway Research Program (SHRP2).

The reviewer also noted that ridesharing is not considered.

Reviewer 5:
The reviewer found the overall approach to be very unclear in how it relates to other efforts. The reviewer said that the title of the project sounds very significant, but the funding is fairly small. The reviewer noted that,

based on the title, one would expect this project to produce some kind of centralized, unified model for urban mobility that captures all inputs from the various pillars.

Based on the slides provided and the narrative from the presenter, it is not clear what aspect of the TUMS workflow this project actually focuses on. The reviewer said that it is not very clear what this project adds that is new or different; in some senses it seems that it may be reinventing the wheel.

The reviewer commented that the key objectives are identified as developing a “locally adaptive scalable simulation model…,” and “enable efficient transfer of analysis and case studies… to interested cities.” However, the reviewer noted, it is not at all clear what the actual final outputs of the project are, or how they would connect to these two objectives.

The reviewer stated that it is good that the approach involves “exploring and understanding the current state of transportation modeling practice by Mid-Ohio Regional Planning Commission (MORPC).” However, the reviewer remarked, it seems as if the goal is to push the TUMS approach onto the MORPC. The reviewer acknowledged not being an expert on the modeling approaches used by MORPC or the limitations thereof, but the reviewer suggested that a better approach might be to fully understand their capabilities, current needs, and likely future needs, then try to figure out how to work within their existing modeling framework. The reviewer said that it is possible that the project is, in fact, taking this approach but, that is unfortunately also not clear.

The reviewer pointed out that the benefits of the traffic simulation output are not well elucidated and that there may very well be some benefits to such a visual tool, but these need to be explored in more detail. The reviewer said that there needs to be much more explanation of how the tool can be used, what controls the user can operate, and what sorts of tests/experiments they can run with it.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer opined that that it is a great start on the project

Reviewer 2:
The reviewer said that the project is new and on track and that initial simulations of some cities are already built.

Reviewer 3:
The reviewer noted that the model appears only to be applicable to urban areas, and rural-to-urban areas are the places of most growth that may be interesting to test with POLARIS.

Reviewer 4:
The reviewer commented that the project is fairly new so there are not many technical outcomes to report. The reviewer said that it appears that they have taken the right first steps though in selecting an urban partner and beginning to collect data.

The reviewer found the TUMS simulation to be interesting and visually appealing. However, the user interface is not at all clear: it is unclear what the purpose of the model is, what the parameters are, and how to operate the simulation. Essentially, it takes a newcomer quite some time to get even a vague sense of what he/she is looking at. The reviewer noted that we can assume that this is a simulation of vehicles moving, but it is not clear what time of day or any of the other parameters involved that would make this meaningful.

The reviewer said that the outcomes of the ORNL workshop are fairly generic and therefore add very little insight. The reviewer mentioned that it is a bit of a truism to say that "data is a major element for transportation models…" The reviewer saw this as obviously true, regardless of whether we are talking about CVs, AVs, or conventional vehicles.

Furthermore, according to the reviewer, if the EPA Motor Vehicle Emission Simulator model is the primary tool for estimating emissions and energy consumption, it is not clear how this relates to (or how the investigators perceive how it relates to) the use of Autonomie and POLARIS and how the SMART Mobility Consortium members should harmonize and/or unify their modeling approaches.

Reviewer 5:

The reviewer stated that the accomplishments to date are understood; however, there is no explanation or justification for the reason why Columbus, Ohio, was identified as the partner city. The reviewer asked what the criteria for selection were, how many cities were vetted, and how these cities and metrics were evaluated. The reviewer noted that also, from a technical perspective, it is not clear what was accomplished to enhance the modeling simulation tools or generate analyses to define baseline metrics. The reviewer asked whether data (insufficient or incomplete data) were available that could be used to provide baseline values for calibration metrics. The reviewer said that it would be very helpful to have a more clear description of the technical accomplishments.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the project has a great team.

Reviewer 2:

The reviewer noted that this is a collaboration effort to combine models and that it is the right mix as both laboratories are involved.

Reviewer 3:

The reviewers commented that researchers have been successful at selecting a target city, developing a relationship with this city, and engaging it in the project. However, the reviewer remarked, it would be helpful to understand if there are specific departments or institutions that are being contacted for data collection or data archives. For example, the reviewer asked if the Columbus DOT or other transportation departments have been contacted.

Reviewer 4:

The reviewer found the collaboration to be very minimal and, in this case, at least some level of collaboration with other modeling/simulation efforts might have been useful.

Reviewer 5:

The reviewer suggested that, based on the team, there should be far more resources of data and computational facilities available.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer mentioned that the proposed research is logical and that it is more of an integration of models so there are not a lot of true barriers. The reviewer said that the tasks will take time but it would be difficult to mitigate the risk with alternatives.

Reviewer 2:
The reviewer stated that the proposed future research is in line with the overall approach and that most of the work remains to be done.

Reviewer 3:
The reviewer said that the efforts will be at risk of not meeting objectives without reaching out to DOT data sources and expertise and that, furthermore, the SHRP2 study results could provide benefits.

Reviewer 4:
The reviewer pointed out that the fiscal year timeline, milestones, and deliverables provide a yearly highlight. However, the reviewer noted, it would be helpful to have seen a more detailed timeline with milestones that assess major work products. The reviewer suggested the following key milestones: traffic data collection complete, model calibration and validation complete, scenario simulation and metric evaluation complete, etc.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that this project helps model the effects of traffic patterns and will integrate synthetic populations and energy usage. The reviewer said that it will help inform decision makers and policy makers what effect changes will have to petroleum usage and allow informed decisions.

Reviewer 2:
The reviewer said that it can be understood how this work will support the DOE objectives of petroleum displacement. However, the reviewer noted, it is not clear how this will be demonstrated. The reviewer asked what the control variables are in the simulation that will impact petroleum displacement (fleet mix, transportation planning, etc.). The reviewer requested that the team make a clear connection among the simulation variables and how they will be able to demonstrate key decisions or factors that will impact petroleum displacement.

Reviewer 3:
The reviewer commented that while the project is relevant to DOE goals, it is not as well aligned as it could be. The reviewer said that if the model could be used as a real-time operational tool, that might have significant value for cities. However, the reviewer noted, it is not really clear what kinds of measured outputs the model will provide; at this point, based on the presentation, it appears to be primarily just a visual simulation. The reviewer said that while this is certainly helpful and can be a useful and thought-provoking tool, it is not clear that this should be a high priority.

Reviewer 4:
The reviewer stated that this is an ambitious study that barely meets the petroleum displacement goals because the approach is primarily modeling with no applicable actions. The reviewer said that it does provide insight though for policy makers.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the resources to be sufficient.

Reviewer 2:
The reviewer said that the resources could be leveraged with cooperation with other research agencies within the DOT.

Reviewer 3:

The reviewer commented that the researchers identified partners/collaborator but the resources/effort to complete tasks and milestones are not identified. The reviewer said that it is unclear what skillsets are supported by team members for each task and that it would be helpful to have some insights into the resource plan for the project.

Reviewer 4:

The reviewer said that based on the funding, it appears to be a relatively low-level, part-time effort that will not be complete until the end of FY 2019. The reviewer suggested that a better approach might be to provide more funding upfront and connect this project more directly with other modeling and simulation efforts to make sure they are fully harmonized and work toward common goals.

Presentation Number: eems019
Presentation Title: Smart Urban Signal Infrastructure and Control
Principal Investigator: H. M. Abdul Aziz (Oak Ridge National Laboratory)

Presenter
H. M. Abdul Aziz, Oak Ridge National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

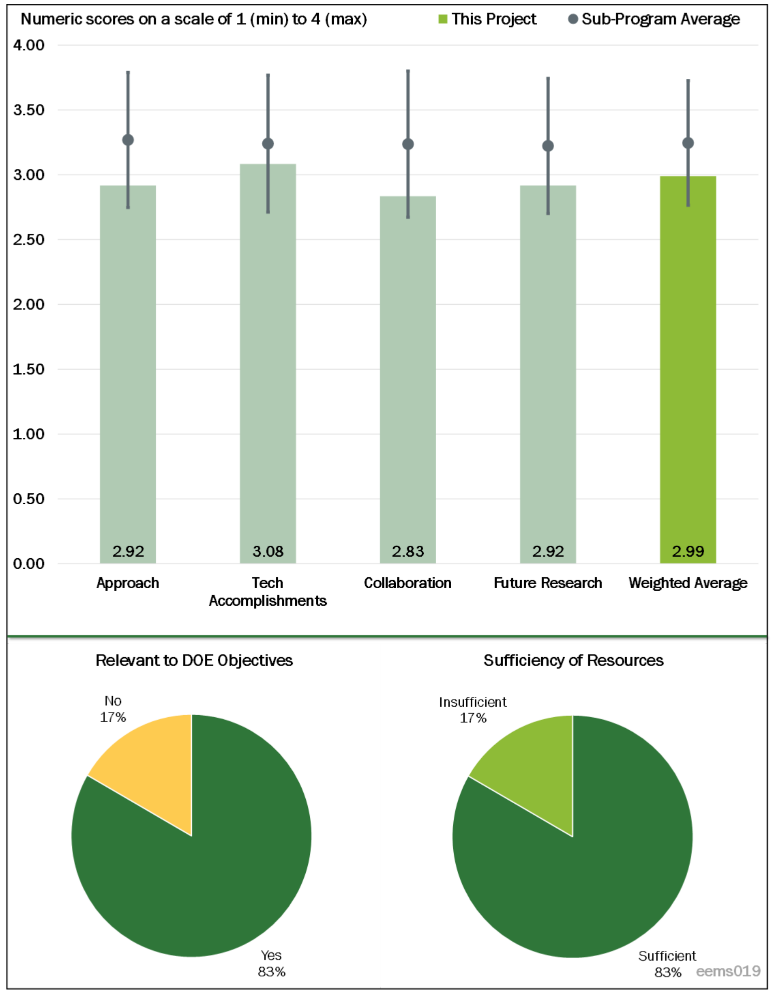

Figure 4-19 - Presentation Number: eems019 Presentation Title: Smart Urban Signal Infrastructure and Control Principal Investigator: H.M. Abdul Aziz (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the approach to this project is very solid with a methodically laid out plan with milestones and deliverables identified and that the approach seems feasible and is integrated with other efforts.

Reviewer 2:
The reviewer remarked that the approach is logical in its understanding of and sensitivity to the question of "take up" rate for the technology and the difficulty in dealing with this transition.

Reviewer 3:
The reviewer pointed out that the project's objective is to investigate the role of traffic signal infrastructure in the connected environment in terms of energy, mobility, and level of service and to develop signal control schemes for optimizing mobility and energy use for CAVs. The reviewer saw that the research team had laid out a reasonable research plan involving a synthesis study to compile existing practice and technology for supporting control scheme development later in the project. The reviewer said that the research team will engage with Smart City Challenge participants to develop relevant scenarios for smart signal systems and to assess future control system needs for CAVs. The research team plans to define simulation tools, while final scenario development is currently less well defined, it will be clarified in collaboration with SMART Mobility Consortium members in later phases of the project.

Reviewer 4:
The reviewer stated that the researcher explained that a modeling approach will be taken to simulate the control algorithms to impact vehicle mobility and energy utilization; the researcher explained that a small-scale analysis (single or local intersection) will be used to evaluate the algorithms and controls, which then could be scaled up to larger systems. However, the reviewer noted, the control variables and analysis metrics were not

well defined. The reviewer said that it would be helpful to have additional details around these technical aspects to provide further clarification on the modeling, simulation, and technical metrics.

Reviewer 5:

The reviewer suggested that the collaborative work to develop initial scenarios and the deliverable "Scenarios relevant to the future SMART signal infrastructure" should be moved to the fourth quarter of FY 2017. The reviewer said that the fourth quarter of FY 2017 milestones are outlining the requirements for SMART signal infrastructure and the scenarios are a part of defining those requirements. The reviewer stated that it also does not make sense to develop tools until after the majority of critical scenario functions that need to be modeled by the tools is defined. The reviewer cautioned that the current approach schedule has significant risks because it lists tool development and scenario development as concurrent development tasks for FY 2018.

Reviewer 6:

The reviewer observed that the project did not address barriers or implementation challenges in the approach and that the approach has the majority of the work biased to the end of the project. The reviewer cautioned that the project is at high risk of not finishing within the time scheduled and that the project is not integrated with other projects at this time. The reviewer noticed that the project has reducing energy usage listed as two goals, with level of service and mobility as other goals. The reviewer said that the approach does not appear to be focused on the energy usage; it is too broad and concentrating on small pieces that do not happen very often (emergency vehicles at signals). The reviewer commented that the modeling activity has the potential to feed into other DOE models, but is not focused on that; the project needs more focus on DOE objectives and needs to start the work quickly in order to finish on time. The reviewer indicated that the project is currently behind schedule due to the approach.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the project has already delivered a successful synthesis study in its short execution and that the project has identified the barriers, objectives, and key elements.

Reviewer 2:

The reviewer said that it is very early in the project, but noted that progress had been made and multiple milestones have been identified in 2017 while outgoing years only have full year objectives. The reviewer recommended that milestones within the larger task be identified in years two and three also.

Reviewer 3:

The reviewer observed that the researcher explained that the most significant accomplishment was the completion of the synthesis study and that the study provided a baseline analysis of existing signal control infrastructure and variables. However, the reviewer noted, it would be more insightful to have provided a clear connection between the synthesis study and the impact on the model and control algorithm. The reviewer questioned how the findings from the synthesis study impact the intersection model and the control parameters for the control algorithm.

Reviewer 4:

The reviewer remarked that according to the ORNL PI, the second quarter deliverable of "a complete report including evidences and existing case studies from major cities" that was due on March 31, 2017, to the DOE client had not yet been delivered (as of on June 8, 2017). The reviewer learned that the report was still in the internal review process at ORNL and as mentioned in the approach section, the development of the requirements for the signal systems scenarios needs to be moved forward into FY 2017.

Reviewer 5:
The reviewer commented that the researchers claimed to be 15% complete in conducting the research plan as of the end of the second quarter of FY 2017 and that the researchers stated that they are on- rack in completing the remaining FY 2017 milestones and deliverables. The reviewer stated that the results of the synthesis report provide some valuable insights into current smart signal control systems, costs, automated traffic signal performance management systems), high-resolution control data collection, control system potential errors, and fault tolerance.

Reviewer 6:
The reviewer found progress to be slow on the project and 15% of the work to be complete with 30% of the project time gone. The reviewer commented that collaborations from cities and other organizations that may be able to use the data have not happened and that the building of the base simulation code has not started yet. The reviewer said that a study of signal controls has been written and is in the process of being released; points described in this project brief about the study appeared to be focused on EPA and DOT goals more than DOE goals.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the collaboration is limited in this project, but not necessarily a negative at this stage. The reviewer recommended further collaboration with others who are likely developing this or who have expertise in traffic flow and control.

Reviewer 2:
The reviewer commented that the research seems to have a good level of collaboration and coordination with other national laboratories and with Smart City candidates. However, the reviewer noted, it would be informative to understand what the roles and responsibilities for the laboratory partners are as well as the key metrics to assess the Smart City candidates.

Reviewer 3:
The reviewer saw that collaboration exists but the brief fails to explain the roles and responsibilities of the partners effectively.

Reviewer 4:
The reviewer pointed out that the evidence for providing detailed feedback regarding collaboration and coordination is sparse in the project presentation and that there is some basic information outlining the players and their roles.

Reviewer 5:
The reviewer stated that the researchers have identified PNNL and NREL as collaboration partners in the context of the SMART Mobility Consortium; researchers have also identified the University of Tennessee as a partner for supporting research activities in the fourth quarter of FY 2017. The reviewer said that the research team has also collaborated with several Smart City Challenge participants as input to the Synthesis Study report and will be collaborating with one or more in developing relevant smart signal operational scenarios. The reviewer said that the project has been accepted for a presentation at the Institute for Transportation Engineers/Canadian Institute for Transportation Engineers 2017 conference entitled, “Opportunities and Challenges in Traffic Signal Operations and Infrastructure Deployment in the Era of Connected and Automated Vehicles.”

Reviewer 6:
The reviewer noted that there is a division of tasks with other research laboratories and that the project is still trying to get a city partner (ongoing task). The reviewer pointed out that a major weakness is that project this does not appear to feed into the other similar simulation projects that DOE is working on.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the project has a very detailed plan of future work that includes milestones and deliverables while considering barriers to realization of the proposed technology.

Reviewer 2:

The reviewer stated that this project has a natural conclusion with full CVs and intersections so future work beyond that is unnecessary to identify.

Reviewer 3:

The reviewer commented that a better project plan for the future research would be more useful and that a suggestion would be to identify key work packages and milestones to provide high-level visibility to the project activities and risks.

Reviewer 4:

The reviewer indicated that the planned future work logically flows from the work that will be completed in FY 2017. The reviewer would have preferred some early indications of possible simulation tools that might be used in the fiscal year, rather than a reliance on future collaboration with SMART Mobility Consortium and project partners. The reviewer said that the researchers have identified significant challenges for their future work including developing signal control schemes for mixed traffic environments, development of a simulation platform for large-scale networks of signalized intersections, and integration of energy reduction objectives into an overall signal control optimization framework. However, the reviewer noted, the researchers did not intimate additional pathways or mitigation methods in the future research for addressing these challenges other than reliance on collaborative efforts with partners.

Reviewer 5:

The reviewer observed that the project did not provide decision points and that the future work is not listed in a logical manner. The reviewer suggested that the simulation should be able to be started now with enough fidelity to enter in various use cases. The reviewer mentioned that the simulation tool is not scheduled to be selected until next year with implementation after that, and that there is a high risk of the schedule slipping as the main work is compressed to the end of the project. The reviewer pointed out that the challenges listed were really project tasks, but barriers to completing the tasks were not presented. The reviewer also noted that there was not any risk mitigation presented.

Reviewer 6:

The reviewer remarked that during the poster presentation of this project, the PI indicated that this analysis would likely include representation of many intersections being represented by a Markhov model with each intersection represented by a node in the Markhov matrix; the Markhov model representations would be introduced in the late phase of the project. The reviewer cautioned that the late introduction of Markhov representations to be used in a complex network model introduces unnecessary risk to the project, and it would be desirable that the Markhov representations begin to be introduced/developed in the very near future of the work schedule. The reviewer urged that these representations should first address the state transitions of a single intersection for the baseline (current technology) signal system and that as the SMART Mobility concepts are defined, they should be represented as additions or modifications to the single intersection baseline Markhov state transition model. The reviewer said that after the state transitions have been mastered for the simple cases, they can be generalized for the larger network and finally the network optimization can be addressed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said, that, yes, this project is relevant as there are huge gains that can be had by optimizing the signals based on desired parameters to include fuel savings.

Reviewer 2:
The reviewer stated that the project supports overall DOE objectives in reviewing the role of smart signal infrastructure in a CAV environment, assessing the state of current technology, and developing possible signal control schemes for integrating within overall CAV control architectures.

Reviewer 3:
The reviewer said that the successful development of signal infrastructure that enables minimum energy transportation networks supports the DOE's objective of petroleum displacement. The reviewer noted that smart signals have the potential to minimize the number of stops and maximize the flow of traffic resulting in higher fuel efficiency and lower fuel consumption.

Reviewer 4:
The reviewer understood how this project supports the DOE objective of petroleum displacement; however, the reviewer recommended that a clear explanation/illustration of how this will be measured or demonstrated in the project be provided. The reviewer questioned how the intersection simulation showcases how CAVs or the control algorithm will improve energy efficiency and what the hypothesis is for the research.

Reviewer 5:
The reviewer observed that the relevance is uncertain as the presenter is not certain that petroleum will be displaced in heavy traffic areas, but the reviewer believed it is likely in the vast majority of locations, which would offset any areas where traffic volume increased vehicle idling and associated fuel use. The reviewer commented that by the time this technology reaches the potential identified in the project plan, most vehicles will be fueled by something other than petroleum anyway.

Reviewer 6:
The reviewer saw that a small part of this project supports the overall DOE objective of petroleum displacement. The reviewer noted that if delays are reduced for cars, then there could be some petroleum reduction. The reviewer stated that the main focus of this project appears to cross into civil engineering and the DOT (instead of DOE) realm, and that the majority of traffic controls being modeled are for larger social issues (pedestrian crossing, emergency vehicle prioritization, automated vehicle/hybrid vehicle priority). The reviewer mentioned that all of these would have some effect on fuel consumption (more fuel/energy consumption at a macro level for most of the cases).

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the resources for this project seem to be sufficient as there is a detailed plan laid out for the given project and there is proposed future work if additional funding becomes available.

Reviewer 2:
The reviewer found the resources to be sufficient.

Reviewer 3:
The reviewer said that the project appears to be adequately funded, both for the current fiscal year as well as future years based on the planned activities and period of performance.

Reviewer 4:
The reviewer noted that the resources provided are sufficient for the project to make substantial progress on defining requirements and modeling a limited set of SMART Mobility concepts/scenarios and SMART signal infrastructure solutions. The reviewer said that narrowing the scenarios to be addressed early in the timeline will help ensure that the resources are matched to the project scope.

Reviewer 5:
The reviewer saw nothing to indicate that the resources are insufficient at this time but recommended additional collaboration.

Reviewer 6:
The reviewer said that there is no clear resource plan for the project and that it would helpful to have an illustration of key work packages and timing with the associated effort. The reviewer indicated that this will help to identify the skillsets and team members for each task and their responsibilities for completing the project.

Presentation Number: eems020
Presentation Title: Energy Impact of Different Penetrations of Connected and Automated Vehicles
Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

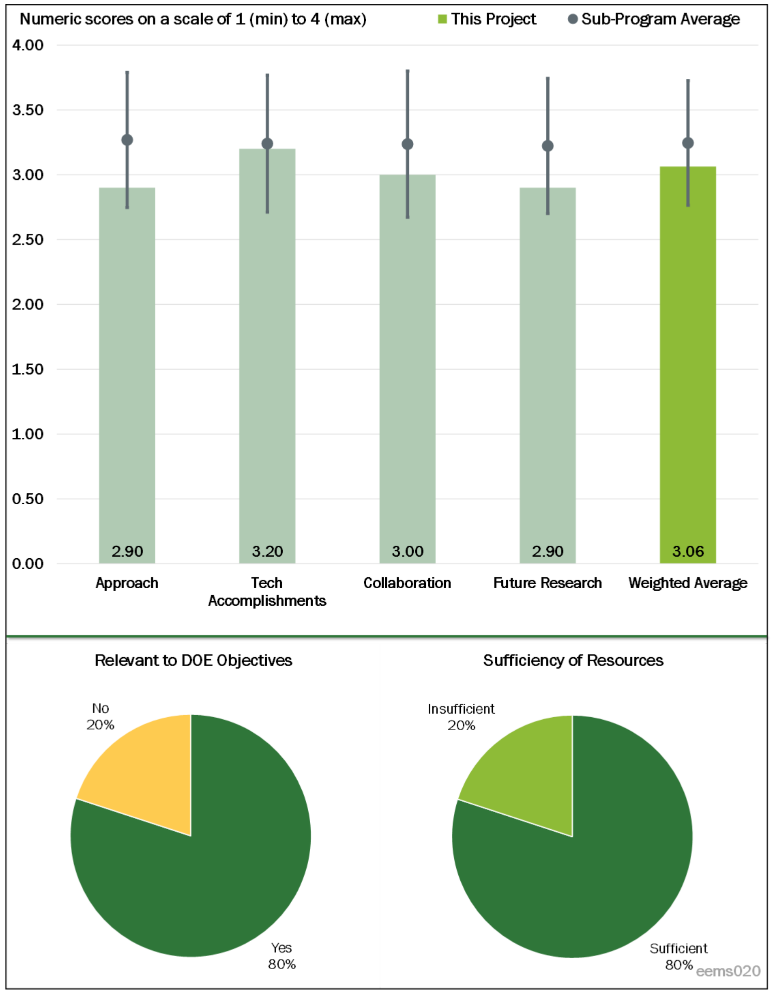

Figure 4-20 - Presentation Number: eems020 Presentation Title: Energy Impact of Different Penetrations of Connected and Automated Vehicles Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

Presenter

Jackeline Rios-Torres, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the research takes a similar approach to other projects in this AMR cycle on CAV energy and mobility analysis and that the research has taken a reasonable approach by initially starting with a simplified traffic model (highway merge scenario) to address control and simulation complexities before eventually working up to additional scenarios and regional framework. The reviewer said that the proposed investigation of vehicle communication and sensor error impacts on CAV control in mixed traffic environments should provide interesting results.

Reviewer 2:

The reviewer remarked that the current approach is pure model-based and that some actual data input either as final model validation or model tuning may be helpful.

Reviewer 3:

The reviewed said that only analyzing one traffic flow is rather simplistic.

Reviewer 4:

The reviewer said that the barriers that are mentioned are very vague with no real detail although the project does seem well designed with objectives and specific tasks laid out.

Reviewer 5:

The reviewer pointed out that, in giving this project a “Good” rating for the approach, the researchers are being given the “benefit of the doubt” because they have not fully described the goals or the technical barriers or why they have selected the variables they are exploring in preference to other potential variables. The reviewer said that the researchers state the goals fairly clearly but they talk about assessing impacts (of CAV penetration rates) on energy use, mobility, and safety, and also about developing frameworks for driver feedback systems and for optimal CAV control algorithms; these are a lot of diverse objectives. The reviewer stated that the poster deals mainly with the energy and mobility issues and imposes a safety constraint rather than studying issues that affect safety. The reviewer suspected that really addressing all the goals/objectives is beyond the scope of this effort so the reviewer thought the project could be improved by thinking more carefully about the barriers, goals, and objectives and then defining a smaller set of objectives in a more measurable and quantifiable way.

Similarly, the reviewer noted, the poster identifies a large number of collaboration partners but offers no information about the role of each participant or the interaction among them. The reviewer said that it would help to know what each participant is bringing to the project, how their work fits together, and what information or data they are sharing. The reviewer gave the researchers the “benefit of the doubt” but the researchers need to clarify roles to justify continuation.

The reviewer found the question of whether the project is well designed to be an interesting one that the reviewer cannot fully assess from the poster. The reviewer mentioned that the poster talks about assessing impacts (of CAV penetration rates) on energy use, mobility, and safety, but it does not seem to include some relevant parameters that surely have impacts on all of these factors. The reviewer said that it would seem that reaction time for drivers in heavy-duty vehicles (HDVs) would be a critical parameter to consider, but that the reviewer did not see it mentioned. Similarly, the reviewer noted, there should be some way of simulating other parameters such as driver skill, distracted driving, or the assistance of various types of sensors. The reviewer indicated that not all human drivers are the same and so there should be a distribution of skill or “risk tolerance” (e.g., preferred following distance, speed over the limit, etc.) or reaction times that should characterize the HDVs. It should then be possible to show their impact on energy use, mobility, and safety. The reviewer was sure that some of the largest fleets use models of driver behavior both to train drivers and to assess the impacts of driving skill on energy use and safety: the present research does not show an awareness of this type of work or an attempt to connect with it.

The reviewer realized that the intent of the project is to understand the impact of CAVs and not to perfectly model HDVs, yet it seemed to this reviewer that it is difficult to assess the improvements made possible by CAVs without modeling them in a similar way and then systematically comparing their performance to a scenario of 100% HDVs. The reviewer remarked that if humans instantly absorbed all available data, had infinitely fast reactions, and were never distracted, then they would presumably perform as well or better than CAVs and that it is the potential improvement in driving performance by CAVs that presumably results in positive impacts on energy use, mobility, and safety. Yet, the reviewer did not see anything in the poster that talked about the differences between CAVs and HDVs in these aspects. The reviewer mentioned that it seems that these are the interesting issues when one considers interspersing CAVs with HDVs and not just assuming a single performance level for each of these types of vehicles.

In summary, the reviewer would like to have seen the researchers first define a small set of variables whose impact they want to study and then construct their model to make this possible. The reviewer did not believe this set of variables is well defined at the moment.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer found the progress of the project to be outstanding as six technical accomplishments were explained in great detail to include formulas used, results, and graphed data.

Reviewer 2:
The reviewer saw that both the HDVs model and the CAVs model were implemented and that the energy impacts of CAVs in mixed traffic were assessed.

Reviewer 3:
The reviewer said that the researcher estimated project completion at 15% as of the AMR, which seems reasonable at roughly a mid-point in FY 2017, and that the researcher has demonstrated significant progress toward the first FY 2017 milestone identified in the research plan (i.e., analysis of CAV penetration in a merging scenario). The reviewer stated that key FY 2017 progress to date has included evaluation and implementation of CAV and human-driven vehicle (HDV) models, integration of CAV and HDV models with initial simulation framework for the merging scenario, assessment of energy impacts for varying CAV penetration rates under merging scenario conditions, and early assessment of CAV penetration under the merging scenario in high traffic density conditions. The reviewer noted that planned activities for later in FY 2017 include CAV penetration analysis for regional traffic scenario and initial work on assessing communication and sensor error impacts on CAV control.

Reviewer 4:
The reviewer commented that the researchers seem to have made reasonably good progress in setting up their HDV and CAV models and in assessing the impact of different penetration rates of CAVs on energy use and mobility (travel time). The reviewer noted that while this is a good start, it seems like a fairly simplistic set of results and a clearer plan for studying the impact of some crucial variables is needed. The reviewer thought that this type of model would be very useful for studying the impact of a host of sensors and communications parameters and that the effects of different penetration rates for things like adaptive cruise control, lane departure warning systems, or automatic collision avoidance systems should all be within the model's capability and should all be very interesting. The reviewer asked what penetration rate of CAVs is needed to have a desired impact on safety (number of collisions) or on energy use. The reviewer inquired if these same impacts could be reached by other means, and questioned if the impact of CAVs is greater in mixed traffic, urban traffic, or open road traffic. The reviewer said that there are many questions that could be explored and many parameters whose effects could be studied, and the reviewer thought that the researchers need to do a better job of defining what questions they want to answer and what parameters they want to evaluate. The reviewer said that this will help focus the future work better.

Reviewer 5:
The reviewer noted that one merged piece of traffic is rather simplistic. The summary, going to the graphs on Slide 11, says "show significant fuel consumption benefits" whereas the reviewer's initial look at the data for the one-lane flow shows a decrease in fuel consumption at 25% CAVs, but marginal as percentages of CAVs increase. The reviewer asked why increase the percentages of CAVs on the road. Also, the reviewer noted, the total travel time, as shown by total travel time (seconds) versus percentage CAVs graph, shows only a slight decrease in travel time whereas the summary describes it as "significant reductions in travel time." Again, the reviewer begged to differ on summary of the analysis on one merger lane. This is the reviewer's whole concern with this write up.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the project seems to have good collaboration, but the details on the collaboration are not provided.

Reviewer 2:
The reviewer said that this project is supported by the SMART Mobility Consortium, which leverages expertise of different national laboratories.

Reviewer 3:

The reviewer gave the project a "Good" rating in this area simply because of the interaction with the SMART Mobility Consortium and with a few universities, but commented that it would help if the nature of the interactions and the roles for each participant were defined. The reviewer thought that it would also be useful for the researchers to interact with some private companies who have an interest in the results of this work. Whether the companies involved with automated vehicles (Google, Uber, Big 3, etc.) would participate is an open question, but it would be good to know that they were contacted. The reviewer said that there are fleet owners who would also be interested and should be contacted (e.g., UPS, FedEx, Frito-Lay, etc.) and that there may be others, such as the U.S. Postal Service (USPS), taxis, or over-the-road carriers. The reviewer stated that if the model shows that substantial energy use savings accrue from long road trains of CAVs behind a Class 8 HDV leader, then it would help to know what the issues are for the leader, his company, and for the following vehicles. Similarly, it would be interesting to know if an Uber fleet or taxi fleet were 100% CAVs versus 100% HDVs, then what would be the impacts on energy use and safety. The reviewer said that these may not be the goals of the current project, but that interactions with some private companies would add some immediate and long-term relevance to the work.

Reviewer 4:

The reviewer remarked that the researcher indicated that collaboration on the project thus far has been limited to the SMART Mobility Consortium member meetings; however, the researcher does plan on increasing collaboration once the research is further underway. The reviewer noted that this includes working with several universities although this planned collaboration is not well described in the presentation. The reviewer observed that there appears to be plenty of collaborative opportunities as this project progresses in the areas of CAV and HDV models, simulation framework development, and vehicle-to-vehicle and vehicle-to-infrastructure communication impacts on optimal CAV control in mixed traffic environments.

Reviewer 5:

The reviewer said that, basically, this is coordinating within DOE, and the reviewer would like to have seen coordination with DOT to see whether one-lane merger is realistic or what the right combination of complexity should be for modeling.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the project provides specific details on the future work that is being proposed for all the out-years along with milestones and decision points.

Reviewer 2:

The reviewer said that the proposed future research seems reasonable but lacks details.

Reviewer 3:

The reviewer noted that the proposed research plans progressively build off accomplishments to date and increased collaboration will benefit from parallel research being conducted; for the remainder of FY 2017, the researcher will look to expand previous analysis of CAV traffic merging scenarios and investigate CAV penetration in regional/highway corridor scenarios. The reviewer said that the planned future work for FY 2018 on vehicle communication and sensor errors/delays and their impacts on CAV control and operation will be very relevant, especially for future mixed traffic (CAV and conventional vehicles). The reviewer added that additional or preliminary details on this aspect of the research, at least as known today, would have been useful in the presentation in terms of approach and that the work will culminate in FY 2019 with development of driver feedback systems for optimal interaction with mixed traffic environments, also a very relevant barrier to near-term CAV implementation.

Reviewer 4:

The reviewer thought the plans for future research are satisfactory but could be improved. Part of that improvement could be effected by simply making the plans more quantifiable and measurable. The reviewer said that the descriptions of the future work use words like “large scale” analysis and “optimal” interaction and that the plans would be improved if such terms were more clearly and realistically defined. The reviewer asked what is meant by “large scale” and asked who is defining the term “large.” The reviewer wanted to know what is meant by “optimal,” and questioned what is being optimized. The reviewer thought the project would be much improved if the researchers stated that the team was going to evaluate the impact of sensors A, B, and C on outputs X, Y, and Z, or if the team said they were going to explore variables one, two, and three in the human driver model and compare them against “best available” performance for the same variable in the CAV model. The reviewer said that clearer goals and a clearer set of parameters to be studied are needed to devise a research path that has decision points and that recognizes risks; the plans, as currently stated, do not allow for a critique of the research path or for any discussion of risk or risk mitigation.

Reviewer 5:

The reviewer referenced prior comments on trying to figure out what is realistic for merges and number of merges on a typical drive into work. The reviewer’s quick analysis was that the reviewer would save 6 minutes driving to work, which does not make the reviewer want to have a CAV. The reviewer would be better off leaving earlier in the morning, which would decrease commuting time.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said that, yes, the goal of the project is to study the energy impacts of optimal control algorithms in CAVs and their operation in a mixed traffic environment.

Reviewer 2:

The reviewer answered that, yes, the project supports the overall DOE objectives of petroleum displacement and that it provides fuel consumption benefits along with associated travel times.

Reviewer 3:

The reviewer responded that this research is relevant to DOE objectives as related to SMART Mobility and EEMS and that the project is investigating CAV control in mixed traffic environment and the resulting impacts on energy and safety.

Reviewer 4:

The reviewer stated that this project can have an impact on petroleum displacement by assessing the impacts of CAVs on energy use. However, the reviewer said that this work also gets into other areas such as safety and productivity/mobility so it would be appropriate if some of the funding came from other sources (such as the DOT or the Transportation Research Board [TRB]). The reviewer commented that if the project is going to continue for another 2 years and all of the funding is to come from DOE, then perhaps the focus should be narrowed to just impacts on energy use, but this would seem to neglect some potentially useful insights on safety.

If the focus is mainly on energy use and petroleum displacement, then the reviewer thought it would be best to look at a variety of traffic situations in the simulator to see where CAVs can have the most impact. For example, questions to ask include do CAVs help more in congested urban driving or in mixed urban/highway driving; do they allow higher speed limits or greater traffic flow, and if so, what is the impact on energy; and do they reduce congestion/backups. Again, if so, the reviewer would like to know what the impact on energy is and what types of vehicles would have the greatest impact on energy/petroleum displacement if they were switched to CAVs. As examples, the reviewer pointed out taxis, delivery trucks, HDVs, or others. The reviewer said that these are the types of questions that could be addressed with clearer goals and a stronger focus on energy use and petroleum displacement.

Reviewer 5:

The reviewer thought that this is a good start to helping to model what would be DOE objectives for moving to CAVs, but that using the word "significantly reduces" in the summary undercuts what would be a good start. The reviewer said that this project needs to be "re-thought" with some real-world facts and figures for traffic.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the current budget and resources are sufficient for this type of model-based research.

Reviewer 2:

The reviewer said that the project seems to have sufficient resources for FY 2017 but fails to state the funding for the out-years beyond FY 2017.

Reviewer 3:

The reviewer stated that only FY 2017 funding allocation was reported by the researcher but the reported level appears to be sufficient for the proposed activities.

Reviewer 4:

The reviewer commented that this question is a bit difficult to answer without more knowledge of how the funds are distributed. The reviewer said that if the stated amount of funding is spent only on one or two people doing research at ANL, then the level of resources is adequate or about right; if this funding has to be shared with any of the other research partners or collaborators, then the funding is too little. However, the reviewer noted, it is not clear whether the $364,000 budget is being spent entirely in one year at ANL, or if that funding has to carry the project through to completion in 2019. The reviewer did not think the level of funding is excessive, but that is based on the assumption that the $364,000 is only for ANL staff and that it may need to cover multiple years.

The reviewer thought that the funding should be adequate to continue to make progress toward the goals, but that the goals should be made clearer by DOE and ANL and then the resource needs may need to be reassessed. The reviewer said that the interactions with private industry might bring some additional funding, or at least in-kind data or insight contributions, and that both of those would help in meeting the milestones.

Reviewer 5:

The reviewer said that this is under-thought as a project and asked if that is because of resources put on this project.

Presentation Number: eems022
Presentation Title: A Model to Assess Impacts on Fleet-Wide Energy Use from Multi-Modal Opportunities—Freight Fleet-Level Energy Estimation Tool (FFLEET)
Principal Investigator: Tim LaClair (Oak Ridge National Laboratory)

Presenter

Tim LaClair, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the approach of the project seems have an outstanding lock on the critical barriers that exist and that project is well designed, very feasible, and integrated with other efforts.

Reviewer 2:

The reviewer said that the approach is a logical and simple web tool that takes simple input and provides simple savings calculations that will meet the need and the project's objective.

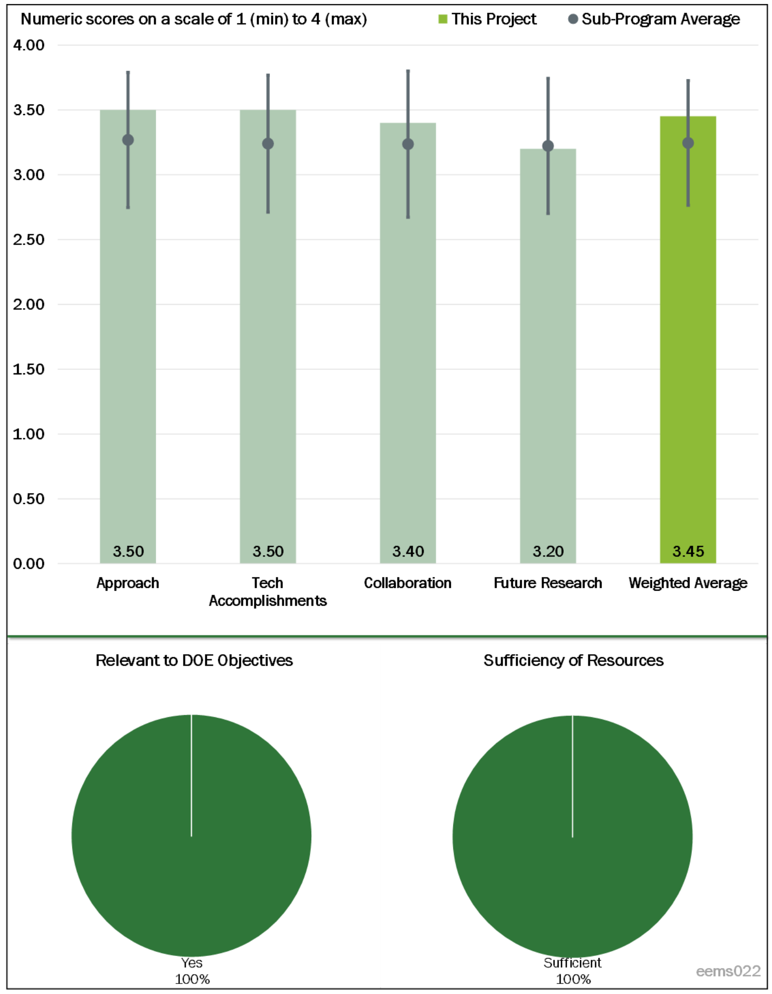

Figure 4-21 - Presentation Number: eems022 Presentation Title: A Model to Assess Impacts on Fleet-Wide Energy Use from Multi-Modal Opportunities – Freight Fleet-Level Energy Estimation Tool Principal Investigator: Tim LaClair (Oak Ridge National Laboratory)

Reviewer 3:

The reviewer said that the current project leverages the existing technologies to develop a web-based evaluation tool to allow trucking fleets to estimate the energy savings due to SMART Mobility systems, alternative fuel technologies, and freight modal shifts. The project also loops in UPS to perform an assessment at its newly renovated Midwest distribution center in Columbus, Ohio.

Reviewer 4:

The reviewer commented that the approach is a good one with data collection and modeling and then refining, but that the model does not appear to capture some relevant data, such as population/housing/business density, type of district (business, light industrial, industrial, residential apartments, housing, etc.), and demographics (i.e., elderly population may embrace the use of shared automated vehicles more readily as an alternative to walking to a public transit location). The reviewer pointed out that without these data there will most likely be substantial variation among the various cities being used for data, and it will be more difficult to predict routes. The reviewer said that the project is well integrated with other efforts, both by being populated by data from other projects and by being able to support predictions for other projects.

Reviewer 5:
The reviewer stated that the approach is not well documented, but the reviewer applauded the idea of making the complicated analysis available for fleet users. However, how that will happen is not clear.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer thought that the project has made excellent progress in a short period of time.

Reviewer 2:
The reviewer said that the project has made great progress to date with only starting in October 2016. The project has locked in collaboration partners and has acquired a large fleet operator to provide data and evaluate the tools being developed under this effort.

Reviewer 3:
The reviewer mentioned that the project is progressing on schedule with the initial model almost complete.

Reviewer 4:
The reviewer indicated that the project is making progress at the right pace.

Reviewer 5:
The reviewer said that the documented progress is a literature review and energy consumption models.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project seems to have appropriate collaboration partners and has a large fleet operator to provide data and evaluate the tool's performance.

Reviewer 2:
The reviewer commented that there are sufficient and appropriate collaborators

Reviewer 3:
The reviewer said that the project gets contribution from national laboratories and UPS.

Reviewer 4:
The reviewer observed that the project has a good team with municipality, research laboratories, and a fleet owner/operator involved, but that having an additional fleet owner/operator as a partner would be a little better \as fleets may operate a little differently.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that there was good clarification of progressive use of technologies and the impact on fuel consumption with their use.

Reviewer 2:

The reviewer said that the impact of CAV technologies will be analyzed using results from both literature and updated results from the CAVs pillar. Data on vehicle operations and modal selections in Columbus will be obtained from UPS for evaluation. The reviewer remarked that this sounds like a good plan.

Reviewer 3:

The reviewer expressed worry about data sources for this effort and that maybe the researchers just need to present more example datasets that are going to inform the work. The reviewer said that it sounded like the literature search was not so fruitful and asked for more detail.

Reviewer 4:

The reviewer observed that the project shows good detail for FY 2017 and for future work in FY 2018, but does not state any plans for FY 2019.

Reviewer 5:

The reviewer noticed that the proposed research is to deploy and further refine the tool and that as more information and technologies are built into the tool, it will become ever more important to DOE. The reviewer pointed out that the barriers listed are administrative, which can be overcome with time, and that the project could try to find an additional end-use fleet operator so there is not just one fleet being modeled and to mitigate the risk of non-disclosure agreements being signed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer said that, yes, this project has great potential to make a big impact on fleet companies as they can invest minimal time to research whether the potential business case for different technologies available is cost effective to implement in their fleet. The reviewer pointed out that because most technologies are optimized for certain duty cycles, a theoretical best fit can be potentially determined prior to any purchase of hardware.

Reviewer 2:

The reviewer acknowledged that, yes, the tool that will be developed will help truck manufacturers and fleets to understand the benefits from fleet-level implementation of SMART Mobility technology options and modal choices by shippers.

Reviewer 3:

The reviewer commented that clearly the benefit from this dissemination of information on these technologies supports DOE efforts to reduce petroleum consumption.

Reviewer 4:

The reviewers noted that, yes, this project supports the overall DOE objective of petroleum displacement.

Reviewer 5:

The reviewer said that this project is a tool for fleet owners, DOE, and municipalities to see what the impact is on fleet fuel efficiency when new vehicle technologies are introduced. The reviewer said that convincing fleet owners of a payback when they ultimately purchase and implement the tool will help DOE meet the objective of reduced petroleum usage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that there is no indication that resources are excessive or insufficient.

Reviewer 2:
The reviewer found funding to be sufficient to effectively achieve the stated milestones in a timely fashion.

Reviewer 3:
The reviewer noted that the resources appear to be sufficient.

Reviewer 4:
The reviewer commented that the resources provided to the current project are sufficient.

Presentation Number: eems023
Presentation Title: WholeTraveler Survey on Life Trajectories and Mobility Decisions
Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory)

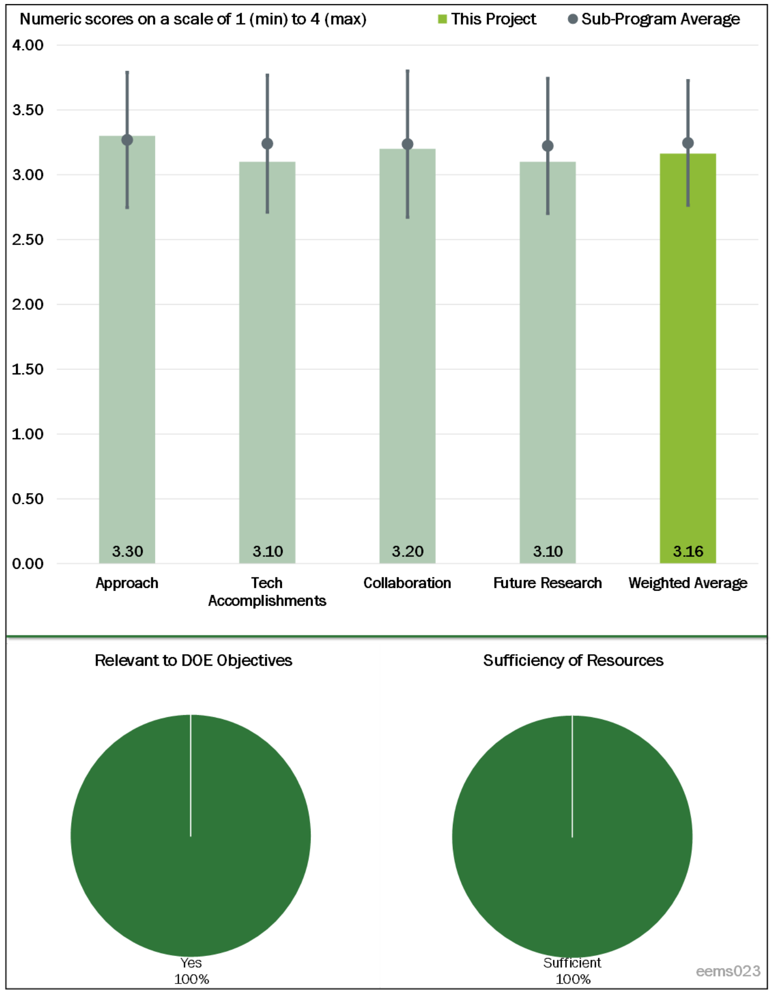

Figure 4-22 - Presentation Number: eems023 Presentation Title: WholeTraveler Survey on Life Trajectories and Mobility Decisions Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory)

Presenter

Anna Spurlock, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that developing an understanding of individual consumer travel preferences is a challenging task and that the project team has developed what appears to be a novel approach that uses simple tools to collect time history data on travel preferences and uses existing resources (cell phone GPS data) to interlink consumer preferences and actions. The reviewer said that the approach is good and uses resources efficiently to achieve the stated goals; the focus on local travelers in the Bay Area is appropriate given the locations of the project partners.

Reviewer 2:

The reviewer observed that the project targets surveying of individuals in the San Francisco Bay area to determine their life history, transportation trends, and preferences and tendencies regarding new mobility options. The effort will develop and integrate innovative survey methods, GPS data collection mechanisms, and cutting edge analytics to collect information on long-run life-cycle trajectory patterns, psychological and personality characteristics, and risk and time preferences.

The reviewer stated that the goal is to better understand people's tendencies and then use this information to inform the other SMART Mobility pillars (specifically CAVs, Multi-Modal, and Urban Science), including agent models, and produce a series of white papers. The reviewer noted that other studies have looked at portions of these areas, but none has examined the broad picture and unified things together. This project will develop a comprehensive understanding of travel choice patterns, preferences, and decision-making processes across different time scales (future-oriented, long-, medium-, and short-run) to better understand how these patterns interrelate with other personality characteristics and circumstantial constraints.

The reviewer mentioned remaining challenges and barriers including: Institutional Review Board Human Subjects Review; successful collection of sample data; and uncertainty in the timing for review and approval steps, which may present a challenge leading to project delays. The reviewer said that substantial details on the technical barriers are not provided, nor are specific methods to address or mitigate them. For example, it is mentioned that a significant response is not expected for the Phase 2 GPS location data. The reviewer asked how this challenge can be overcome.

The reviewer said that a few other questions also arise, including whether a survey of the San Francisco area accurately represents drivers and their expected behavior and preferences across the country and whether another locale would be more representative of a typical, representative city. Additionally, it is mentioned that only online survey instruments will be used. The reviewer asked if this will accurately encompass the population, especially older respondents.

The reviewer remarked that the presentation provides an adequate project plan and schedule through FY 2018 and that it mentions a number of previous studies being tapped to provide the basis and theoretical underpinnings in the areas of life history calendars, psychological /personality characteristics, and time and risk preferences.

Reviewer 3:

The reviewer pointed out that the development of innovative survey methods, GPS data collection mechanisms, and advanced analytics, while fitting work for the Mobility Decision Science pillar of EEMS, is a significant departure from traditional VTO-funded activities, which focus more directly on development of petroleum use reduction technologies. The reviewer said that the information being collected and derived is focused on impact of long-run, life-cycle trajectory patterns.

Reviewer 4:

The reviewer noted that given the overall approach—to use surveys to “reduce uncertainty associated with behavioral and human factors in transportation as a system modeling and analysis”—the methodology appears to be about as good as one could hope. The reviewer also found it to be very thorough, comprehensive, and well thought out.

On the other hand, the reviewer brought up that such stated-preference surveys face a very steep challenge when trying to understand the impact of completely new technologies. The reviewer said that the obvious analogy comes from the famous quote attributed to Henry Ford: “If I had asked people what they wanted, they would have said faster horses.” The reviewer said that users themselves may have no idea how they will use the product until they actually start using it (or some very high-quality prototype or simulation).

However, the reviewer mentioned, the extreme limitations of stated preference surveys could be addressed to a degree by focusing more on questions that do not require as much imagination—i.e., focusing more on what is known about current behaviors and decision making and less on potential actions under different scenarios. To its credit, the reviewer said, this project appears to adopt some of the latter approach. For the short-, medium-, and long-run questions, the focus appears to be on behaviors that survey respondents should be familiar with and be able to answer without too much extrapolation or imagination (e.g., what makes one use a certain mode over another, or the reasoning for having purchased one’s current car, etc.). The reviewer noted that a good approach might be for the project to focus on developing and elaborating on a framework of decision- making based on those facts (or at least more-solid beliefs), then apply the much-less certain questions to this framework to predict people’s preferences more accurately than they would predict them themselves. The reviewer said that the presenter did not make this very clear but that does appear, on more careful review, to be part of the project’s intent.

The reviewer indicated that, in terms of integration with other efforts, it would be very helpful to combine this broad-and-shallow survey approach with a “narrow-but-deep” approach. The reviewer remarked that the presenter explained that the program did not have the resources for a longitudinal study—it was not clear whether she meant "resources" in terms of time or funding. The reviewer said that this appears to be a fairly large, well-funded project so it would seem that more value might have come from integrating these efforts with something more longitudinal or observational in nature.

The reviewer found the bibliography provided for survey methodology and theoretical underpinnings to be helpful in establishing what the team has consulted, considered, and how well they have thought through the whole approach.

Reviewer 5:

The reviewer said that the precept to this project is good, but the reviewer questioned the role of this project team doing what appears to be consumer analysis of new technologies whereas there are excellent firms out there in the United States that do similar work.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the team has achieved quite a bit in the first year of activity—the life history survey is a very interesting method for collecting basic household mobility information. The reviewer said that the questions regarding mobility as a service and online shopping will likely get at the critical question of whether these new paradigms represent the replacement of or addition to traditional mobility. The reviewer noted that the use of existing smartphone GPS data could be useful in the future as it does not require any on-vehicle hardware and records the movement of the travelers themselves (which will be more important in a mobility-as-a-service world where people are buying mobility, not vehicles).

Reviewer 2:

The reviewer indicated that the project completed a study plan, designed an innovative survey, and submitted human subjects' protocol for review.

Reviewer 3:

The reviewer pointed out that in the 6-9 months since inception, the project appears on schedule and has achieved several technical accomplishments, including completion of the study plan, design of a two-phase survey with innovative features, and submission to LBNL's Human Subjects Protocol for review.

The reviewer mentioned that an innovative life history calendar (recently pioneered in Europe and Japan for transportation behavior) has been developed, which enables recall of retrospective information in a single shot survey. Basically, this looks at key factors as a function of longitudinal time scales. The reviewer said that an approach to address the issue of stated versus revealed (or actual) preferences has also been developed. This includes establishing an innovative GPS system to conveniently link and assess respondent's actual vehicle use. The reviewer stated that this GPS system allows participants to quickly and efficiently (in a secure fashion) upload their GPS data to LBNL servers, thereby reducing error and improving data collection. Subsequently, the reviewer noted, this daily transportation behavior will be compared to survey responses to develop better predictive models.

Reviewer 4:

The reviewer commented that this was interesting to see up to Slide 7, and then the reviewer began to wonder if enough people were surveyed. This reviewer also inquired about how the project team might turn the graph on Slide 7 into something and how the team might forecast what people will do in the future.

Reviewer 5:

The reviewer said that the use of the "life history calendar" appears to be a valuable and innovative way to obtain longitudinal data without the time and expense of a true longitudinal study and that the innovative questions provided seem to move in a good direction: putting people in scenarios where they can easily imagine their behavior.

However, the reviewer remarked, a significant weakness here is in how the questions are worded. The reviewer said that if the aim is to get someone's honest ("gut") reaction, the respondent needs to be kept in a low-key conversational frame of mind and where the respondent can react quickly, non-verbally, the way most people make snap decisions when planning a discretionary trip. The reviewer posited that when details like cents-per-mile are included, along with other factors that increase the cognitive load, the respondents' awareness is likely to be shifted away from their normal decision-making frame of mind. For example, rather than ask a very long, multi-part question such as: "Imagine that you recently learned that it will cost $0.20 a mile to take a ridesharing service, such as Uber or Lyft. So if your destination is 10 miles away, this would mean.…" The reviewer suggested that maybe it should be broken down into very simple, easily digestible pieces. For example: "If you could pay $2 to be driven door-to-door to your doctor's appointment 10 miles away, would you do it, or would you drive your own car?" Also, the reviewer noted using terms like "ridesharing" and using names like "Uber" and "Lyft" are very likely to prejudice people's answers, especially those who may be biased by negative news about these companies. Ultimately, the reviewer proposed, to get the most honest answer, the respondent should be encouraged to adopt the kind of frame of mind that they will be in when they make those decisions. In other words, they should not imagine themselves counting pennies, or calculating the impact of different cents-per-mile figures, or considering what their long-term habits would/should be. And, the reviewed noted, generally, the language needs to be precise, but the more conversational it can be, the more likely people will answer in an unguarded, honest way.

As another example, a question could better be framed as: "How many times last week did you drive to a store or restaurant?" and "How many times last week did you walk or bike to a store or restaurant?" instead of "Please fill in how many times during the past two weeks that you or someone in your household took a vehicle (car, truck van, etc.) to a …" The reviewer said that the more tangled, convoluted wording of the latter example (the one used by the project) is likely to fatigue the respondent.

The reviewer brought up the fact that the "innovative features" described also suggest that the project is trying to squeeze as much value as possible from the survey and that combining this approach with revealed preferences from GPS data is also a very useful leveraging of inexpensive data. However, the reviewer stated, it is not entirely clear how this ability to compare stated and revealed preferences will be used—whether the project team will develop some calibration mechanism or if the team will simply use it to throw out outliers whose stated/revealed preferences are too divergent.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer mentioned that the collaborations shown in the presentation are appropriate given the scope and context of the project within the SMART Mobility framework. The reviewer said that the team has made good use of the transportation survey research subcontractor.

Reviewer 2:

The reviewer saw the collaboration with INL and NREL and subcontracting with a transportation survey research firm as appropriate for the nature of proposed project, given a very high-perspective investigation of lifelong transportation decisions (i.e., there do not seem to be many entities with directly relevant experience).

Reviewer 3:

The reviewer said that the Resource Systems Group appears to be an excellent choice for collaboration on survey design as they are a well-established and respected player in the field and widely used by transportation planners and public agencies for travel surveys. The reviewer noted that they also have a solid reputation for in-house expertise that would suggest they are more than up to the task of developing innovative surveys.

Reviewer 4:

The reviewer said that the project appears to be demonstrating adequate coordination and supports the research of all pillars within the SMART Mobility Initiative; to date, the team members from LBNL, INL, and NREL have been integral to the design and execution of project activities. The reviewer indicated that a subcontractor to LBNL (Resource Systems Group, Inc.) with extensive experience in transportation research is programming and implementing the survey.

The reviewer noted, as mentioned earlier, some previous studies looked at some similar areas, but none examined and integrated the whole picture. The reviewer asked whether the results of some of the previous studies could be used to augment or potentially serve as a substitute for some elements of this effort, thereby freeing up resources for additional activities.

Reviewer 5:

The reviewer affirmed that DOE is coordinating with DOT. The reviewer asked where the outreach is to those experts in consumer behavior in industry, advertising, or in advanced product planning (e.g., even technology companies).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the future work is focused on survey implementation and analysis of results.

Reviewer 2:

The reviewer found the future research set forth by the team to be a logical result of the research plan and noted that it would be interesting to have seen this Whole Traveler process applied to other regions of the United States (other cities and perhaps less urbanized areas) to see if the broad trends in the demand for mobility are consistent across regions or if there are differences. The reviewer said that the future work will add to the understanding of how individual consumers are beginning to think about mobility.

Reviewer 3:

The reviewer commented that the future research, as described, seems to fit well in line with the project goals and that it will be very interesting to see how this interfaces with the five pillars. The reviewer acknowledged that, if at all possible, it would be great to see future research in this area integrated with more focused, observational studies. The reviewer said that one might suspect that some well-targeted combination of (very expensive) observational studies with the survey might provide a powerful opportunity to calibrate the (much more affordable) survey data and thereby squeeze much more value from it. For example, one simple observational tool could be to give a small sample of people access to Uber/Lyft at a very low cost (in order to simulate a CAV taxi service that does not have to pay a driver) and then let them use this service for 6 months or so to see how their behavior adapts. Similarly (but even more expensive) would be to provide full-time, on-demand car service that operates like a private limousine where the user only pays for gas. The user could also pay a monthly fee similar to what the expected lease-price of a private AV would be and then get a "simulated AV" in return, with a full-time driver (perhaps even hidden behind a screen). Of course, the reviewer noted, this is likely to be prohibitively expensive, but it would provide behavioral data that would be impossible to get any other way. Based on that, the reviewer pointed out, it would seem that there should be opportunities for substantial collaboration with industry to collaborate on ways to obtain and share these kinds of data. The reviewer suggested that a model similar to NREL's National Fuel Cell Technology Evaluation Center (formerly Hydrogen Secure Data Center) might be worth considering.

Reviewer 4:

The reviewer said that the proposed future research presented is adequate, if somewhat generic. The reviewer noted that it provides the proposed basic activities for the rest of FY 2017 and all of FY 2018, and the reviewer assumed that the results of these activities will determine project plans for FY 2019. The reviewer stated that it would have been informative if greater detail could have been provided, possibly further touching on specific technical issues to be addressed with regard to implementation/analysis of the survey, highly salient questions that would be answered, specific trends that are being looked for, and/or a hint at potentially determinative items regarding the establishment of FY 2019 activities.

Reviewer 5:

The reviewer saw the concept as good but as a baby set that is set forth here in this project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer indicated that understanding how individual consumers are making mobility decisions will be critical for developing the energy efficient vehicle systems of the future that consumers will choose. The reviewer said that, ultimately, the consumers will drive the uptake of efficient mobility and DOE needs to understand the consumer motivation in order to achieve petroleum displacement.

Reviewer 2:

The reviewer said that the migration to smart mobility requires not only technical progress on multiple fronts but also an understanding of and change in consumer attitudes and behaviors. The reviewer said that to encourage the positive evolution of consumer behavior toward Smart Mobility, a thorough understanding of their past and present perspectives and tendencies is needed and that this project aims to better understand behavioral and human factors, apply it to modeling and analyses to improve predictive capabilities, and subsequently inform future strategy and planning development.

Reviewer 3:

The reviewer stated that this project does contribute to better understanding of programmatic pathways to an energy independent and efficient transportation system and that it is an enabler for better understanding of Mobility Decision Science (a pillar in DOE SMART Mobility Consortium), but the project does not directly impact petroleum use reduction.

Reviewer 4:

The reviewer said that very strong and well-thought out connections are drawn among the survey outcomes and the five pillars and that, as a baseline from which to build on, this appears to lay a very solid, broad foundation. The reviewer remarked that as these data will help support the goals of those pillars at many levels, there is clear value in this work toward supporting the overarching goal of displacing petroleum and that it would be unrealistic to think that any significant long-term petroleum displacement efforts will be successful without the kind of understanding of behavior and choices that this project is aiming to establish.

However, the reviewer cautioned as to the limits of these data and how far they should or could be extrapolated. The reviewer noted that new mobility innovations, such as CVs and/or AVs, can be such a radical departure from current experience that it may be impossible to draw any meaningful conclusions from even the best survey. As one example of these limitations, the reviewer recalled a survey from a year or two ago where most parents said they would never send their child unaccompanied in an automated car. The reviewer noted that that is easy to say, from the position of calmly taking a survey, but in the midst of a chaotic school day, when one child is sick, the other has missed the bus, and the parents are late for work, it is very likely that their risk tolerance will suddenly stretch to allow them to send a child to school in an autonomous vehicle. The reviewer noted that, after doing that once or twice, the behavior (which initially seemed totally unacceptable) may become part of everyday life.

Reviewer 5:
The reviewer indicated that this is an interesting project and that consumer adoption of a new technology is always an interesting topic. The reviewer said that, as we look at modes of transportation, it can be an expensive investment by say, the federal government, the local government, and for industry. The reviewer expressed uncertainty if a small survey of people in San Francisco gets the answer that the project is seeking.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the project appears to be on schedule to date and has not indicated any funding deficiencies; therefore, it is assumed that funding resources are sufficient. The reviewer noted that the project partners have the technical expertise, equipment, and facilities necessary to successfully complete the project on schedule.

Reviewer 2:
The reviewer found the resources to be sufficient for the work plan set forth in the presentation.

Reviewer 3:
The reviewer acknowledged not being intimately familiar with the costs involved in designing and executing large surveys of this type. The reviewer said that it could be hoped, however, that some of the up-front costs incurred in designing this innovative survey could be leveraged later on as the survey might be modified and adapted to answer different questions.

Reviewer 4:
The review remarked that this is a chicken-and-egg scenario—the resources may be sufficient for what is outlined as a project--but asked what type of answer the project team is seeking, and whether the team has really thought about how to go about it. The reviewer wondered if the team's survey of San Francisco will spool up to other parts of the country. The reviewer pointed to Detroit, where there is very little mass transportation, and mass transportation has been voted down.

Reviewer 5:
The reviewer said that this project like all EEMS activities in current VTO portfolio is 100% DOE funded. The reviewer commented that $2.4 million over 3 years is a significant amount of funding for a survey that will hopefully provide results that will be of good use in future EEMS modeling activities.

Presentation Number: eems024
Presentation Title: MA3T-MobilityChoice: Analyzing the Competition, Synergy and Adoption of Fuel and Mobility Technologies
Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

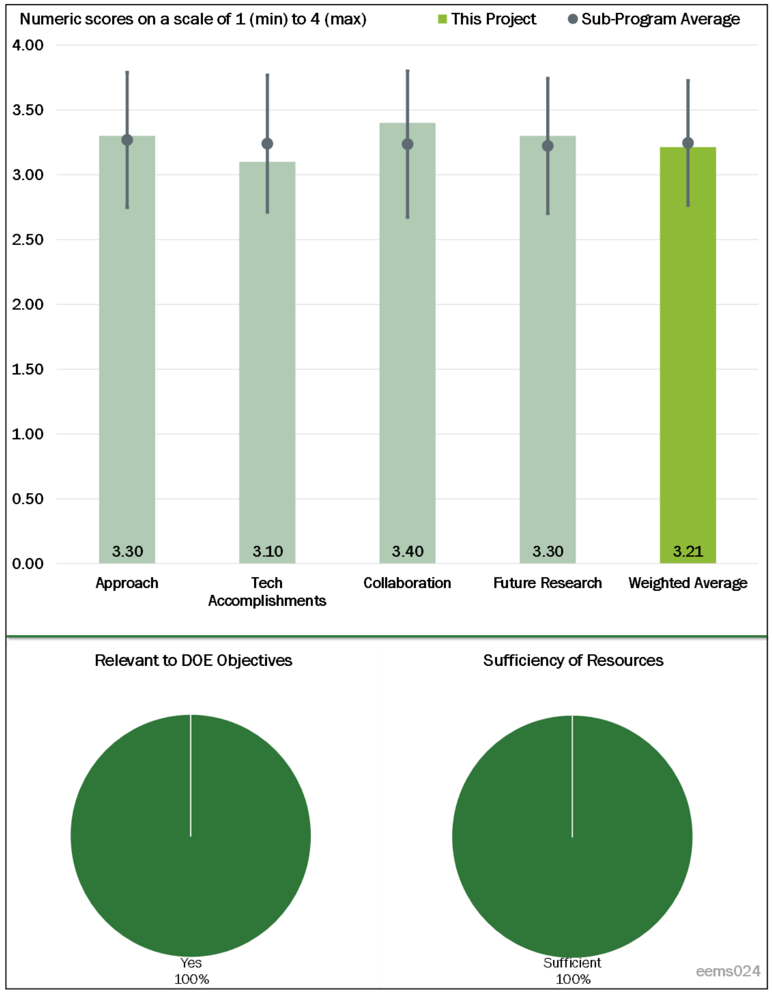

Figure 4-23 – Presentation Number: eems024 Presentation Title: MA3T-MobilityChoice: Analyzing the Competition, Synergy and Adoption of Fuel and Mobility Technologies Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

Presenter

Zhenhong Lin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the approach the team is taking for this project appears logical—modeling how individual consumers make mobility choices and modeling these consumers at a relatively high level of detail (many consumer types). The reviewer stated that the models will also begin to explore how these mobility choices will influence energy efficiency, which is the critical question for DOE to answer in the efficient mobility space. The reviewer noted that the team is taking advantage of existing sources of survey information on consumer preferences and modeling efforts, which ensures efficient use of resources.

Reviewer 2:

The reviewer remarked that this project seems to have a great approach and plan and that it is well integrated with other efforts.

Reviewer 3:

The reviewer liked this project. Additionally, the reviewer noted that it was addressing how other DOE projects interact and that the complexity was interesting.

Reviewer 4:

The reviewer commented that the approach is well thought out, albeit extremely complex, with many interdependencies and that future collaborations will be critical to success.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer indicated that the progress looks good and should lead to a useful tool ready to integrate with other efforts.

Reviewer 2:
The reviewer said that the work is on schedule and preliminary outputs have been developed. The reviewer also noted that collaborations will be critical going forward.

Reviewer 3:
The reviewer stated that the technical accomplishments are good given that the project is in its first year and that the characterization of individual household mobility parameters should yield some interesting results—the results to date are certainly logical and not unexpected. The reviewer noted that the initial modeling appears to provide confirmation of the positive synergies between automation and electrification.

Reviewer 4:
The reviewer pointed out that the project has to be careful to say that there are technical accomplishments. The reviewer saw this more as an accomplishment of a study, but does think this study raised an interesting thought: specifically, if transportation is made easier and adds more autonomy, would one actually drive more miles and cause more emissions, especially because studies show increasing distances that are being driven.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project team draws on an extensive list of collaborators in the national laboratory and academic spaces and that the division of tasks among collaborators appears to take advantage of individual areas of expertise.

Reviewer 2:
The reviewer said that this is a fundamentally collaborative project that is well integrated with other parallel projects.

Reviewer 3:
The reviewer commented that this was not just engaged at DOE national laboratories and the reviewer liked the additional collaborator institutions (see Slide 15).

Reviewer 4:
The reviewer thought that significant collaboration has occurred with other SMART Mobility projects.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer really liked Slide 17 of the presentation (the outline of future research) in particular because it quantifies the four EEMS future narratives of mobility. The review said to keep moving forward on this one.

Reviewer 2:
The reviewer stated that this project appears to be well planned and appears to be configured to address potential barriers.

Reviewer 3:
The reviewer remarked that the PI has a good handle on the challenges of integrating outputs with other CAV and SMART Mobility projects.

Reviewer 4:
The reviewer said that the future work set forth by the team is logical and addresses the key questions for the analysis, specifically in quantifying several future mobility scenarios.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed that we have put so much effort into various powertrain technologies and costs and that this is an excellent project to start putting on all of the powertrains and possibilities together.

Reviewer 2:
The reviewer mentioned that integrating fuel and powertrain options with new mobility options to maintain or increase fuel use reductions is critical to continuation of the DOE mission of energy independence.

Reviewer 3:
The reviewer said that understanding how consumers are likely to make mobility choices in the future is critical for ensuring that these consumers choose highly efficient vehicles that will displace petroleum for their mobility services.

Reviewer 4:
The reviewer said that improving efficiency and switching fuels will reduce petroleum usage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found funding levels to be appropriate.

Reviewer 2:
The reviewer said that the resources seem sufficient and the reviewer liked the thought process on this one. The reviewer asked what the resources would need to be to make this an even more useful project.

Reviewer 3:
The reviewer said that until data are available to allow calibration and validation of models, resources seem to be sufficient.

Reviewer 4:
The reviewer stated that the resources appear to be sufficient to complete the analysis and modeling described by the team.

Presentation Number: eems025
Presentation Title: National Scale Multi-Modal Energy and GHG Analysis of Inter-City Freight
Principal Investigator: Yan Zhou (Argonne National Laboratory)

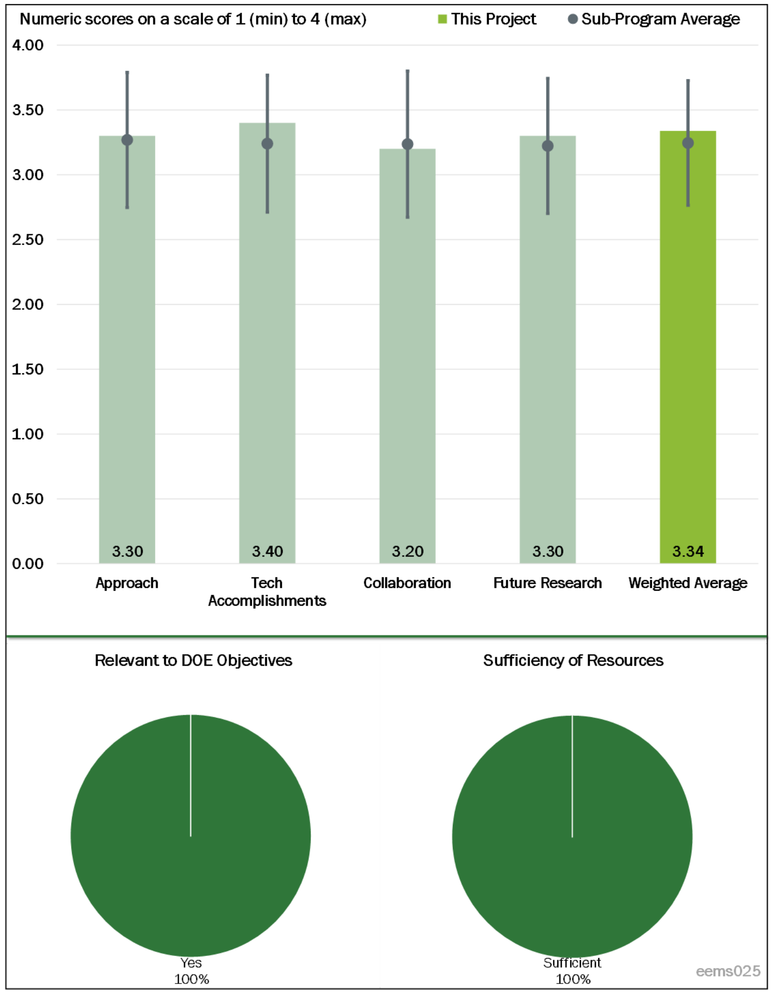

Figure 4-24 - Presentation Number: eems025 Presentation Title: National Scale Multi-Modal Energy and GHG Analysis of Inter-City Freight Principal Investigator: Yan Zhou (Argonne National Laboratory)

Presenter

Yan Zhou, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that it is a very good approach.

Reviewer 2:

The reviewer remarked that the objective is to analyze national level energy and emissions impacts of inter-city freight due to use of smart technologies and mode shifts utilizing literature, real-world data, and simulation/modeling results. The reviewer noted that the FY 2017 focus is on the high-level national impact of low-level automation (i.e., platooning).

Reviewer 3:

The reviewer stated that the approach for this work is reasonable and logical and that the team is analyzing an important future aspect of improving freight transportation efficiency through this work. The reviewer commented that the approach combines existing state-of-the-art research information and existing model resources to develop the results.

Reviewer 4:

The reviewer explained that the overall objective is to analyze national level energy and emissions impacts of inter-city freight due to smart technologies using ANL's non-light-duty energy and greenhouse gas (GHG) accounting tool (NEAT) model. The reviewer added that this effort is largely based on identification and compilation of information via literature reviews, real-world data, and simulation and modeling results from other pillars within SMART Mobility.

The reviewer indicated that this effort is working with NREL, ORNL, and INL to identify and frame the potential of futuristic inter-city operations and smart technologies including modal efficiencies and freight mode shares. The reviewer said that this is important as it helps bound the energy savings potential of various smart approaches and technologies and can inform the direction of future research and implementation.

The reviewer acknowledged that in FY 2017, the focus is on high-level impacts of low-level automation (platooning) and that, from the outset, it is good to focus on smart options that can lead to nearer-term and quantifiable benefits for inter-city freight operations.

The reviewer said that ultimately, the intent is for ANL's NEAT model to identify the "size of the prize" for inter-city freight from a variety of factors including potential mode shift' improved efficiency' demand changes by commodity' increased use of alternative fuels' and alternative economic, regulatory, and policy scenarios.

The reviewer noted that the challenges and barriers have been identified including the lack of real-world freight data with smart technologies, hard-to-quantify impacts on freight efficiency and mode shares by commodity type, and uncertainty on how smart technologies would affect freight operation costs. The reviewer pointed out that this issue of the effect of smart technologies on freight operation costs is particularly compelling and should be heavily focused upon; this will ultimately determine the success or failure regarding the adoption of smart technologies in freight operations.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that the completed preliminary impact quantification of long-haul freight energy has implications.

Reviewer 2:
The reviewer commented that the team's accomplishments are good given that the project has been underway for less than a year and that the work in summarizing the current literature on truck platooning is very helpful and essential to guide the modeling efforts. The reviewer stated that the team has made good use of limited literature data to obtain preliminary results on the long-term effect of truck platooning on overall freight energy consumption.

Reviewer 3:
The reviewer saw this as a very important project with a good start.

Reviewer 4:
The reviewer said that, given the relatively recent start and modest budget, the project has achieved a number of accomplishments.

The reviewer remarked that in FY 2017, the project has identified a number of research gaps and areas in which limited data are available including truck efficiency change by commodity type and various information deficiencies regarding building a knowledge base for platooning.

The reviewer stated that, regarding platooning, the project has identified and compiled statistics on fuel savings via platooning depending upon numbers, spacing, mass, and positioning. The reviewer said that the project found that it is more efficient to be part of a platoon even accounting for requirements for splitting and merging.

The reviewer observed that a number of other important parameters regarding platooning have been identified, including platoonable miles by time thresholds, truck speed adjustments, and the effects of road saturation on platooning opportunities.

The reviewer remarked that the project has framed and quantified the energy and concomitant GHG benefits of modal shifting and platooning at the national level.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the project has a good team.

Reviewer 2:
The reviewer reported collaboration with INL, NREL, and ORNL on data collection and identifying research needs and that it could be useful to look to truck industry groups (i.e., Truck Manufacturers Association) and other relevant agencies like DOT to understand availability of any complementary datasets. Also, the reviewer noted that connecting with truck manufacturers who have a lot of trip information available from their customers (if it could be shared at an aggregated or anonymized level) could provide additional insights.

Reviewer 3:
The reviewer stated that the collaborations appear to be reasonable but are limited to DOE national laboratories and that direct feedback from industry partners (particularly those involved in platooning or vehicle automation) could add to the collaboration and potentially improve assumptions and results.

Reviewer 4:
The reviewer saw that the project is collaborating with INL, NREL, and ORNL on data collection, identifying research needs, and modeling and simulation to produce more robust information on which to base analysis. The reviewer said that real-world data identification, availability, and collection are a challenge and that, as mentioned under remaining challenges and barriers, collaborations are needed with other organizations to address these data challenges. The reviewer noted that the researcher mentioned that efforts will be undertaken to work with UPS via INL.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that there is a good plan for future research.

Reviewer 2:
The reviewer found the future work to be appropriate, with the key being incorporating results and data from other members of multi-modal and CAVs pillars that will hopefully include organizations beyond just the national laboratories.

Reviewer 3:
The reviewer said that the future research plans are logical and will address several key questions within the freight mobility sector. The reviewer noticed that the team is covering the major areas—freight logistics efficiency improvement, shifts in freight demand due to broader macro-trends, conversion of energy savings to freight efficiency (ton-miles)--and that depending on data availability, it might be interesting to look at cubic foot-mile metrics as this may be more relevant for some commodities (although data on cubic feet of cargo shipped may be difficult to obtain).

Reviewer 4:
The reviewer stated that a number of items for planned and proposed future work are presented including converting platoon information into more industry accepted terminology, fuel savings by commodity, and

incorporation of data and information from other members of the Multi-Modal and CAVs pillars as well as identifying future inter-city freight demand due to increasing fast/guaranteed shipping.

The reviewer noted that one of particular interest was to "identify efficiency improvement due to smart technologies other than platooning, such as better logistic operations." The reviewer said that it is good to expand options of smart technologies for freight movement beyond platooning. However, the reviewer went on to say, a question arises: whether transportation/distribution companies would already have been looking at this for a long time to improve the efficiency and lower the cost of their operations. The reviewer suggested that the "logistics areas" that may be untapped are ones that potentially cross the boundaries of more than one distribution firm (as platooning potentially does) and that shared company depots or hubs may be possibilities to explore because individual firms are unlikely to consider that on their own.

The reviewer indicated that one of the areas mentioned for future research is to better understand how the type of community affects the benefits of platooning.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that platooning of Class 8 over-the-road equipment has the potential for significant petroleum displacement.

Reviewer 2:
The reviewer said that yes, this project supports the overall DOE objectives of petroleum displacement.

Reviewer 3:
The reviewer remarked that this project supports the EEMS Multi-Modal pillar efforts and contributes to the understanding (does not directly impact it as it strictly involves analysis) of freight energy use at a national level.

Reviewer 4:
The reviewer pointed out that future freight transport is likely to drive overall petroleum use in the future, particularly in light of strides made in light-duty vehicle (LDV) efficiency. The reviewer noted that addressing the potential energy savings of future mobility systems for the freight sector is a critical part of getting the full petroleum displacement picture of SMART Mobility.

Reviewer 5:
The reviewer said that it is possible for inter-city freight energy use and, by association, criteria and GHG emissions to be reduced by modal shifting and introduction of smart technologies. The reviewer noted that early analysis demonstrates the potential for truck energy consumption and GHG to be reduced by 6% due to mode shifting and by 4.2% from truck platooning while increasing rail energy consumption by only 1.7%.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources appear to be sufficient to achieve the goals of the project.

Reviewer 2:
The reviewer said that only $80,000 for FY 2017 was mentioned in the presentation and it was not clear what the funding might be for FY 2018 and FY 2019 (a 3-year duration was listed). The reviewer noted that there was good progress and a good approach for what seems to be a relatively very small project. The reviewer

commented that due to its size, it might be appropriate to include it for review with other projects in Multi-Modal pillar instead of being a standalone project.

Reviewer 3:

The reviewer remarked that the task as identified is currently on schedule and presumably within budget; thereby, the reviewer assumed that funding for this activity is sufficient.

Presentation Number: eems026
Presentation Title: Expanding Regional Simulations of CAVs to the National Level and Assessing Uncertainties
Principal Investigator: Tom Stephens (Argonne National Laboratory)

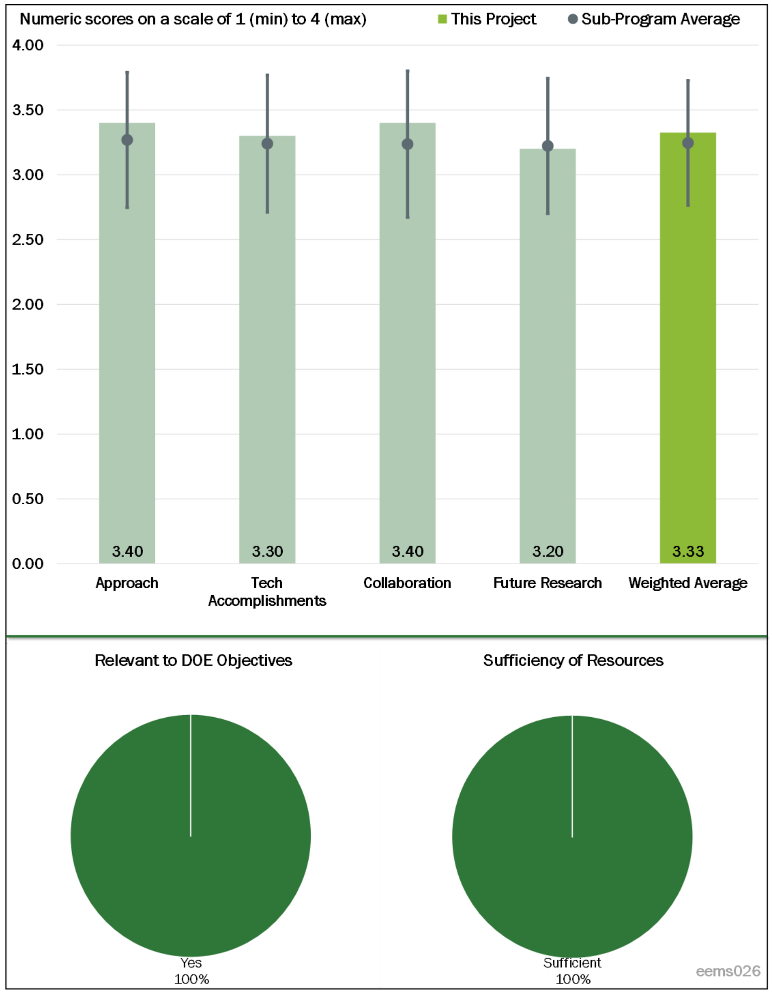

Figure 4-25 - Presentation Number: eems026 Presentation Title: Expanding Regional Simulations of CAVs to the National Level and Assessing Uncertainties Principal Investigator: Tom Stephens (Argonne National Laboratory)

Presenter

Tom Stephens, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach for the work is very well thought out and thorough and should be successful in analyzing the impacts of CVs and AVs on energy use in transportation. The reviewer said that the approach leverages a number of tools and related research efforts to provide the "big picture" impacts.

Reviewer 2:

The reviewer said that the approach to national level is appropriately taken by rolling up local-level results.

Reviewer 3:

The reviewer said that, whatever answer the team comes up with, it cannot be proven to be either correct or incorrect. The reviewer said that given the reality of the situation, it perhaps makes sense to make absolutely clear beforehand whether the purpose of this project is to develop a model that would predict in an absolute sense or to develop a model that provides a prediction as a function uncertain inputs; the second approach would naturally result in an answer that has an even larger level of uncertainty.

Reviewer 4:

The reviewer remarked that this project aims to estimate the potential changes in petroleum consumption and GHG emissions due to deployment of CAVs at the national level and that the approach entails a five-step process: conduct initial literature review and assessment; develop conceptual calculation flows; implement value component methods to estimate CAV adoption rates; aggregate energy/GHG impacts of CAV features nationally; and use transferability modeling to expand detailed local travel simulation results to the national level.

The reviewer said that it is a feasible and innovative approach to which specific details and solutions are provided as to the challenges facing the project. The reviewer stated that it is noteworthy that early in a slide of the CAV Subproject 2B Roadmap, a number of very salient high-level questions are presented that require resolution. Under each of the five steps of the approach, the reviewer noted, comprehensive details are provided as to the methodology process to address the specific challenges and achieve the objectives therein. The reviewer commented that using transferability modeling is especially interesting as it enables identification of rich, local datasets with subsequent extrapolation nationally based upon households with similar characteristics. As is indicated, validation of this approach is still underway.

Reviewer 5:

The reviewer viewed the extrapolation to national scale as being well defined and logical and saw the decision to purchase a CAV as being very difficult to model. The reviewer expressed uncertainty about what the inputs to MA3T would be to model this. The reviewer noted no data to date and asked if there is a survey. The reviewer remarked that many data inputs to this problem do not exist.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that the team has already added to the CAV discussion with its bounding report from 2016 and the work described here builds on those findings. The team has verified its modeling approach and has identified the key questions to answer at a sufficient level of detail to achieve the project goals.

Reviewer 2:

The reviewer commented that in extending the regional data to a national level, it seems that the researchers are relying on very narrow datasets (the reviewer asked if this set is Chicago only) and that it would perhaps utilize the NREL TSDC database in some form to validate the assumptions that move the regional scenario to a national scenario. The reviewer wondered if that perhaps it is already being done, but that it is not quite clear from the presentation.

Reviewer 3:

The reviewer suspected that the accomplishments on a project with such uncertainty are also uncertain and that what may appear to be an accomplishment could very easily be eliminated. The reviewer added that this project is a good exercise where the effort to estimate and project is likely of more value than the resultant projections, which will be very uncertain and or uselessly broad.

Reviewer 4:

The reviewer outlined a number of technical accomplishments for the project under each of the five steps identified in the approach. Regarding the first step of literature review and assessment, bounding of the energy impacts has been established for partial automation, full automation (no rideshare), and full automation (with rideshare) showing a large range from significantly negative to positive energy impacts. For the second step of conceptual calculation flows, the high-level process flow for obtaining the aggregated petroleum and GHG scenario impacts is established. For the third step of implementing value component methods to estimate CAV adoption rates, specific value components (stress, time, energy, mobility, and productivity) are identified including process integration into ORNL’s MA3T model including a revised choice structure. For the fourth step of aggregating energy/GHG impacts of CAV features nationally, in short, the approach is to calculate the total national energy use and GHG emissions by incorporating fuel consumption rates and summing VMT for the entire U.S. road network. For the fifth and last step of transferability modeling to expand detailed travel simulation results to the national level, transferability permits the use of rich datasets of local travel patterns that can be transferred to households with similar characteristics nationally. The reviewer said that so far, there is solid agreement between transferred and observed frequencies and behaviors and that Metropolitan Chicago is being used as the baseline locale.

Additionally, the reviewer noted, a number of key, high-level questions and uncertainties have been identified regarding LDVs (predominately) and HDVs.

Reviewer 5:
The reviewer remarked that the progress is good, but that the timeline as presented in the slides is repetitive/incorrect.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that this project is hugely collaborative in its approach, which is appropriate for the scope.

Reviewer 2:
The reviewer was glad to see university collaboration with University of Illinois at Chicago.

Reviewer 3:
The reviewer found the collaborations to be reasonable for achieving the goals of the program with both formal and informal collaborative efforts.

Reviewer 4:
The reviewer stated that the project is closely collaborating on the CAVs pillar tasks with ANL, NREL, and ORNL as well as the Mobility Decision Science pillar. Additionally, the reviewer noted, the project has informal collaborations with the wider research community through a TRB subcommittee and Automated Vehicle Symposium, universities, and the DOT Volpe National Transportation Systems Center.

Reviewer 5:
The reviewer saw a reasonable level of cooperation with the laboratories and suggested that it would make sense to work with more universities, say the University of Michigan, especially because other ANL teams already appear to be working closely with them on projects related to CAVs.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future work is a logical result of the overall work plan set forth at the outset of the program and the team should achieve its goals through this future work.

Reviewer 2:
The reviewer noted that evaluating additional influences on human behavior in travel and location/re-location provides for many possible areas of future work.

Reviewer 3:
The reviewer stated that the future path appears to be clearly laid out—except that, as mentioned before, all the steps have large uncertainties associated with them. The reviewer said that perhaps a clear statement of the range of uncertainty in the final answer that one can live with will prevent unreasonable expectations. The reviewer indicated that the processes laid out to aggregate existing data and extend them are very interesting.

Reviewer 4:
The reviewer observed that a reasonable presentation of remaining high-level challenges and barriers is provided although it would be beneficial to provide some additional detail. The reviewer commented that future proposed work is provided that includes further information on CAVs scenario simulations and rolling up to the national level.

Reviewer 5:
The reviewer remarked that this is a very large scope and the reviewer is unsure that all will be able to be done with actionable outcomes.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer indicated that identifying the potential efficiency impacts (positive and negative) of CAVs is directly relevant to DOE petroleum displacement goals and that it is essential to determine these positive and negative efficiency impacts now as the technology is still developing and there are opportunities to make adjustments based on the analysis results.

Reviewer 2:
The reviewer responded that, yes, the project does support the overall DOE objectives of petroleum displacement.

Reviewer 3:
The reviewer stated that the presentation makes clear the relevance of the project in supporting DOE objectives.

Reviewer 4:
The reviewer said that CAVs are an important, yet disruptive, element in the move to Smart Mobility. Currently, the reviewer noted, their likely energy and emissions impacts (both positive and negative) are yet to be definitely determined locally or at the national level. The reviewer explained that it is important to identify and understand the key considerations to be addressed to achieve beneficial energy and emissions outcomes while minimizing negative impacts.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the budget appears manageable within the defined project scope and that the project team has the experience, facilities, and equipment to conduct the task successfully within budget and timetable.

Reviewer 2:
The reviewer found the resources to be sufficient to complete the work as described.

Reviewer 3:
The reviewer remarked that there is no indication that funds might be excessive or insufficient.

Reviewer 4:
The reviewer said that the resources are okay.

Presentation Number: eems027
Presentation Title: Opportunities for Improving the Energy Efficiency of Multi-Modal Intra-City Freight Movement
Principal Investigator: Kevin Walkowicz (National Renewable Energy Laboratory)

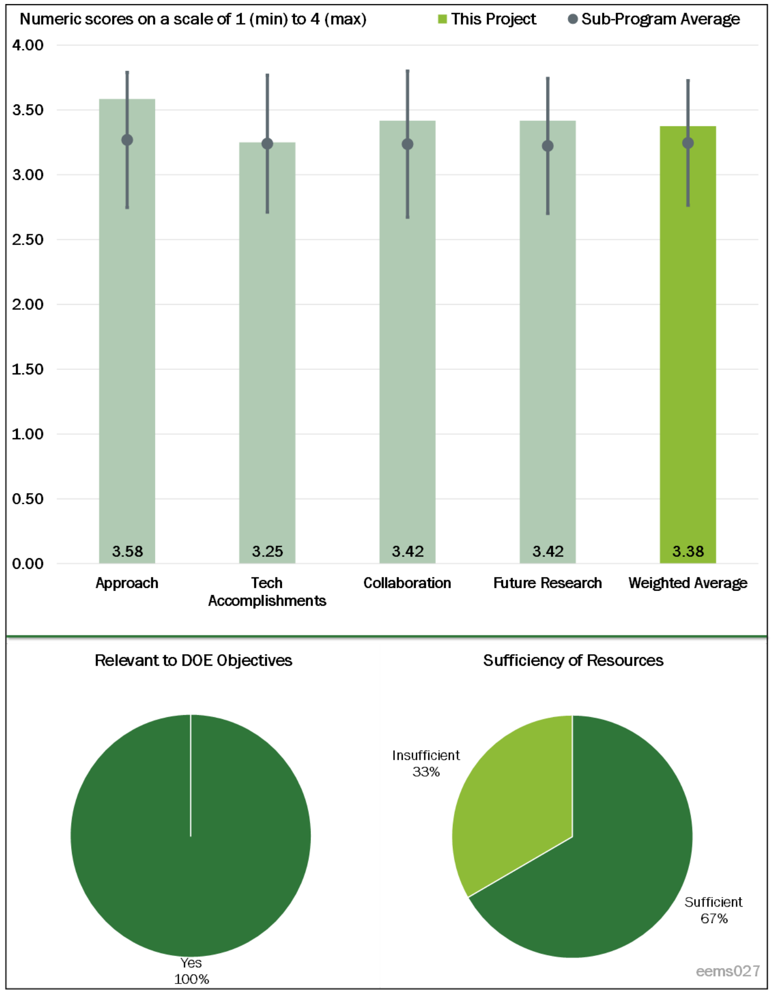

Figure 4-26 - Presentation Number: eems027 Presentation Title: Opportunities for Improving the Energy Efficiency of Multi-Modal Intra-City Freight Movement Principal Investigator: Kevin Walkowicz (National Renewable Energy Laboratory)

Presenter
Kevin Walkowicz, National Renewable Energy Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer acknowledged that this was one of their favorite projects to review this year. The reviewer noted that the approach was excellent and that the partners and collaboration are excellent.

Reviewer 2:
The reviewer said that the overall multi-step process to evaluate current baseline freight movement and future modal change scenarios is excellent. The reviewer remarked that the specific areas of work to be accomplished in this project, which is to gather and validate baseline data and develop estimates for technology-based savings, development of an intra-city freight network model, perform simulations of current baseline freight movements, develop future modal network, and explore a range of scenarios and optimize freight movement, provide excellent opportunities to contribute to overcoming the barriers that exist.

Reviewer 3:
The reviewer commented that this project has a well-defined scope and method and that some of the other studies in this section have very large scopes or poorly defined methods. The reviewer pointed out that this project has a mathematical basis and a nice dataset.

Reviewer 4:
The reviewer stated that the barriers and challenges are specifically laid out for this project and that the approach is provided in great detail explaining how the project will be executed.

Reviewer 5:
The reviewer mentioned that the approach is well laid out to address identified barriers for energy modeling intra-city freight movement and that the research team has identified objectives and provided explanations of a multi-step approach. The reviewer said that the research team partner organizations seem to have been appropriately selected to fill in research information and data gaps for supporting the approach, especially as related to new technology deployment and freight modes. The reviewer stated that the overall approach directly supports the intra-city freight delivery elements of the Multi-Modal Pillar Roadmap.

Reviewer 6:
The reviewer indicated that a key aspect of the stated approach is to optimize for energy within cost and time constraints. However, the reviewer noted, it is not clear if the team has fully explored the various relationships between cost and time. The reviewer pointed out that with automated deliveries, there will be some de-coupling of these factors, as a slower trip that burns less fuel may cost less than a faster trip that burns more fuel, while the opposite may have been true before due to drivers' labor costs. The reviewer remarked that it is unclear if these tradeoffs have been fully mapped out and that presumably UPS should have a solid grasp of these issues.

The reviewer found no mention of the dependencies between potential efficiency benefits and route selection (e.g., there will not be much benefit from platooning or reducing aerodynamic drag if a slow-speed, residential route is selected). Similarly, the reviewer commented, fuel savings from idling reduction is not likely to have much impact if the route selected is mostly on uncongested freeways.

The reviewer said that the project identifies shifting from truck to rail as having the "greatest overall potential for energy reduction," but it is not clear how this shift is possible or relevant in intra-city shipping. The reviewer found it hard to see how rail freight plays any role in intra-city movements. On the other hand, the reviewer noted, if rail is to be considered, then it would be even better to consider marine freight, which is the most efficient (1 ton of freight on a ship will move 243 km per liter of fuel compared with 213 km by rail and 35 km by truck).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer liked the baselining and the development of estimates for technology-based savings. The reviewer thought that this project brought together many of the DOE initiatives over the past several years.

Reviewer 2:
The reviewer said that the project is focused on the critical barriers and provides information on how the team has accomplished them, and that the amount of data and work accomplished to date has been provided.

Reviewer 3:
The reviewer pronounced the progress so far to be fine.

Reviewer 4:
The reviewer remarked that the project's technical accomplishments seem to be satisfactory given that the project only started in October of 2016.

Reviewer 5:
The reviewer noted that the research team has identified technical accomplishments to date and estimated the project to be 17% complete. The reviewer commented that this seems to be reasonable progress for FY 2017 to date, especially given budget limits. The reviewer said that researchers have compiled data and information from a variety of reputable sources for Smart City Columbus, Ohio, to validate intra-city freight movement,

operation and energy use. Researchers have also looked into baseline and new technologies and freight modes for characterizing freight vehicles and modal operations. The reviewer added that the team has begun initial development of a route-based, predictive drive- model based on in-house tools and knowledge that will eventually correlate with existing DOE tools for estimating overall energy use along freight routes.

Reviewer 6:

The reviewer acknowledged that it is still very early in the project so there is not much to report as only a few studies have been initiated. However, the rate of progress seems reasonable and appropriate.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that the project has outstanding collaboration and seems well coordinated. Each partner is spelled out and identified.

Reviewer 2:

The reviewer said that this project has shown very good collaboration with other institutions and seems to be well coordinated.

Reviewer 3:

The reviewer commented that the researchers have outlined a very nice list of collaborative partners for the project, including identification/use of relevant data sources. The reviewer noted that INRIX is an especially relevant and interesting data partner for traffic data; the research team is working with other SMART Mobility Consortium members and has begun to work with other federal agencies. The reviewer said that the team is also collaborating directly with a freight industry partner to validate baseline model results and an automotive industry market data organization for predicting future technology market penetrations.

Reviewer 4:

The reviewer enjoyed seeing collaborative partners other than DOE, such as UPS, INRIX, MORPC, and other indirect providers. The reviewer asked why the USPS is not part of this because it delivers daily to every household in America (except Sunday and holidays).

Reviewer 5:

The reviewer found the collaboration to be fine.

Reviewer 6:

The reviewer stated that partnering with UPS seems like a major collaborative breakthrough and that it would be difficult to imagine a better source of data and expertise on intra-city freight. The reviewer added that one improvement would be to include a company that moves containers (such as a drayage company) and not just delivers individual packages.

The reviewer said that it is unclear if there was any collaboration with the DOT Office of Freight Management and Operations (within the FHWA's Office of Operations). The reviewer pointed out that such interagency collaborations can be complex and difficult to establish so it is understandable if there were no connection made. However, the reviewer encouraged the PIs to be persistent and pursue such collaborations fully as this office in DOT appears to have substantial relevant expertise; e.g., they are the source of the fully deployed Freight Advanced Traveler Information System.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said to keep going and expressed interest in seeing how consumers would react to these new technologies, because some people actually pick up their UPS packages, rather than having them delivered to their homes.

Reviewer 2:
The reviewer noted that the project provides detailed plans of future work in a logical manner while addressing its barriers.

Reviewer 3:
The reviewer stated that the proposed future work will adequately address the remaining challenges and barriers identified in the project.

Reviewer 4:
The reviewer commented that it is a good to see that the future research includes work on potential new distribution network models, enabled by automation, the growth of e-commerce, and other technology advances. The reviewer said that such concepts as neighborhood delivery depots could radically change the nature of freight flows through future modal networks.

The reviewer indicated that it is not clear if future research is devoting enough attention to understanding the potential significance of unmanned vehicle operation and the resulting decoupling of labor cost from the cost of operating a vehicle and that this effect may make business models with many more vehicles and many more different sizes actually viable.

Reviewer 5:
The reviewer said that the researchers have considered remaining challenges and barriers in proposing future work, specifically the need for improved freight movement data, characterization of new intra-city freight modes, future technology and new modal adoption rates, energy use rates for new technologies and modes, and further enhancements of tour-based models. The reviewer said that the proposed research plan for the remainder of FY 2017 and all of FY 2018- 2019 includes further identification and characterization on new modes and tour-based models, development of an initial freight movement network model and baseline results, incorporation of new technologies and modes into the network model, and completion of the predictive route-based, drive-cycle model. The reviewer recommended that as part of identification of new intra-city modes, the researchers consider the variety of "Uber-like" delivery concepts that are springing up or planned, such as Amazon Flex. The freight industry partners that are on this project will provide valuable insight to these future concepts.

Reviewer 6:
The reviewer said that it is still early.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer agreed that this project definitely supports the overall DOE objective of petroleum displacement by providing energy savings through emerging, novel, intra-city, goods delivery modes and through data generation to determine emissions, energy, and transit time reduction in intra-city goods delivery in the future.

Reviewer 2:

The reviewer said that, yes, this work is absolutely relevant and that given the potentially dramatic changes in how freight moves within cities in coming decades, understanding the related impacts on energy use will be critical to any efforts at displacing petroleum use.

Reviewer 3:

The reviewer observed that the research is very relevant to addressing DOE objectives under SMART Mobility's Multi-Modal pillar with a focus on future intra-city freight delivery and energy use implications.

Reviewer 4:

The reviewer responded that, yes, the project supports the overall DOE objectives of petroleum displacement by providing a tool to optimize intra-city freight movement, thus reducing petroleum use.

Reviewer 5:

The reviewer said that, yes, the project supports the overall DOE objectives of petroleum displacement.

Reviewer 6:

The reviewer commented that the project has posed some interesting technical solutions to decrease petroleum in the scenarios and that the reviewer would like to see them modeled out further.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources for this project seem on the lighter side compared to other projects. The work being done involves a lot of partners, and it seems that additional funding should be required to accomplish the stated objectives.

Reviewer 2:

The reviewer was unsure that the funding level is truly "insufficient" and noted that it just seems a little low, based on the potentially broad scope of the work. However, the reviewer said that if the project can effectively leverage resources from UPS and other partners, it may be sufficient.

Reviewer 3:

The reviewer stated that the project appears to be very cost effective based on the planned project scope for the FY 2017- 2019 period and the available budget.

Reviewer 4:

The reviewer found the resources to be sufficient to complete the tasks involved in this project.

Reviewer 5:

The reviewer remarked that there are resources for this study and asked if the PI were able to model these items further, what it would take in terms of resources.

Reviewer 6:

The reviewer thought that the resources are fine.

Acronyms and Abbreviations

ACC	Automated Cruise Control
AFV	Alternative Fuel Vehicle
AMBER	Advanced Model Based Engineering Resource
AMD	Automated Mobility Districts
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARPA-E	Advanced Research Projects Agency-Energy
AV	Automated Vehicle
BEAM	Behavior Energy Autonomy Mobility
CACC	Cooperative Adaptive Cruise Control
CAV	Connected and Autonomous Vehicle
CDOT	Colorado Department of Transportation
CNG	Compressed natural gas
CV	Connected Vehicle
DCFC	Direct Current Fast-Charging
DFC	Detroit Future City
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EEMS	Energy-Efficient Mobility Systems
EPA	U.S. Environmental Protection Agency
ESS	Energy Storage Systems
EV	Electric Vehicle
EVSE	Electrical Vehicle Supply Equipment
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FY	Fiscal Year
GHG	Greenhouse Gas

GMU	George Mason University
GPS	Global Positioning System
HDV	Heavy-Duty Vehicle
HPC	High-Performance Computing
Hz	Hertz
INL	Idaho National Laboratory
ITS-JPO	Intelligent Transportation System Joint Program Office
LBNL	Lawrence Berkeley National Laboratory
LDV	Light-duty vehicle
MA3T	Market Acceptance of Advanced Automotive Technologies
MATSim	Multi-Agent Transport Simulation
MORPC	Mid-Ohio Regional Planning Commission
MOU	Memorandum of Understanding
MPC	Model-Predictive Control
NEAT	Non-Light Duty Energy and GHG Emissions Accounting Tool
NREL	National Renewable Energy Laboratory
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
ORAD	On-Road Automated Driving
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
PMP	Pontryagin's Minimum Principle
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
PRT	Personal Rapid Transit
R&D	Research and Development
ROI	Return on investment

SAE	Society of Automotive Engineers
SEMCOG	Southeast Michigan Council of Governments
SHRP2	Second Strategic Highway Research Program
SMART	Systems and Modeling for Accelerated Research in Transportation
TNC	Transportation Network Company
TRB	Transportation Research Board
TSDC	Transportation Secure Data Center
TUMS	Toolbox for Urban Mobility Simulation
USPS	U.S. Postal Service
VMT	Vehicle Miles Traveled
VOTT	Value of Travel Time
VTO	Vehicle Technologies Office
WTP	Willingness-to-Pay

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5. Fuel and Lubricant Technologies

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Fuel and Lubricant Technologies (FT) subprogram supports early-stage R&D to improve our understanding of, and ability to manipulate, combustion processes, generating knowledge and insight necessary for industry to develop the next-generation of engines and fuels. The primary means for accomplishing this is through the Co-Optimization of Fuels and Engines program (Co-Optima), which is working to identify the critical fuel properties needed to enable advanced engine architectures and emission control systems that optimize engine efficiency and operability, along with scalable and cost-effective low-carbon fuels that have those properties. FT also supports research to promote fuel diversification through the direct substitution of emerging domestic fuel. Increased use of these fuels can promote national energy security and reduce the operation costs for domestic fleets. Additionally, FT projects are researching advanced lubricants that are compatible with future and legacy vehicles and can reduce friction losses in engines, transmissions, and axles, thereby improving fuel economy across the vehicle fleet.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: ft000 Presentation Title: Overview of the DOE Fuel and Lubricant Technologies R&D
Principal Investigator: Kevin Stork (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer stated yes, all areas were briefly covered. The strategy seeks to displace petroleum based fuels through improved combustion efficiency and reduced engine and vehicle friction.

Reviewer 2:

The reviewer stated that the information regarding the strategy of the fuels and lubricants that can enhance combustion efficiency programs was provided. The strategy includes identifying fuel properties to enable advanced engine and emission control systems that optimize engine efficiency and increase energy security by enabling fuel substitution.

Reviewer 3:

The reviewer commented that the presentation did a good job of identifying the key challenges for the program area (fuels and lubricants) for both light and heavy-duty applications. In addition, the strategy/approach for addressing the identified barriers was adequately covered.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:

The reviewer responded yes, there is an appropriate balance between near-, mid-, and long-term research and development. For lubricants, near term work includes developing drop-in lubricants while long term includes researching new base stocks, additives and methods to measure and predict performance. For fuels, the benefits of high ethanol blends are being studied and new fuel molecules or blends are being studied which are lower carbon footprint than current petroleum fuels and enable more efficient combustion.

Reviewer 2:

The reviewer commented that there was an adequate discussion of today’s fuels and that of what is needed in future fuels to help to achieve efficiency goals.

Reviewer 3:

The reviewer stated that the presentation started with two of the most pressing concerns for light-duty vehicles (i.e., knock resistance/octane of gasoline fuel, and low-viscosity lubricants for reducing friction losses). Addressing the aforementioned concerns has the potential to perhaps have the greatest impact on national fuel consumption and expenditure on transportation in the near term. In addition, the overview addressed the looming challenge of balance in gasoline and diesel volume demand, which can have significant implications particularly for the heavy-duty market. The scope of the Co-Optima program covers the mid-to-long term research and development needs.

Question 3: Were important issues and challenges identified?

Reviewer 1:

The reviewer commented that an important issue for the drop-in lubricant for in-use vehicles is the use of lower viscosity oils in engines which were not originally designed for them, figuring out who is taking the risk of introducing them, and motivating a customer to purchase them for only a 2% fuel economy gain. This reasoning has been used for years to help justify the lubricant program, but the path forward is not clearly identified. Lubricant research is important for future engines and vehicles, but I think justifying the program on fuel savings with current vehicles may be a fallacy.

The reviewer observed that the world has changed and petroleum displacement is not nearly as important as it was 5 or 10 years ago. I think the main justification for this research is to minimize supply disruptions, to reduce generation of CO_2, to support development of higher efficiency engines, and to extend the use of natural resources into future generations.

Reviewer 2:

The reviewer noted that the two barriers were identified: a lack of understanding of how fuel properties impact the efficiency of modern engines and in light-duty application; and a lack of fueling infrastructure and compact on-board storage for gaseous fuels.

Reviewer 3:

The reviewer responded yes, the important issues and challenges have been identified. In particular, the most pressing need for gasoline fuel - knock resistance or octane - has been highlighted. Improving the octane of the market fuel is arguably the most cost-effective measure for improving the efficiency and fuel economy of the entire vehicle fleet. As the entire vehicle fleet can benefit from improved fuel octane, the benefit to society in reduced fuel consumption can be substantial.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer observed that Co-Optima is a relatively new program aimed at matching new fuels with advanced combustion regimes with a very broad range of molecules being studied and many down-select gates for the fuels as research becomes more focused.

Reviewer 2:

The reviewer noted that the Co-Optima program will identify the optimal fuel-engine combination to lead to higher efficiency and this will lead to addressing the challenge of how fuel properties effects the efficiency of modern engines.

Reviewer 3:

The reviewer commented that while fuel knock resistance/octane has been rightly identified as the most important fuel property for light-duty vehicles, the plan to address the need for improved fuel knock resistance has not been explicitly addressed. In general, the plan for addressing the challenges identified has been presented at a very high level. It would be beneficial to tabulate the challenges and associated action plans on one slide.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

The reviewer noted that the presentation highlighted progress since last year, but details were not given due to breadth of program. Those details were discussed in the individual talks.

Reviewer 2:

The reviewer commented that there was a general discussion about how from 2000 to 2016 there has been a great deal of improvement in fuel economy and downsizing engines and that by having higher octane fuels and higher compression ratios fuel economy can be increased, However, there was not an adequate discussion regarding progress benchmarked against previous year successes.

Reviewer 3:

The reviewer stated no, the overview presentation did not address progress at all.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer observed that VTO is aimed at improving truck and automotive fuel economy and to substitute new fuels in place of petroleum derived fuels. Additionally, this reviewer continued, VTO wishes to maintain air pollution control and to enable the evolution of engines, materials, and vehicles.

Reviewer 2:
The reviewer commented that projects in the Fuels and Lubricants Program area definitely are working towards helping to increase fuel efficiency of engines as well as providing lubricants that can also have a positive impact on fuel economy efficiency.

Reviewer 3:
The reviewer stated yes, the ongoing work described in this overview presentation is directly addressing the goals of improving energy independence by reducing fuel consumption as well as facilitating greater use of biomass based fuels.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer commented that the Fuels and Lubricants Program area continues to be extremely well managed by very technically competent managers and has projects that fit well into the VTO portfolio to help increase fuel economy of light,

Reviewer 2:
The reviewer stated yes, the program area appears to be focused, well-managed, and effective in addressing VTO's needs.

Reviewer 3:
The reviewer was a little confused about the divergence of octane and compression ratio. It appears that the efficiency gains of higher compression ratio can be gained both through higher octane as well as by improved engine design. It would be interesting to learn more about and to study design changes that enable higher compression ratio with a fixed octane.

The large multi-laboratory lubricants program did not seem to have an overarching vision, but seemed to be mainly a shot gun combination of the research each laboratory had been doing separately and previously.

The reviewer commented that the presentation talked about the octane index (OI) being a better measure of fuel performance than anti-knock index. But the OI is just a correlation developed after the fact and with an adjustable factor that tunes for different engine types and model years. It is not a fundamental measurement.

The reviewer noted that if program is cut back, I think it would be most important to improve engine efficiency with current lube and fuels portfolios, rather than continuing to develop new fuels.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer commented that the co-optimization projects are a real strength of the Fuel and Lubricants Program. Pulling together fuels and engines is essential to continuing to increase fuel economy of both gasoline and diesel engines.

Reviewer 2:

The reviewer noted that a key strength of the program is the development of new science relative to fuels and lubricants which will allow continued evolution of engine and vehicle technology. Co-optima is a fresh look at a wide range of fuels and should be considered a strength. Justifying the lubricants program on the development and adoption of a lower viscosity lubricant for in use vehicles is probably a fallacy, but the research is still very important for future engines and vehicles.

Reviewer 3:

The reviewer noted that the strength of the program is that the key challenges facing both light and heavy-duty markets have been rightly identified. The reviewer identified the weakness of the program as focusing on the advanced combustion concepts and thus on projects that are addressing longer term goals. By the time these advanced combustion concepts reach a maturity level ready for industrial considerations, they may no longer be relevant as the same level of efficiency improvement would have been achieved through alternate technology pathways including increased electrification of the powertrain. In addition, while increased energy independence due to use of domestic feedstock has been identified as an opportunity, no clear action plan has been identified to facilitate adoption and introduction of biomass based fuels in the market.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer commented that program seeks to develop more efficient research and screening methods and models, both to speed up the rate of research and learning and also to discover underlying science.

Reviewer 2:

The reviewer noted that the co-optimization projects represent an extremely innovative method of how to address the issues of increasing fuel economy by looking at a complete systems approach of both the engine and the fuel interaction.

Reviewer 3:

The reviewer stated yes, the projects do represent innovative ways to approach the technical challenges identified. However, for the fuels projects, the emphasis is on longer term solutions which may never come to fruition due to the substantial challenges associated with engine controls and aftertreatment that are currently considered out of scope. Shifting the balance more towards some of the near-to-mid-term solutions may be better for achieving VTO’s goals of reduced petroleum consumption and greater energy independence.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

The reviewer observed that the program has a large number of partners including large auto and truck companies, Tier 1 suppliers, universities, small businesses, government laboratories, trade organizations, fuel and chemical companies, lubricant and additive manufacturers, and instrument manufacturers. The participation of all these diverse groups ensures that research will be directed in the most useful manner.

Reviewer 2:

The reviewer noted that through the work in the Fuels Working Group within the United States Driving Research and Innovation for Vehicle Efficiency and Energy (U.S. DRIVE) organization and through Co-Optima monthly conference calls, the program is actively involved with partners that will add to the value of the projects within the program.

Reviewer 3:
The reviewer stated that the program area has engaged partners in industry (automotive and energy) and academia. In addition, the program area is fostering greater collaboration between the participating national laboratories.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer noted that the program does a good job of collaborating within the restraints of funding, proprietary

Reviewer 2:
The reviewer stated yes, the program area has a very good relationship with the partners that work in the program and uses their input very effectively.

Reviewer 3:
The reviewer stated yes, the program area is collaborating effectively with project partners. However, there is room for improvement in interaction with stakeholders, in particular for the Co-Optima program. The monthly stakeholder conference calls serve the purpose of apprising stakeholders of the various projects and are much appreciated. However, the stakeholder calls are not necessarily the most effective means for seeking stakeholder feedback. One potential option could be to set up a website for stakeholders where all the review presentations are posted and stakeholders have the options of providing written feedback.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer stated that there are no obvious gaps in the program. There is an appropriate balance between fuels and lubricants and between near-term and far-term development.

Reviewer 2:
The reviewer noted that the Fuels and Lubricants Program area projects do not have any apparent gaps that need to be addressed.

Reviewer 3:
The reviewer stated that as advanced combustion concepts are investigated, it would be beneficial to take into consideration the variations in properties of market fuels. Testing fuel blends representative of the extreme ends of the market fuel spectrum would provide valuable information about the robustness of the various combustion concepts. Also, as the project results are reported, especially for projects focused on biomass based fuel components, it would be beneficial to include assessment of the Analysis of Sustainability, Scale, Economics, Risk, and Trade (ASSERT) team (techno-economic analysis) in the project reports.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer commented that the fuels and lubricant topics that were discussed were adequately addressed.

Reviewer 2:
The reviewer stated that it would be nice to know more about how engine design interplays with compression ratio, so that compression ratios continue to increase, even in the absence of octane increase. It would be nice to know if there is a better or more fundamental way of evaluating octane or cetane than those currently used. However, the reviewer recognized that engine design steps over into proprietary company decisions and that a more fundamental measurement of octane or cetane has already been the subject of much research, with no clear winner emerging.

Reviewer 3:

The reviewer commented that when the project results are reported, especially for projects focused on biomass based fuel components, it would be beneficial to include assessment of the ASSERT team (techno-economic analysis) in the project reports. Assessing the feasibility of combustion concepts or potential new fuel components would help identify the more promising candidates and increase the likelihood of realizing the opportunities identified in the presentation.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer stated that the program could benefit from continuing to develop closer collaboration and/or joint programs with combustion engines, controls, bio-energy, modeling, and materials. Co-Optima is a good example of this. There is also some work developing new lubricants, additives, and measurements corresponding to new materials being introduced into vehicles, such as plastics and coatings.

Reviewer 2:

The reviewer commented that the program should make sure to continue funding the Co-Optima projects because it is very important to look at engine and fuel interactions.

Reviewer 3:

The reviewer noted that there were insufficient funds to address existing program goals.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer stated that the modeling of fuels, engines, and materials should continue to bear fruit. The reviewer realizes that a lot of modeling has and is being done, but as computers and computation speed and complexity.

Reviewer 2:

The reviewer observed that currently the program area adequately addresses the barriers. However, if funding is reduced to the fiscal year (FY) 2018 budget request levels this will not be the case.

Reviewer 3:

The reviewer suggested to promote greater use of modeling tools to complement and augment the experimental work, in particular related to the non-linear variation in fuel properties and how that impacts engine combustion.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer suggested that the program continue to engage with other parts of the DOE program and continue to engage with industry and universities. This broad exposure and viewpoint should ensure that the program maintains its relevance.

Reviewer 2:

The reviewer stated that the program is structured very well and is effective as it stands now.

Reviewer 3:

The reviewer suggested that the program evaluate existing projects based on their feasibility and likelihood to impact production technologies and re-allocate funding accordingly. Some of the current projects purportedly have the potential to deliver large efficiency gains but are extremely unlikely to be incorporated into automotive applications due to controls, aftertreatment, and reliability concerns. It would be better to fund projects that may have a smaller benefit but greater likelihood of influencing technology in production.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 5-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft023	Polyalkylene Glycol (PAG) Based Lubricant for Light- and Medium-Duty Axles	Arup Gangopadhyay (Ford Motor Co.)	5-13	3.10	2.80	3.00	3.10	**2.94**
ft024	A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement	Q. Jane Wang (Northwestern U.)	5-17	3.40	3.20	3.50	2.90	**3.25**
ft025	Improved Fuel Economy through Formulation Design and Modeling	Gefei Wu (Valvoline)	5-21	3.25	3.25	3.75	3.38	**3.33**
ft037	Co-Optimization of Fuels and Engines (Co-Optima)—Overview	John Farrell (NREL)	5-25	3.25	3.45	3.30	3.40	**3.38**
ft047	Advanced Lubricant Technology—Surface and Lubricant Interactions	Oyelayo Ajayi (ANL)	5-33	3.38	3.13	3.75	3.38	**3.30**
ft048	Advanced Lubricant Technology—Technology Innovation, Design, and Synthesis	Lelia Cosimbescu (PNNL)	5-37	3.10	3.30	3.50	3.40	**3.29**
ft049	Lubricant Effects on Combustion and Emissions Control	John Storey (ORNL)	5-41	3.70	3.70	3.50	3.40	**3.64**
ft050	Power-Cylinder Friction Reduction through Coatings, Surface Finish, and Design	Arup Gangopadhyay (Ford Motor Co.)	5-46	3.50	3.40	3.60	3.50	**3.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft051	Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction	Robert McCormick (NREL)	5-50	3.50	3.75	3.50	3.63	**3.64**
ft052	Co-Optimization of Fuels and Engines (Co-Optima)—Topic 7 - Fuel Kinetics and Its Simulation	Matthew McNenly (LLNL)	5-54	3.36	3.50	3.43	3.29	**3.43**
ft053	Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 1: Research Octane Number, Sensitivity, and Heat of Vaporization	Jim Szybist (ORNL)	5-60	3.75	3.75	3.50	3.63	**3.70**
ft054	Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 2	Chris Kolodziej (ANL)	5-64	3.33	3.58	3.33	3.33	**3.46**
ft055	Co-Optimization of Fuels and Engines (Co-Optima)—Multimode Lean Spark Ignition: Experiments and Simulation	Magnus Sjoberg (SNL)	5-69	3.40	3.70	3.40	3.30	**3.54**
ft056	Co-Optimization of Fuels and Engines (Co-Optima)—Exploratory Advanced Compression Ignition Combustion Tasks	John Dec (SNL)	5-73	2.67	2.83	3.00	2.33	**2.75**
ft057	Co-Optimization of Fuels and Engines (Co-Optima)—Emissions, Emission Control, and Sprays	Todd Toops (ORNL)	5-76	3.70	3.40	3.40	3.40	**3.48**
ft058	High-Efficiency Cost-Effective Natural Gas Engine	Alexander Freitag (Bosch)	5-80	3.00	3.25	3.38	3.13	**3.19**
ft059	High BMEP and High Efficiency Micro-Pilot Ignition Natural Gas Engine	Jeffrey Naber (Michigan Technological Institute)	5-83	2.33	2.83	2.17	2.83	**2.63**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft060	Single-Fuel Reactivity Controlled Compression Ignition Combustion Enabled by Onboard Fuel Reformation	Ben Lawler (Stony Brook U.)	5-86	2.88	3.25	3.13	3.00	**3.11**
ft061	Methods to Measure, Predict, and Relate Friction, Wear, and Fuel Economy	Steve Gravante (Ricardo)	5-90	3.20	3.00	3.30	3.00	**3.09**
Overall Average				**3.28**	**3.35**	**3.36**	**3.26**	**3.32**

Presentation Number: ft023
Presentation Title: Polyalkylene Glycol (PAG) Based Lubricant for Light- and Medium-Duty Axles
Principal Investigator: Arup Gangopadhyay (Ford Motor Co.)

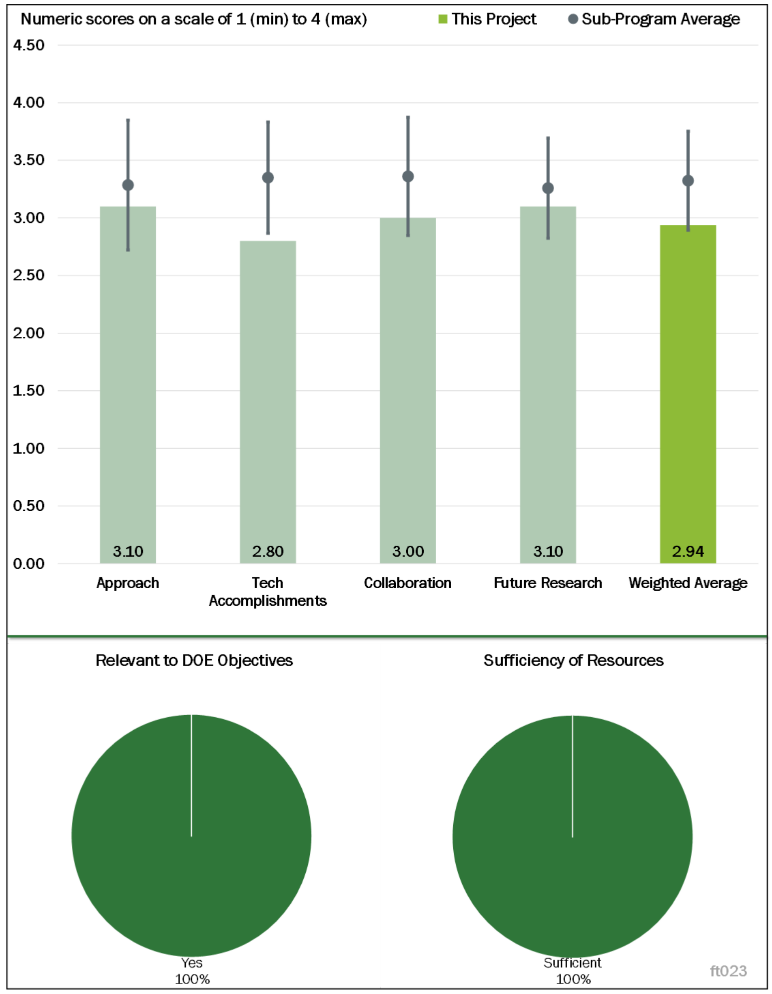

Figure 5-1 - Presentation Number: ft023 Presentation Title: Polyalkylene Glycol (PAG) Based Lubricant for Light- and Medium-Duty Axles Principal Investigator: Arup Gangopadhyay (Ford Motor Co.)

Presenter

Nikolaus Jost, Ford Motor Co.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the author had selected a quite unique approach to formulating axle lubricants by using polyalkylene glycol (PAG) base stocks.

Reviewer 2:

The reviewer stated that the approach and strategy presented appear to be adequate to provide information to meet the barriers identified.

Reviewer 3:

The reviewer commented that while the overall approach is reasonable, better planning might have obviated some of the setbacks encountered. In particular, according to this reviewer, project planning seems to have lacked a well thought out screening sequence including literature searching and screening tests for such properties as toxicity and foaming.

Reviewer 4:

The reviewer commented that the project has continued to encounter some surprises along the way, such as toxicological issues and foaming, and that although the project team has diligently addressed all the issues they have encountered, these issues have certainly hampered the progress considerably. The reviewer believes that many of these issues can be prevented by implementing a rigorous bench screening protocol, and strongly recommended inclusion of the following property evaluation as a minimum on each candidate before doing any performance testing: demulsibility; foaming and aeration tendencies; haze, additive drop out, and/or precipitation (usually requires several weeks of storage stability testing at various temperatures of interest); and regulatory issues (e.g., toxicology).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that while the project has shown the PAG family to have interesting and useful properties, progress towards the end goal has been severely hampered by unpleasant surprises, and as a result, the latest candidate formulation is essentially at the starting block.

Reviewer 2:
The reviewer said that progress is being made despite some setbacks in the testing.

Reviewer 3:
According to this reviewer, the author reported on the project's technical progress by providing details identifying all the reformulations that were carried out. The reviewer stated that the lessons learned from the data collected were well summarized. The reviewer noted that the author was forced to change the base fluid for safety and toxicology requirements, which impacted and slowed down progress.

Reviewer 4:
The reviewer commented that technical accomplishments have not been very good to date. The reviewer added that there have been several failures of some of the formulations, including significant scoring on both drive and coast side of the ring and pinion gears; a cloudiness showing evidence of a precipitate; and a base fluid change required for safety and toxicological requirements. The reviewer noted that there are now some promising wear scar test results but it still needs to be determined whether the fuel economy impacts can be delivered using the new oil formulations.

Reviewer 5:
The reviewer commented that lubricant formulations have demonstrated significant efficiency improvements and passed a number of the tests, but other properties present obstacles that may or may not preclude their ultimate use with modifications to the formulations, particularly with regard to the precipitate formation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the project lead for having put together a very good group of partners and collaborators including Dow Chemical, Argonne National Laboratory (ANL) and testing service companies to provide input and guidance to the project.

Reviewer 2:
The reviewer commented that the collaboration between Ford and ANL seems to be working well; however, it is not clear if the third partner, Dow, is as engaged as they need to be. The reviewer added that Dow needs to proactively advise the project on the chemical nature of the base fluids and their potential consequences in terms of bench properties. The reviewer stated that the team has also correctly pointed out the absence of an additive partner as a critical issue, and that this matter should be addressed urgently because an additive partner can help a lot by advising on appropriate bench testing prior to any performance testing.

Reviewer 3:
The reviewer remarked that a strong collaborative team was established, but no additive supplier was invited to join this project, and that the lack of additive technology may have impacted progress of this project.

Reviewer 4:
The reviewer said that an additive company would be a good addition. DOW may not have enough expertise to fully formulate oil.

Reviewer 5:

The reviewer found that the presentation did not make clear how active the collaborations are within the project; rather it listed "collaborators" for specific defined tasks. The reviewer noted that two of the project participants shown are clearly just (testing) service providers while a third, ANL, is also shown firstly as conducting tests, as well as providing expertise which may amount only to analysis of the test results for tribofilm and friction reduction mechanism. The reviewer commented that the main collaborator with the principal organization (Ford) is Dow Chemical, which is not accepting DOE funding and is responsible for the formulation of the lubricant packages; further, it is not clear how active its role is in planning, screening, candidate selection and formulation rather than merely being responsive.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer found that the work plan clearly outlines the issues that need to be resolved, but added that the plan should include finding an additive partner as a high priority.

Reviewer 2:

The reviewer commented that this is one of the unique projects where the authors are actually planning to explore optimization of candidate formulations. The reviewer also noted that several critical performance tests are being planned: moisture corrosion resistance; shock loading; and Ford axle wear and efficiency and vehicle fuel economy testing.

Reviewer 3:

The reviewer suggested adding some testing to show how PAG behaves if contaminated with water.

Reviewer 4:

The reviewer stated that the proposed future work appears satisfactory, but with only 4 months left in FY 2017 it is unclear if all the future work and remaining challenges can be met.

Reviewer 5:

The reviewer observed that the principal investigator (PI) expects to have the project back on schedule by this summer and has made some progress that appears to make that feasible, but it is still not clear that the planning and coordination/collaboration is adequate to prevent the recurrence of similar setbacks.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked that optimization of driveline fluids, especially axle fluids, remains one of the few areas that has not received sufficient attention from the industry, and that, therefore, the project team should be complimented for providing the much-needed attention to this area. The reviewer noted that optimization of axle fluid can offer measurable efficiency gains to support the overall DOE goals of reducing petroleum consumption.

Reviewer 2:

The reviewer found that, based on proposed project structure, this project definitely supports overall DOE objectives.

Reviewer 3:
The reviewer commented that the objective of this project, to reduce petroleum consumption by improving fuel economy and to reduce energy dependence by using non-petroleum based lubricants, definitely supports the overall DOE objective of petroleum displacement.

Reviewer 4:
The reviewer responded yes, reduction of axle friction could significantly enhance overall efficiency, and the project has goal of overall 2% fuel economy improvement, due to reduction of axle friction.

Reviewer 5:
The reviewer said that the project could save petroleum due to efficiency improvements if successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that, between Ford and ANL, the project has enough resources on the primary performance aspects of the projects; however, the project could benefit from the addition of a skilled formulation resource (potentially from an additive partner.)

Reviewer 2:
The reviewer commented that the authors do not discuss and include in their budget money contributed by DOW Chemical and ANL.

Reviewer 3:
The reviewer observed that, according to the presentation, only 12% of the DOE's funding has been spent and, with only a few months left in the project, it is not clear how the balance of the $350,000 can be used.

Reviewer 4:
The reviewer stated that the project budget of $700,000 appears reasonable for the work done. The reviewer noted, however, that no explanation is recorded for why only approximately $42,000 of the $350,000 DOE share had been used by FY 2016, with the project shown as 75% complete by the time the presentations were prepared.

Presentation Number: ft024
Presentation Title: A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement
Principal Investigator: Q. Jane Wang (Northwestern University)

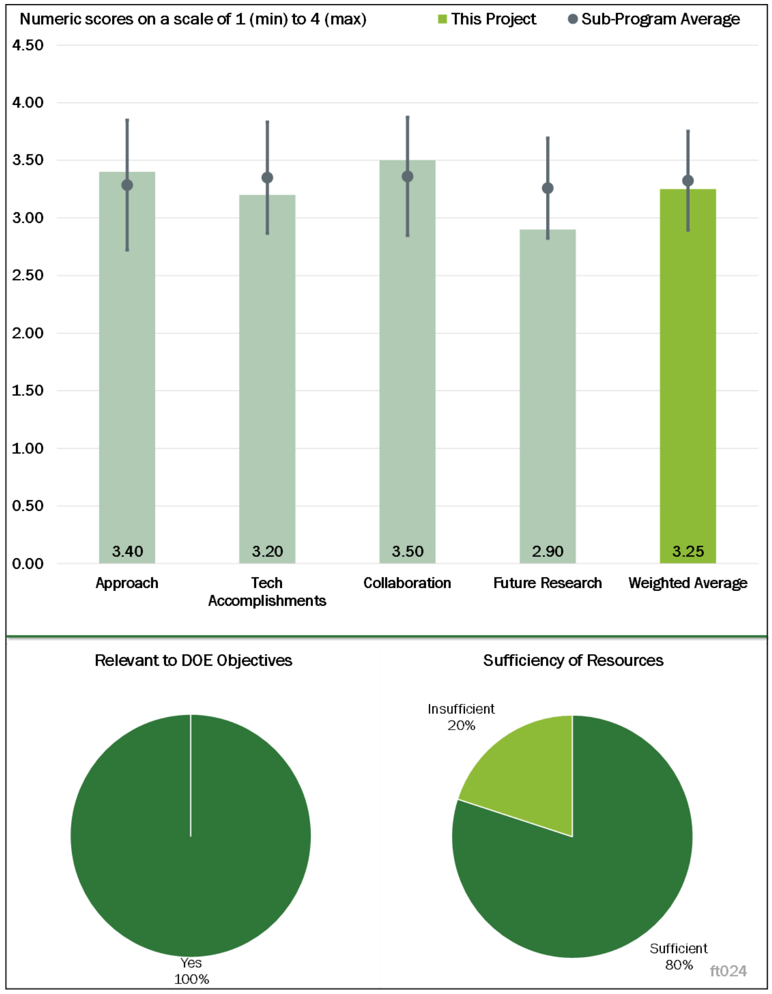

Figure 5-2 - Presentation Number: ft024 Presentation Title: A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement Principal Investigator: Q. Jane Wang (Northwestern University)

Presenter

Q. Jane Wang, Northwestern University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the authors have provided a clear and focused vision of their project, listing all potential technical barriers that must be overcome to address DOE goals.

Reviewer 2:

The reviewer noted that the approach seeks to simultaneously develop enhanced friction modifiers, wear reduction additives (nanoparticles), and shear thinning viscosity modifiers, and integrate them into formulations with each other so that all three critical properties are addressed jointly. The reviewer observed that the project uses novel approaches, particularly for the heterocyclic friction modifiers, which align on the surfaces so as to adsorb on them, thus substantially reducing asperity caused friction.

Reviewer 3:

The reviewer remarked that the overall project approach seems valid, and that the scope is targeting both hydrodynamic and boundary lubrication by using friction, viscosity and nanoparticle additives. The reviewer noted that friction modifiers will be used to reduce boundary lubrication friction, and that nanoparticles are theorized to impact both boundary and hydrodynamic, and, the reviewer speculated, mixed lubrication, as well. The reviewer recommended that careful stribeck mapping be used to understand how nanoparticles affect each lubrication regime.

Reviewer 4:

The reviewer commented that the project team has done quite a bit of bench evaluation, which shows some interesting and encouraging results for the friction modifier (FM) and viscosity modifier (VM) candidates; however, the issue is that this project is operating in a very mature industry, and as such there is an extensive array of existing technologies against which these candidates must compete. The reviewer further stated that the project team has neither the access to the large number of existing technologies, nor to the relevant formulations, nor the background in the testing required to prove out their candidates. The reviewer highly recommended that the team seek an additive company partner to conduct the requisite testing in the relevant formulation space. The reviewer added that, given the secretive nature of the additive industry, this will not be an easy task; but that nevertheless it is the only way to prove that this project is creating value.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that work to date has successfully identified candidate FMs, nanoparticles (NPs), and VMs utilizing the mechanisms discussed in Question 3, narrowed the selection field, and demonstrated the success of each in accomplishing the respective objectives, even demonstrating synergies by combining them in oil formulations. The reviewer noted that modeling toward the actual efficiency and fuel efficiency (FE) goal was not discussed.

Reviewer 2:

The reviewer said that progress is being made to a sufficient level.

Reviewer 3:

The reviewer stated that the project team has done everything that they can do to progress the project; however, they need an additive partner to conduct the testing to show that these candidates are better than the existing range of additive technologies.

Reviewer 4:

The reviewer commented that nanoparticles have shown significant wear reductions in this effort; however, further investigation should be conducted to understand the mechanisms for this enhancement. The reviewer noted that nanoparticles can act in several different fashions, depending on their functionalization, chemistry, material properties, charge, etc., and that the utmost importance would be the investigation of a tribofilm. The reviewer stated that, if generated by nanoparticles, chemistry, morphology, material properties and thickness should all be documented. The reviewer observed that, on Slide 8, PAO4 was shown to have even a lower coefficient of friction than a fully formulated 5W30 oil under the ball on flat rotational test in boundary lubrication. The reviewer commented that this seems very unlikely, as neat PAO4 under boundary lubrication is a very poor lubricant without any friction or wear modifiers to prevent steel on steel contact; however, the proposed friction modifiers show a rather large reduction from this test.

Reviewer 5:

The reviewer remarked that the researchers should be congratulated on the successful frictional/wear bench testing of novel classes of organic, metal free, boundary lubrication effective FM (i.e., alkyl cyclenes). The reviewer noted that, in their presentation, the authors did not attempt to optimize concentration of C18 cyclopropane (C18 cyc), or C12 cyc additives blended into 100% synthetic base stocks (PAO 4). The reviewer observed that all bench testing was carried out with additives present at 1% wt. concentration level, potentially missing the "sweet" performance point at lower or higher concentration levels offering superior FE and exceeding DOE set goals. The reviewer further stated that progress with di-block copolymers utilized as VMs is difficult to judge without a side by side performance comparison to standard olefin copolymer VM structures (including commercially available di-block polymers.) The reviewer inquired about the following: the uniqueness of the currently tested VM structures; whether patent literature has been checked in detail; why the intellectual property (IP) application was planned but not submitted; why only one concentration level (8% wt.) of di-block polymers was examined; whether a structure of NP was examined; whether any of these additives contain metals, and if so, what type of metals (e.g., boron); the NP size examined in bench tests and how these NPs were dispersed (dissolved) in PAO; and if boron reduces the efficiency of aftertreatment catalysts. The reviewer pointed out that no progress is reported on suppressing lubricant aeration problems, yet this goal was listed in the 2015 presentation. The reviewer questioned whether it is still going to be pursued.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that a well-balanced team of technical collaborators is contributing to this project, including a specialty chemical industry representative (Ashland), National Renewable Energy Laboratory (NREL), and an Original Equipment Manufacturer (OEM), General Motors (GM).

Reviewer 2:
The reviewer commented that Slide 22 describes the roles of the project collaborators and reflects considerable interaction between them, and that interaction between representatives during the actual presentation further confirmed this.

Reviewer 3:
The reviewer stated that the project has a good mix of auto OEM, oil formulator, national laboratory, and university partners, and that all invested parties seem to be fulfilling their respective obligations.

Reviewer 4:
The reviewer commented that there is good evidence of close cooperation between Northwestern University (NU), ANL, and Ashland. The reviewer noted that, to date, GM appears to be acting as a validator of results, but the reviewer would hope to see GM play a more direct role in the future, in terms of engine testing.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the team has documented the future tasks but has not outlined the strategies for accomplishing these tasks; for instance, it is not clear how they will develop an "optimized oil" based on these additives unless they have access to the core additive components. The reviewer further noted that one of the candidates they are considering, nanoparticles, is well-known to have stability issues in the oil, i.e., a tendency to drop out over time, and this should be included in the future work.

Reviewer 2:
The reviewer said that some testing to look at the long-term impact of shear thinning would be beneficial, especially because this is a newer molecule for friction modification.

Reviewer 3:
The reviewer commented that planned industrial tests are not defined in detail, and that, surprisingly, no engine dynamometer testing is proposed to be included as a part of proof of the performance for novel chemistries. The reviewer questioned why this was the case, and also wondered what GM's contribution to this project is, beyond assessing bench testing results.

Reviewer 4:
The reviewer noted that the project is due to be completed within 3 months from the AMR meetings, and that the slides as prepared earlier show 80% completion with a few remaining knowledge gaps to be filled in, i.e., more severe testing, final optimal formulations to be chosen, as well as some additional variations of the FM concept to be tested.

Reviewer 5:
The reviewer observed that the project will address the huge barrier of synthesizing novel fully formulated lubricants, and indicated that interest from an oil formulation company should help determine commercial viability. The reviewer stated that the project is lacking some of the fundamental work to understand the mechanisms behind the performance enhancements of the novel additives, and suggested the addition of more thorough posttest analytics.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that, based on a well-planned project structure, this project definitely supports overall DOE objectives.

Reviewer 2:
The reviewer commented that the project is attempting to improve fuel efficiency through lubricant redesign, which aligns well with the DOE objective.

Reviewer 3:
The reviewer observed that friction reduction aims at 2% efficiency improvement, which translated to increased fuel economy.

Reviewer 4:
The reviewer said that it should save petroleum in both new vehicles and legacy vehicles due to efficiency improvements if successful.

Reviewer 5:
The reviewer commented that targeting all lubrication regimes is a good approach to achieve the overall DOE objective, and that the technical approach seems feasible in achieving this goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project appears on track for successful completion, with all DOE funding having already been received by the participants.

Reviewer 2:
The reviewer observed that the project is nearing completion and has been running on schedule and budget without delays.

Reviewer 3:
The reviewer stated that the project needs an additive supplier partnership to conduct real-world testing on the additive chemistries developed by the team.

Reviewer 4:
The reviewer commented that the budget expenses were not clearly described, e.g. amount of money spent in 2016 or 2017.

Presentation Number: ft025
Presentation Title: Improved Fuel Economy through Formulation Design and Modeling
Principal Investigator: Gefei Wu (Valvoline)

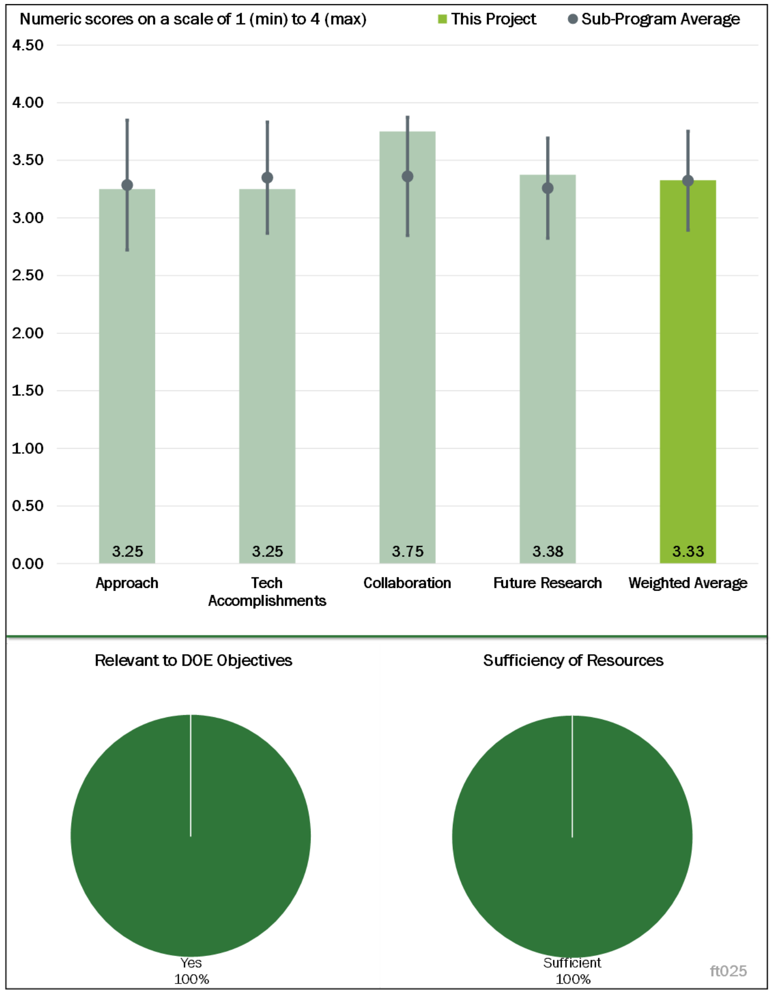

Figure 5-3 – Presentation Number: ft025 Presentation Title: Improved Fuel Economy through Formulation Design and Modeling Principal Investigator: Gefei Wu (Valvoline)

Presenter
Gefei Wu, Valvoline

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked that it is a unique program proposing to examine FE in heavy-duty (HD) transport vehicles. The reviewer noted that the program is planning to address a holistic approach by testing three types of fluids: engine oil performance in an ISL 8.9L FE verification engine; axle oil efficiency; and transmission fluid in Society of Automotive Engineers (SAE) #2 test.

Reviewer 2:
The reviewer commented that the project seeks to develop fuel savings through a new engine and axle lubricant, with at least a 2% overall improvement and a 2,000-hour durability test in a medium-duty diesel engine. The reviewer remarked that these targets are rather modest, and appear to be directed at short term, real world development rather than at a totally new discovery.

Reviewer 3:
The reviewer praised the project, from bench tests all the way to field testing.

Reviewer 4:
The reviewer observed that the project started with the formulation of candidate engine and axle oils for evaluation, then joined a modeling effort with full engine testing for fuel economy validation. The reviewer commented that this approach is a very conventional and effective way to demonstrate potential fuel-efficient products.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the technical target has not been fully reached, and noted that overall testing has been delayed due to discrepancies between Valvoline proprietary modeling and actual results obtained from dynamometer testing. The reviewer stated that the project summary does not provide the expected fundamental knowledge to the technical community, because the contributors do not share critical information regarding changes made in their formulation approaches of any new candidate fluids tested, i.e., engine oils, transmission fluids or axle fluids. The reviewer indicated that using the labels Oil 1, Oil 2, and so on is not sufficient. The reviewer further commented that no baseline fluids description or kinematic viscosity data were listed for any engine, axle, or transmission tests performed, and that no information was given regarding how in-house Valvoline models used to predict FE performance were developed. The reviewer indicated that the authors quote the IP document filed (14548850), claiming advantages of silicone oil as a part of engine oil formulation, but questions whether this approach was used to formulate currently assessed candidate fluids. The reviewer noted that silicone may severely impact durability and performance of aftertreatment catalysts, and stated that it is not clear that testing of exhaust catalyst exposure to silicone containing oils was carried out or is planned in the future.

Reviewer 2:

The reviewer commented that the program did not meet the fuel savings target with the first round of lubricants, and Valvoline reformulated and retested at their own expense, which shows real commitment. The reviewer noted that the authors are evaluating against a 15W-40 oil as a baseline and switching to 5W-30 and 5W-20, and that gear oil remains at 75W-90, but with improved additives. The reviewer remarked that a 2% improvement goal seems to be readily reachable, but the durability requirement may be very challenging in a diesel engine.

Reviewer 3:

The reviewer remarked that it is good to see multiple reformulations in response to test results, and noted that the project achieved the 2% goal on dynamometer tests. The reviewer observed that there were weather delays on J1321 testing, but the project is still moving forward.

Reviewer 4:

The reviewer observed that the technical accomplishments seem to be running on schedule, but the results are somewhat mixed. The reviewer commented that modeling seemed to over-predict the actual fuel economy gains demonstrated in engine tests. According to the reviewer, the speaker noted that zinc in zinc dialkyldithiophosphate poisoned the catalyst, where it is actually the phosphorous content. The reviewer believes this was just a misspoken statement, as the speaker is very knowledgeable in the field. This reviewer would like to know more details on the selection of the baseline engine and axle oils, and whether they were FE approved oils. The reviewer noted that, on Slide 7, there was a recalculation of fuel economy based on carry-over effect, and cautioned that the speaker should be careful when doing this to carefully quantify the hysteresis before recalculation. This reviewer observed a test progression as follows to track carry-over: baseline to candidate oil to baseline to candidate oil. The reviewer further remarked that the additional candidate oil test at the end would require additional funding, but may be important to establish a trend.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer complimented the project for its excellent collaboration with major commercial entities in the heavy-duty mobility sector.

Reviewer 2:
The reviewer remarked that Valvoline had a tight collaboration with Cummins and NREL that provided test hardware components and fuel economy testing performed in this project, and noted that the group also subcontracted J1321 testing, which will be finished shortly. The reviewer noted that Valvoline also has great connections with additive manufacturers needed to formulate fuel efficient candidate oils.

The reviewer noted that contributors include Valvoline (as lead), NREL, Transportation Research Center, and additive suppliers (i.e., Afton, Ovonic, Infimum, and Lubrizol).

Reviewer 3:
The reviewer commented that the program team includes Cummins as the engine supplier, 4 additive companies to support oil formulation, and NREL for 2,000-hour durability tests, and indicated that it seems like a very comprehensive team. The reviewer was unable to get a sense of how much new, research technology was being used in the oils, however, and how much was just re-formulation of commercially available additives and base oils.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that future research follows the project plan and is appropriate for completing this project.

Reviewer 2:
The reviewer suggested that the project might be able to minimize delays in SAE J1321 testing by working with multiple partners from different locations.

Reviewer 3:
The reviewer noted that, due to missing expected performance levels, additional testing on reformulated engine oil fluids will be carried out and Valvoline will cover all expenses. The reviewer commented that no clear definition of proposed vehicle testing is given, however, and questioned what baseline fluids will be used to establish expected improvements in FE.

Reviewer 4:
The reviewer commented that the project is nearing its conclusion and fuel economy gains have been demonstrated, a comparative fuel economy test will be conducted before the end of the project, and engine durability testing will be done as well. Additionally, the reviewer noted that further durability and tear down testing will be completed next year to quantify fuel economy retention. The reviewer remarked that it would have been better to have some of this durability testing mixed in with the fuel economy testing, considering the candidate oils are low-viscosity lubricants which could lead to wear issues, but the proposed durability testing seems to be comprehensive.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the work being performed by an oil formulator is a good approach to keep the fuel-efficient candidates within the realm of commercial possibilities, and thus, this project has a high potential to deliver commercially viable, fuel efficient engine and axle lubricants.

The reviewer stated that, based on reported project structure, this project definitely supports overall DOE objectives.

Reviewer 2:
The reviewer commented that the goal of achieving real world fuel economy improvements through the introduction of drop-in lubricants with demonstrated durability is very relevant to DOE's mission of reducing petroleum consumption, although the targeted gain is rather modest and may not provide sufficient incentive for commercially developing the oil as a drop-in. However, according to the reviewer, the research could also support the development of future engines, through identification of potential problem areas, and could support the development of future lubricants, through the identification of friction and wear reducing additives and additive blends.

Reviewer 3:
The reviewer noted that the project demonstrated a 2% reduction in multiple phases of testing.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that resources seem sufficient to complete the project as long as funding is maintained and as long as Valvoline is willing to re-do portions of the research at their expense if performance targets are not met.

Reviewer 2:
The reviewer stated that there is a good balance with the PI's company's funding level.

Reviewer 3:
The reviewer observed that this project has been running on schedule and budget for multiple years, and can be expected to continue this performance until project conclusion.

Reviewer 4:
The reviewer noted that, with current and possible future delays, no clear definition of future costs is given.

Presentation Number: ft037
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Overview
Principal Investigator: John Farrell (National Renewable Energy Laboratory)

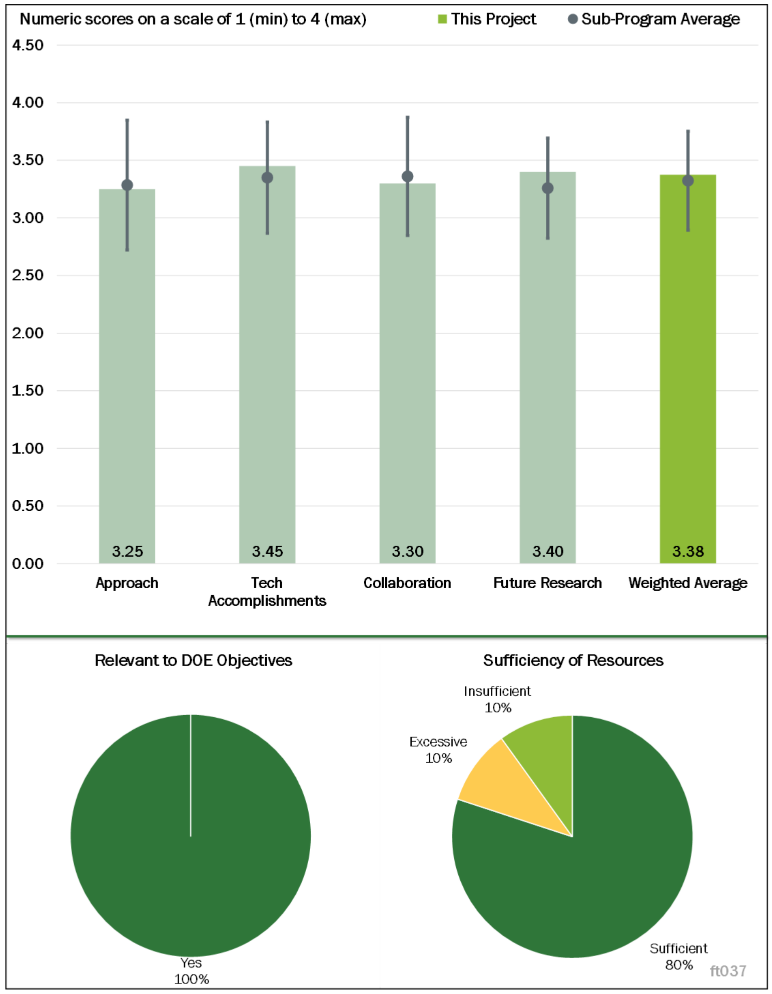

Figure 5-4 - Presentation Number: ft037 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Overview Principal Investigator: John Farrell (National Renewable Energy Laboratory)

Presenter
John Farrell National Renewable Energy Laboratory

Reviewer Sample Size
A total of 10 reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that the approach was excellent.

Reviewer 2:
The reviewer stated that the overall approach of the Co-Optima program, which is focused on fuel properties that optimize engine performance and allow the market to define the best means to blend and provide the fuels, is very good and should help to address DOE barriers and meet the goals of the VTO.

Reviewer 3:
According to the reviewer, conceptually, the approach of developing fundamental information on fuel property effects on efficiency, performance, and emissions of a variety of engine combustion platforms is excellent, and that information will be very valuable input to industry for their individual market decisions for the future. The reviewer also commented that the ongoing sharing of results with, and obtaining input from, a wide range of stakeholders is noteworthy, although industry could benefit from more detailed discussion of results in a timely manner. The reviewer voiced concern that, although the basic premise of Co-Optima was the co-optimization of fuels and engines, full-time kinetically-controlled advanced combustion light-duty has disappeared from the slides and appears to have been replaced by "multi-mode spark ignition/advanced compression ignition (SI/ACI)." The reviewer commented that, if this observation is true, the potential benefits of full-time ACI operation would be mitigated/lessened by reverting to SI and likely the fuel choice would be driven by SI requirements, so contrary to the stated overarching goal of Co-Optima, it would not truly be co-optimizing engine design and fuel properties. The reviewer added that, if this decision has been made, rather than inadvertently left off the slide, it is unclear what the basis was, i.e., was this driven by technical results, input from specific stakeholders, or other factors? The reviewer noted that the Merit Function is discussed throughout all of the presentations, suggesting that it will play a key role in the selection of candidate components; it is critical that the SI Merit Function be validated in multi-cylinder SI engines that are

representative of those that are likely to be introduced into the market in the near future. Further, the reviewer stated that the Merit Function has been portrayed as only relating to SI engine efficiency, a key, but not the sole, technical criteria for assessing candidates. The reviewer suggested that other performance aspects, such as emissions, including toxics, need to be assessed, as well as other aspects such as production viability, infrastructure compatibility and costs to stakeholders. The reviewer contended that because these are intended to be fundamental studies and measurements, they should also include more hydrocarbons, rather than just oxygenates, to make the learnings more robust.

Reviewer 4:

The reviewer commented that the scope of this project is very aggressive and sets out to provide strong tools to the industry to optimize systems for improvements in fuel consumption. Further, the reviewer commented that the goals of the program are very strong and address an industry need. The reviewer was impressed by the project's very unique approach, by the central fuel hypothesis and the approach to identifying the key properties, rather than specific blends that can be used to optimize performance. The reviewer voiced skepticism that the approach would work, but indicated that the initial results seem to be supporting that it is heading in a good direction. The one barrier that the reviewer indicated was not clear is how to address the fuel effects on emission control systems, as mentioned on Slide 4. In the reviewer's opinion, the propensity to form particulates and create hydrocarbon species in the exhaust that aftertreatment systems are capable of reducing, and the impact of exhaust temperature, are important factors that may allow for emissions control optimization; otherwise the optimized engine system may need to be operated in a less efficient manner to meet emissions control requirements. The reviewer noted that there was no emphasis on the durability impacts of the fuels on the engine system, for example, their wear characteristics for injectors and ring packs, which again lead to the combined system efficiency.

Reviewer 5:

The reviewer commented that the overall plan for Co-Optima is sound, well-conceived, and is being executed well, from a research standpoint, although it may not be fair to make this observation only on this presentation. The reviewer wondered about the "big picture" issue of engine manufacturers and fuel providers, adding that if the objective is to move toward a description of fuel properties that are optimal for efficiency and/or fuel economy, it seems likely that the engines using these fuels will need to be designed and operated in a somewhat uniform way. The reviewer questioned whether engine manufacturers would get on board with this, as typically they want to have their own proprietary designs and features, and may not want to conform to the idea of a common design.

Reviewer 6:

The reviewer noted that the presentation is an overview rather than an actual project, so it is difficult to comment, but added that Co-Optima overall seems well designed, particularly with the revised decision point approach to Thrust I. The reviewer cautioned that an important concern is that the results of Thrust I will become available just as automakers have completed the phase in of corporate average fuel economy (CAFE) standards to 2025, so that the major efficiency improvements contemplated for a period of 15 years will have already been accomplished.

Reviewer 7:

The reviewer commented that fuel-engine co-optimization provides the potential of achieving additional engine efficiency by up to 15%, and that the project is well-designed, feasible, and integrated with other efforts. The reviewer wondered why this project considers renewable fuels only, and explained that blendstock for oxygenated blending (BOB), which will consist of at least 70% of the future fuels, should also be included in the Co-Optima program.

Reviewer 8:

The reviewer commented that, in view of the reduced level of funding going forward, a reasonable approach has been undertaken to adjust the Co-Optima program's goals and research priorities. The reviewer added that, unlike 2016, it is encouraging to see that in addition to defining goals, metrics have been specified to assess the success/completion of the project. The reviewer stated that, while the overall approach is reasonable, the fuel economy targets currently specified appear to be too optimistic. The reviewer elaborated, saying that the work being conducted under the Co-Optima program has a lot of value, and in order to avoid the pitfall of being gauged against extremely ambitious targets, the fuel economy targets should be revisited and revised to more reasonable numbers. The reviewer stated that, at present, it is somewhat unclear how the merit function and the Co-Optimizer will be used to drive or facilitate change in market fuel and consequently realize the opportunities identified as benefits of the Co-Optima program, and that providing a clear vision of the use of the Co-Optimizer would help further establish the value of the Co-Optima program.

Reviewer 9:
The reviewer commented that, if the Governing Hypothesis is used as a surrogate for the approach, it assumes that higher engine efficiency is needed for some of the advanced combustion regimes. The reviewer questioned whether really impressive efficiencies had not already been demonstrated for several advanced combustion regimes with market fuels. The reviewer suggested that the barriers to those concepts were limited operating range, transient control, cold operation, combustion noise, high hydrocarbon (HC) and carbon monoxide (CO) emission, cold exhaust temperature, mode switching, complexity, cost, and other factors. The reviewer stated that from this overview presentation one does not get the impression that Co-Optima will focus on these barriers, but instead will continue to pursue high engine efficiencies, primarily while expanding operating range. The reviewer observed that having a single-issue program will probably not prove to be successful, and questioned whether there will be more effort devoted to removing these other barriers in the detailed presentations to follow. The reviewer stated that vehicle fuel economy is a complex function of vehicle characteristics, engine speed-load characteristics, and drive cycle, and questioned how the fuel economy goals presented in Slides 2 and 3 were arrived at, and what assumptions were made. The reviewer noted that the x-axis on the figure in Slide 3 is taken as the time a lab demonstration is targeted to be made, and questioned whether the Lab demo will include all the barriers mentioned above, or whether it will just focus on increased fuel efficiency. The reviewer suggested that the challenge presented in bullet #1 on Slide 24 is really the primary challenge for Co-Optima, and questioned how Co-Optima proposes to address it; without that, the reviewer questioned whether having a timeline like in Slide 3 has any meaning.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the group has done a lot of excellent work in a very short timeline, and they should be commended for their efforts.

Reviewer 2:
The reviewer stated that the project made significant progress.

Reviewer 3:
The reviewer said that great progress is being made.

Reviewer 4:
The reviewer commented that there has been some significant progress to date, but the extent of the collaborations is such that it will take a significant effort to manage, between gathering inputs, prioritizing all of the inputs, and the logistics of working with such a cross-functional group. The reviewer stated that there has already been excellent work in making this working group function and setting a strong path forward. The reviewer noted that the progress to date on the merit function for SI engines, data gathered to validate the central fuel hypothesis, and initial stages of the Co-Optimizer tool has been excellent.

Reviewer 5:

The reviewer noted that this program is large, highly collaborative, and has a lot of moving parts, which requires a great deal of coordination. According to the reviewer, the program must overcome a lot of inertia to get going, but it seems that this is starting to happen now.

Reviewer 6:

The reviewer noted good progress in Tier 1 and Tier 2 screening and down-selection of fuel component candidates for Thrust I. The reviewer commented that the statement is made about accomplishments in the ASSERT and Market Transformation, but those detailed results have yet to be shared externally, and the authors need to get that information out. The reviewer stated that the authors need to conduct testing in multi-cylinder engines representative of the range of GDI technology that will be in the market place in the near future, to validate that the theoretical, calculated Merit Function is applicable.

Reviewer 7:

The reviewer stated that in 2016-2017, multiple projects under Co-Optima made substantial progress. In particular, according to the reviewer, the progress made in the following areas was very encouraging: refinement of the Merit Function for Boosted SI engines; nonlinear blending of fuel properties and down-selection of promising fuel components; simulation toolkit; and spray characterization and particulate emission studies.

Reviewer 8:

The reviewer commented that this question is best directed toward the component parts of the overall Co-Optima program, rather than the overview, but noted that some significant improvements have been made at the overall program level, such as considering potential synergies between Thrust I and 2, by using similar fuels for boosted SI and gasoline compression ignition. The reviewer noted that testing of the central fuel and engine hypotheses has progressed, merit functions have been refined and high-level fuel screenings and tier 2 selections have been completed.

Reviewer 9:

The reviewer observed that the overview of the co-optimization project identified ten major accomplishments which will help move the overall project towards helping to address the barriers identified in the presentation.

Reviewer 10:

The reviewer opined that the progress made on the Merit function is good, and the engine test programs at Oak Ridge National Laboratory (ORNL) and NREL that address boosted SI engines are making reasonable progress; however, the overall Co-Optima program is making slow progress towards DOE goals.

The reviewer questioned how the Co-optimizer is envisioned to work, and whether, as a result of various stakeholders exercising it, there will be various fuels then in the market place, all having roughly the same Merit function score but different fuel properties and molecules. The reviewer questioned whether that will work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the scope of collaboration for this project is very impressive, and that it appears to have an excellent representation of critical industry partners. The reviewer noted that the project takes advantage of the strengths of various national laboratories and universities, and the Advisory Board has some very strong industry experts that are ensuring good technical direction. The reviewer further noted that the number of partners also ensures that there are not strong biases or technical interests that influence the conclusions.

Reviewer 2:
The reviewer commented that overall this program is highly collaborative and involves many sub-projects, institutions, people and capabilities.

Reviewer 3:
The reviewer praised the collaboration and coordination in the overall co-optimization project as being excellent, and noted that the effort includes an industry led advisory group, as well as collaboration with multiple DOE laboratories, and several academic institutions, which will help to continue to focus the effort to successfully address the barriers.

Reviewer 4:
The reviewer stated that the overview includes collaboration with a multiplicity of DOE laboratories and other research institutions, as well as other stakeholders.

Reviewer 5:
The reviewer commented on the excellent collaborations among national laboratories, universities, and industries, and noted that the partners are full participants and well-coordinated.

Reviewer 6:
The reviewer commented that increased collaboration between the participating national laboratories has been one of the strengths of the Co-Optima program. In addition, the reviewer found that a concerted effort has been made to schedule and update stakeholders with periodic updates. The reviewer found that the Stakeholder Listening Day in January 2017 helped foster further interaction between the Co-Optima team and pertinent stakeholders including OEMs, the energy industry, and regulatory agencies such as the U.S. Environmental Protection Agency and California Air Resources Board. The reviewer encourages further involvement of the retail and infrastructure stakeholders.

Reviewer 7:
The reviewer found that the collaboration between all the labs and universities is very good.

Reviewer 8:
The reviewer noted that collaboration is predominantly within the national laboratory community, and it looks like there is much better coordination of the R&D activities within the national laboratories. The reviewer stated that various mechanisms and forums have been held to get input from various external stakeholders, which is very valuable, but probably should not be characterized as “collaboration.” The reviewer commented that dissemination of detailed technical information on a timely basis is needed for stakeholders to truly understand and assess the results, and noted that the monthly teleconferences are ok, but topics are rotated and do not permit extensive presentation or discussion of results. The reviewer said that there is frequent mention of reports that are being drafted, but those never seem to be released.

Reviewer 9:
The reviewer commented that working more closely with energy companies and refining stakeholders would enable the team to look for more value-added pathways. For instance, some of the fuels being looked at could be co-produced in the refinery and be a win-win for the auto and oil companies.

Reviewer 10:
The reviewer noted that Co-Optima’s collaboration between labs is excellent, but that there is a lack of university input and little to no industry input into their programs except after the fact.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the R&D work makes sense; however, it seems that important decisions and recommendations will be based on merit function calculations, so it will be very important to determine under which conditions and which boosted SI engine platforms the merit function is valid, and that appears to be missing in the plans. The reviewer suggested that the inclusion of hydrocarbon candidates (even those that are petroleum-derived, but not necessarily viable for biologic production processes) in the studies would greatly increase the robustness of the fundamental R&D.

Reviewer 2:
The reviewer found that the path forward for the project is well defined and has a strong approach, but had reservations regarding whether the aftertreatment and emissions control impacts, based upon fuel properties, are being sufficiently addressed in the merit functions and tools.

Reviewer 3:
The reviewer observed that the proposed future research in the Co-Optima program, including completing the merit function development and initiating a more focused ACI research approach for medium and heavy-duty applications, will continue to move the project towards a successful completion.

Reviewer 4:
The reviewer commented that future research is outlined in the presentation and is logical and well thought out.

Reviewer 5:
The reviewer found that the future work is very well planned in a logical manner, by incorporating appropriate decision points.

Reviewer 6:
The reviewer noted that the proposed future research is in line with the Co-Optima program's goal to help develop advanced compression ignition combustion concepts that are targeted at providing high efficiency and low emissions solutions for both light and heavy-duty applications. The reviewer stated that, as the outputs of the Co-Optima program are supposed to be low technology readiness level (TRL) technologies, barriers to proposed technology and alternate pathways are not relevant.

Reviewer 7:
The reviewer questioned when the fuel property values (research octane number [RON], sensitivity, HoV, flame speed, etc.), or range of values, for the eight candidate fuels to achieve a Merit function score greater than E10 Premium will be published. The reviewer recommended that a majority of the project's resources be spent on the first two bullets on Slide 26 for the light-duty gasoline fleet, and noted that even though the efficiency gains are only modest, the implementation risks are low, while the consumer benefits are very large, due to the sales volume. The reviewer commented that, on the other hand, a majority of resources can be spent on bullet #3 on Slide 26, with the understanding that risks are very high while benefits are also high. The reviewer questioned whether both approaches can be pursued in the future, given the budget and resource constraints.

Reviewer 8:
The reviewer remarked that some additional work on the formation (quantity and morphology) of particulate matter with the different fuels would be beneficial.

Reviewer 9:
The reviewer found that, other than the overall plan, future research was not laid out.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that yes, this project supports the overall DOE objectives of petroleum displacement, and noted that the project is very well designed to improve engine efficiency and better use of renewable fuels.

Reviewer 2:
The reviewer commented that this project has a high probability of success in identifying opportunities for fuel consumption improvements of engine systems, because it is taking a total system optimization approach to determining how to optimize the fuels and engine systems in order to recognize fuel economy gains. The reviewer noted that the Co-Optimizer tool will be valuable to the industry, for improving powertrain efficiencies.

Reviewer 3:
The reviewer found that the work performed in the Co-optimization of fuels and engines is definitely supportive of the DOE objective of petroleum displacement. The reviewer noted that the projects include increasing fuel economy in both light-duty and heavy-duty applications as well as research to help diversify the fuels resource base.

Reviewer 4:
The reviewer indicated that the improvement of existing engine combustion technologies, identification of desirable fuel properties, and development of new biofuels are all expected to contribute to DOE's goal of petroleum displacement.

Reviewer 5:
The reviewer found that improvement of engine efficiency and incorporation of bio-components in fuel blends support DOE's objectives.

Reviewer 6:
The reviewer noted that the project aims at maximizing efficiency of fuel and engine technology, which would greatly increase fuel economy.

Reviewer 7:
The reviewer noted that the project's end goals are to displace petroleum consumption by 30%.

Reviewer 8:
The reviewer concluded that yes, the project does support the overall DOE objectives of petroleum displacement.

Reviewer 9:
The reviewer said that the project should save petroleum in new vehicles due to efficiency improvements and biofuels if successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that there are sufficient resources for the project to achieve the stated milestones in a timely fashion.

The reviewer noted that this project has a very large scope and requires a large number of resources, which are necessary to meet the stated goals, and added that the project has a high potential for success at the projected resource levels.

Reviewer 2:

The reviewer stated that overall resources for the co-optimization project appear to be adequate.

Reviewer 3:

The reviewer commented that project resources appear adequate at this time for this level of planning, but may need to be extended or otherwise adjusted as the project progresses.

Reviewer 4:

The reviewer found that resources are sufficient for now, but wondered what the impact of likely budget cuts will be, i.e., will the cut be spread out and affect all of the projects, or will there be certain projects or aspects of projects that are dropped entirely?

Reviewer 5:

The reviewer commented that resources appear to have been sufficient up to this point; however, budget cuts seem imminent for 2018, and that would affect program progress.

Reviewer 6:

The reviewer stated that it is not possible for the project to achieve the stated goals with the resources allocated under the 2017-2018 budget proposal, and noted that additional resources are required to support the ongoing work, in particular for the near term boosted SI engine technology. The reviewer noted that, while the improvement of the boosted SI engine technology may only lead to modest gains in engine efficiency, due to the sheer size of the vehicle fleet that employs such engines, the potential gains for society in terms of lower fuel consumption and cost savings are substantial.

Presentation Number: ft047
Presentation Title: Advanced Lubricant Technology—Surface and Lubricant Interactions
Principal Investigator: Oyelayo Ajayi (Argonne National Laboratory)

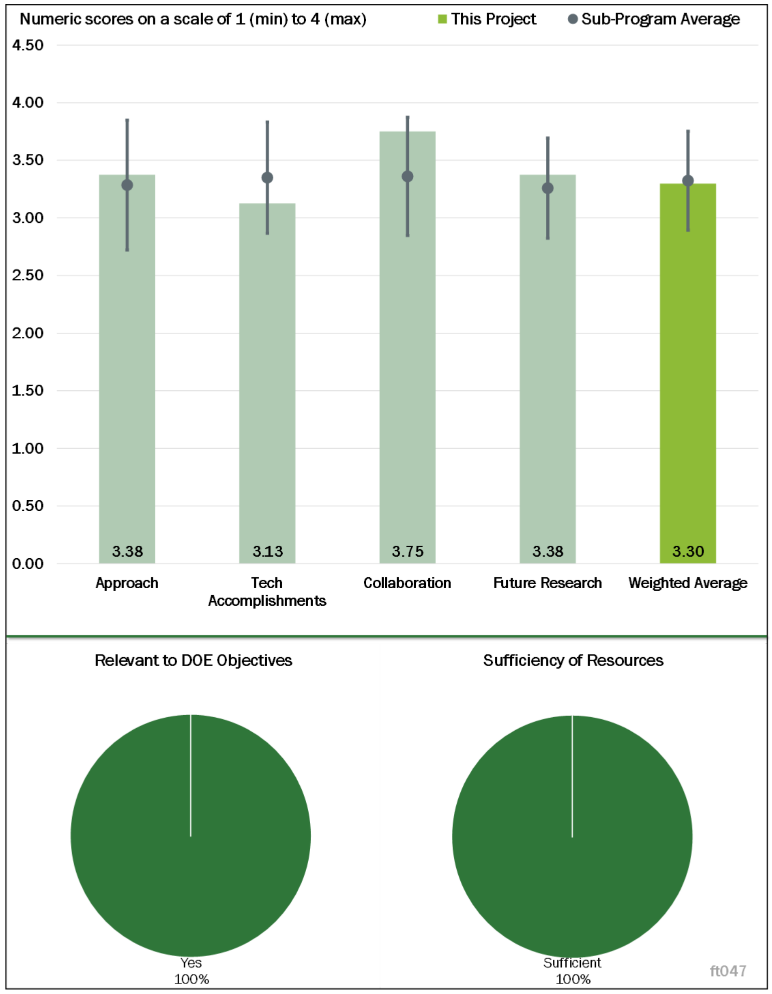

Figure 5-5 - Presentation Number: ft047 Presentation Title: Advanced Lubricant Technology—Surface and Lubricant Interactions Principal Investigator: Oyelayo Ajayi (Argonne National Laboratory)

Presenter

Oyelayo Ajayi, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that this sub-project is focused on developing rapid methods capable of predicting the impact of friction reduction technologies on engine related fuel economy and wear. The reviewer commented that the methods of prediction will be both empirically and analytically based and will require a lot of coordination between various labs and contributors, due to the complexity of the overall list of proposed tasks.

Reviewer 2:

The reviewer stated that the project seeks to study surface and lube interactions through test methodology; film characterization; and models for wear and scuffing, nonferrous materials, and effect of soot. The reviewer commented that the baseline is 5W30 GF5, but it was unclear if this was FM or non-FM oil. The reviewer further remarked that the project does not verify results in vehicle or engine tests, so targets need to be very clear, but they were not.

Reviewer 3:

The reviewer found that, overall, this is a very well-developed project, with many moving parts and different technologies that have the potential for overlap and optimization. The reviewer remarked that one area that needs to be further developed is the characterization of tribochemical films. The reviewer noted that Slide 10 shows the use of energy-dispersive X-ray spectroscopy (EDAX) to quantify chemical properties of films, but, according to the reviewer, this method is far from optimal to understand the film. The reviewer went on to say that, typically, EDAX is used as a qualitative quick test to demonstrate evidence, and then methods such as X-ray photoelectron spectroscopy are used to quantify chemical percentages as a function of tribofilm depth. The reviewer praised the use of X-ray diffraction to determine crystallinity, or lack thereof, and indicated that nano indentation and nanoscratch testing should be done carefully as well, although a conventional nano indenter can have a hard time quantifying thin tribofilms even at the nanoscale. This reviewer suggested cross sectioning the tribofilms and indenting various positions of the tribofilm to develop a relationship of tribofilm hardness as a function of depth, claiming that this approach would eliminate the potential effects of substrate material.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked good progress to date.

Reviewer 2:
The reviewer expressed surprise that a summary slide describing proposed variables to be included as a part of a rapid bench testing protocol was not presented. The reviewer indicated that testing parameters used as an optimized approach to examining the most severe conditions for frictional contacts and wear contacts in IC engines cover many ranges, and need to be wisely selected. The reviewer elaborated, saying it would be important to contrast two protocols mimicking DI diesel versus GDI engine conditions. The reviewer noted that results collected for five commercial application programming interface (API) GF5 fluids did use standard bench testing conditions, and indicated that it would be of great value to the technical community if ANL has developed a unique rapid performance testing protocol. The reviewer asked what the repeatability or reproducibility of coefficient of friction data reported were, and suggested that the authors include SD bars on all the experimental data graphs in the future. The reviewer noted that compatibility testing of AW additives with a non-ferrous alloy included only two types: Bronze alloy 600 and A380 Al alloy, and questioned why these specific alloys were selected, and why no were presented for copper (Cu) and lead. The reviewer further questioned whether these are the most commonly used overlays for bearings; how stable the suspension of selected carbon black CB (R250R) in a base oil was; and whether CB (R250R) resembles GDI soot or diesel soot from the perspective of particle size distribution and surface chemistry.

Reviewer 3:
The reviewer commented that it looks like the project team has a good start on test methods and surface analysis and need to begin tying things together. The reviewer added that baselines and targets need to be better established.

Reviewer 4:
The reviewer praised the great progress thus far, even though it is early in the project, and noted that every task seems to be well developed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said excellent collaboration among the multiple labs. This should continue and be a model for other work.

Reviewer 2:
The reviewer commented that a well-balanced team of technical collaborators is contributing to this project: specialty chemical industry representatives, national laboratories, and OEMs. The reviewer added that this sub-project will require a lot of coordination between various laboratories/contributors due to the complexity of the overall list of tasks proposed.

Reviewer 3:
The reviewer stated that there was very good collaboration with industry for used oils, additives, and used engine parts, and that the program is a multiple lab partnership, with each lab working on its specialties. The

reviewer criticized the lack of a grand vision for the overall project, which consisted of the individual labs continuing what they had done previously.

Reviewer 4:
The reviewer complimented the project as an excellent example of multiple organizations working well with each other; however, the reviewer added, there seems to be some uncertainty regarding what exactly the overall project goal is and how to obtain it.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the results from future plans can provide significant understanding of the role of lubricant components in reducing friction and protecting hardware, although some of the tasks may be too challenging to provide expected answers within the planned time frame.

Reviewer 2:
The reviewer found that there was a good plan for moving forward. The reviewer indicated that several items need to be further developed, but added that it seems this work will be done as the project proceeds, although the information was not conveyed in the presentation. The reviewer observed that below the tribofilm, there was a plastic deformation, and the tribofilm was sputtered away, but no subsurface analysis was proposed. The reviewer suggested the use of a Focus Ion Beam Scanning Electron Microscope (FIB-SEM) to look deeper, until pristine substrate is reached, as there could be severe subsurface damage, grain deformation or cracks that should be quantified.

Reviewer 3:
The reviewer said please add more extreme temperatures to the testing protocol to better represent real world conditions.

Reviewer 4:
The reviewer stated that the goals seem unclear, e.g., 2% or 4% fuel economy improvement, 25% or 40-50% total engine friction reduction, and expressed surprise that the project team could not project what viscosity oil would be needed to achieve this. The reviewer commented that, overall, the project seems to have a shotgun approach, which may be appropriate, but needs to be very carefully managed to meet deliverables and targets.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that, based on the proposed structure of detailed tasks, this project definitely supports overall DOE objectives.

Reviewer 2:
The reviewer found that improving fuel consumption and reducing engine friction losses support the DOE goal of petroleum displacement.

Reviewer 3:
The reviewer stated that this ground-up approach has the potential to yield the DOE set project metrics.

Reviewer 4:
The reviewer commented that it should save petroleum in both new vehicles and legacy vehicles due to efficiency improvements if successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that all proposed resources are needed to make this project successful.

Reviewer 2:
The reviewer stated that, although it is early on in the project, the resources seem to be allocated properly and the project is progressing on schedule.

Reviewer 3:
The reviewer commented that, at planned funding levels, resources would be sufficient; however, if funding is reduced, the project will have to be re-planned to provide the most relevant results on a timely basis.

Presentation Number: ft048
Presentation Title: Advanced Lubricant Technology—Technology Innovation, Design, and Synthesis
Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

Presenter

Lelia Cosimbescu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

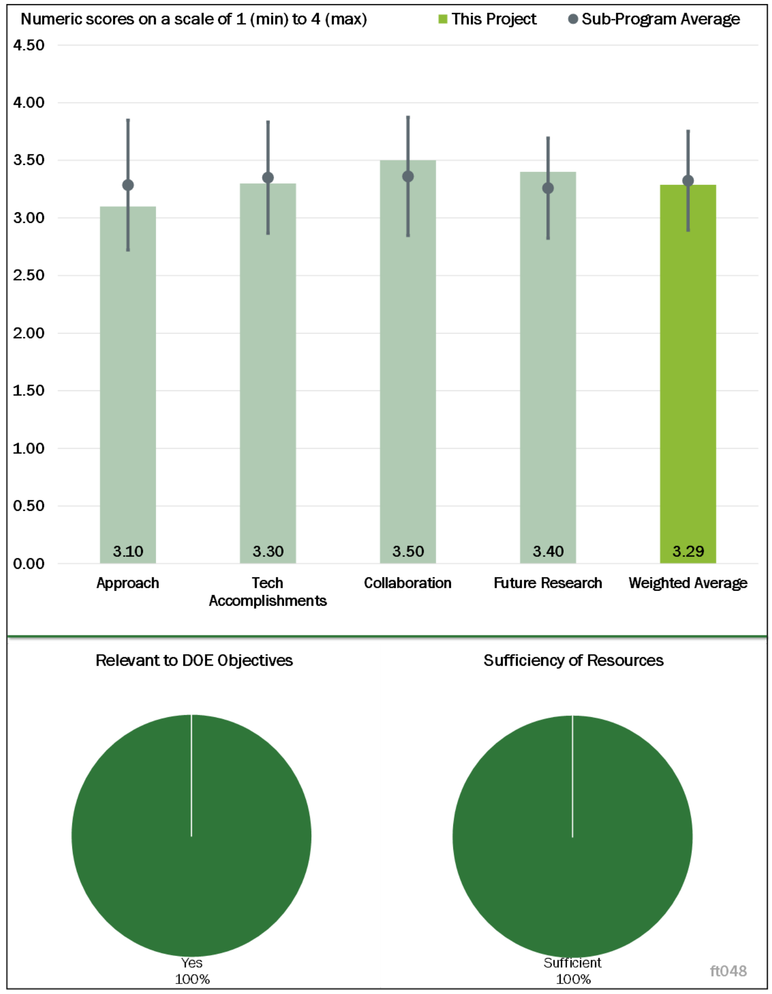

Figure 5-6 - Presentation Number: ft048 Presentation Title: Advanced Lubricant Technology—Technology Innovation, Design, and Synthesis Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the authors have provided a clear and focused vision of their sub-project, listing all potential technical barriers that need to be overcome to address DOE goals. The reviewer noted, however, that there is no clear indication of how new candidate fluids will be formulated and tested. The reviewer questioned whether the approach is to totally reformulate GF5 type fluids, which would mean running and passing API required engine tests, or whether new base stocks, additives, and VM will be treated as "add-on" technologies.

Reviewer 2:

The reviewer stated that, overall, the project was well organized, considering the number of partners, although the large team of collaborators may have led to some lack of focus. The reviewer suggested that perhaps coatings should be a different project.

Reviewer 3:

The reviewer commented that it was a little unclear as to what test was run to generate the data on Slide 10. The reviewer stated that, as shown on Slide 11, the AW candidates of aluminum oxide (Al_2O_3), silicon dioxide (SiO_2), and zirconium dioxide (ZrO_2) are all potentially abrasive particulate if not harnessed correctly, and it would be interesting to understand how these particles are formed and functionalize to control the particle performance. The reviewer observed that two of three seem to be abrasive in nature, which does not seem surprising, but one seems to have some promise, and that understanding the mechanisms behind the AW performance benefit is crucial to optimizing these lubricants.

Reviewer 4:

The reviewer found that the slides and presentation are very sketchy for a major scale project such as this. The reviewer commented that the project is shown as consisting of three thrusts, with Thrust I appearing intended to inform Thrust II, yet the very short presentation focuses almost solely on Thrust II, with no mention of how the results from Thrust I (which was the subject of a separate presentation) have informed Thrust II. The reviewer stated that the project is both examining hybrid base fluids, which it says could address rheology, friction and wear without additives, and examining enhanced additives, but it is not clear why the investigations of the two are presented as alternatives rather than examining optimal combinations of the two, i.e., which properties each can best address and how the two can work together to address properties. The reviewer observed that the project also includes an investigation of coatings for reduced friction and wear, but says it will do so for the purpose of eliminating stringent requirements of lubricants (Slide 6) rather than examining the best lubricants for use with such additives, for maximum feasible and cost justified friction reduction. The reviewer noted that this appears to be different, per a bullet on Slide 24.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that there were many moving parts with the partners, but that early on technical accomplishments seem to be on schedule, except for multifunctional VII. The reviewer commented that the results seem promising thus far, with interesting work and conclusions drawn from the multifunctional base fluids. The reviewer would especially like to see the shear stability results once available, and noted that there is high potential for the newly developed multifunctional base fluids to be more shear stable.

Reviewer 2:

The reviewer observed that the multifunctional colloidal additives showed impressive performance on the bench test, but there still is some concern about potential issues when the surface agent breaks down.

Reviewer 3:

The reviewer commented that the project was still in its early stages when the slides were prepared, but has demonstrated some early progress in down-selecting which candidate base fluids and additives to pursue and which not to pursue. The reviewer observed that some base fluids investigated were determined to be possibly viable as additives, rather than base fluids. The reviewer found that the initial results on VN coatings were also achieved with promising indications, and the results indicate substantial promise, but the presentation is too sketchy and unclear to confirm substantial progress toward the goals.

Reviewer 4:

The reviewer questioned how the proposed ester chemistry differs from the commercial ester chemistry currently used in Mobil 1 brand, and asked whether Mobil 1 fluid is going to be used as a comparison baseline to achieve proposed performance goals. The reviewer also questioned how the overall stability of colloidal dispersions of molybdenum disulfide, Cu, Al_2O_3, SiO_2, ZrO_3 additives was tested, what the particle size of these dispersions was, and whether they effect the color of the lubricants tested. The reviewer further asked how the 20% improvement in FE over API GF-5 baseline oil will be examined, i.e., bench testing alone or engine testing. Additionally, this reviewer inquired about the viscosity grade of the baseline API GF5 fluid selected for this Thrust II project to be used as a “poor” reference fluid.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that this project joins three national laboratories and several industry partners to investigate a full, ground-up, tribological approach, and that it will take careful coordination among all parties, of which this group is very capable.

Reviewer 2:

The reviewer remarked that there is a well-balanced team of technical collaborators contributing to this project, from the national laboratories and academia, and that this sub-project will require a lot of coordination between the various labs and contributors, due to the complexity of the overall list of tasks proposed.

Reviewer 3:

The reviewer stated that there are many partners, but overall the project seemed well coordinated.

Reviewer 4:

The reviewer commented that the presentation at the meeting included contributions from various team partners, indicating substantial and appropriate collaboration, but that the answers were somewhat different from the project participants, indicating that collaboration is less than perfect. The reviewer noted that no vehicle or engine makers are included as project collaborators. The reviewer pointed out that Slide 24 states that the participants work closely with vehicle OEMs to evaluate coatings, but that they are "unlikely to disclose their testing platforms." In the reviewer's opinion, this seems questionable and unfortunate, considering that they participate openly in other projects, but the actual meaning of that phrase is not altogether clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that, although early on in the project, the progression of work seems to be well planned, and it will be interesting to track the progress of this project over time.

Reviewer 2:

The reviewer stated that the VN coating testing sub-proposal is quite vague and needs to be rewritten, to provide clear direction of potential benefits of this technology versus implementation of novel base stocks+ additive technologies.

Reviewer 3:

In the reviewer's opinion, this project is too broad, and it would be nice to see more focus on the oil formulations for drop-in, for example, to achieve goals. The reviewer commented that coatings seem to be on a good forward path, but questioned the interactions of the coatings with the optimal lubricants. The reviewer stated that it makes sense to perform early tests using base oil/commercial formulations, but this needs to progress to compatibility with potential future formulations.

Reviewer 4:

The reviewer commented that the future work identified in Slide 17 will be useful but, as presented, it furthers the appearance that the "project" is actually a combination of different approaches and examinations, with the hope that one or more of them will provide a solution, rather than an integrated program, either within Thrust II or with Thrust II incorporating results from Thrust I.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

According to the reviewer, based on a well-planned project structure, this project definitely supports overall DOE objectives

Reviewer 2:
The reviewer commented that the project targets a 4% FE improvement from friction reduction, which would be a major source of petroleum displacement.

Reviewer 3:
The reviewer noted that several potential replacement candidates were presented.

Reviewer 4:
The reviewer stated that a ground up technical approach is vital for the successful implementation of novel base stocks, additives, and surface modifications, and the compilation of such technologies could greatly increase fuel efficiency by reducing frictional losses.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that $985,000 for Thrust II is an appropriate level of resources, more so because a 25% friction reduction resulting in a 4% FE improvement is targeted. It is not clear to the reviewer, however, why Thrust II does not command a greater share of the overall $3 million budget for the 3 thrusts, because the core of the work is in Thrust II and it involves a multiplicity of approaches.

Reviewer 2:
The reviewer stated that resources seem to be properly allocated, and that, with such a large project, they are doing well to stay on budget and mostly on schedule.

Reviewer 3:
The reviewer stated that all proposed resources are needed to make this project successful.

Reviewer 4:
The reviewer commented that resources are more than sufficient if the project becomes a bit more tightly focused on fewer candidate formulations.

Presentation Number: ft049
Presentation Title: Lubricant Effects on Combustion and Emissions Control
Principal Investigator: John Storey (Oak Ridge National Laboratory)

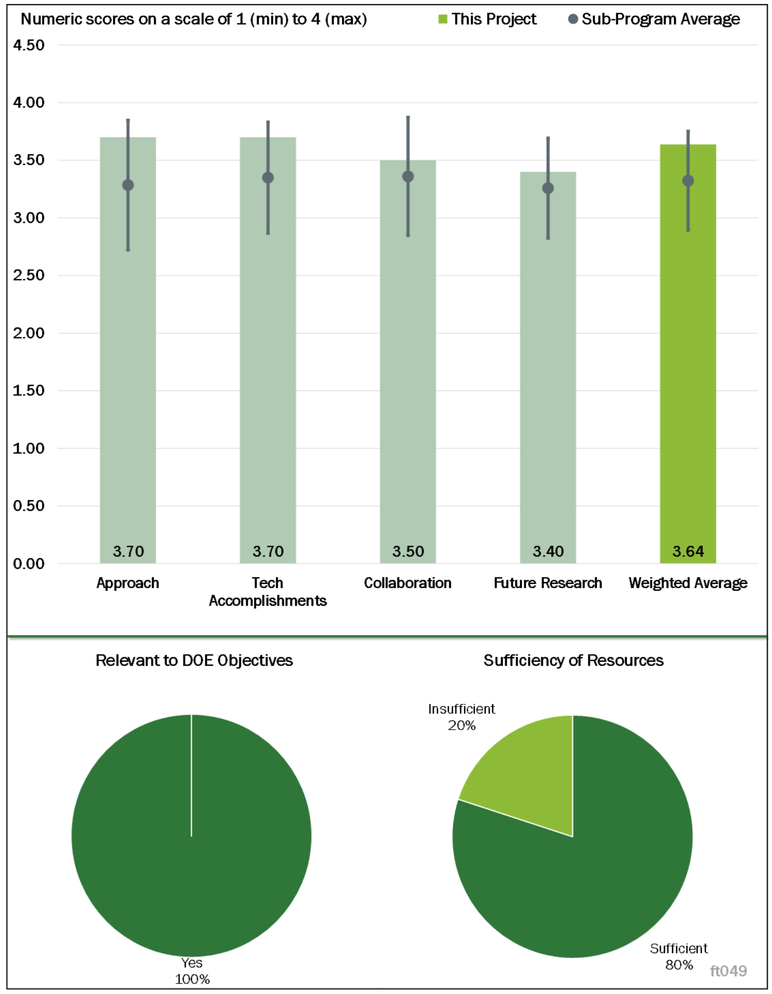

Figure 5-7 – Presentation Number: ft049 Presentation Title: Lubricant Effects on Combustion and Emissions Control Principal Investigator: John Storey (Oak Ridge National Laboratory)

Presenter

John Storey, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach identified in the project that includes in-depth characterization of particulate matter (PM), HCs and fuel economy to better understand lubricant effects is proving to be excellent and should successfully address the barriers identified.

Reviewer 2:

The reviewer remarked that the project is looking at how lubricants contribute to PM and low-speed pre-ignition (LSPI) and are critical to enabling future efficiency increases.

Reviewer 3:

The reviewer praised the work as being very interesting and relevant, and said it will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer added that there is important research going on in this project that needs to continue. The reviewer suggested looking at the impact of wear testing with these thinner weight oils, as the project is focused on fuel economy and involves testing with oils. The reviewer stated that, even though fuel economy improvements could be shown with thinner weight oils, the challenge is really with the engine wear over time with these oils, and this is a more relevant challenge to study. On Slide 9, the reviewer questioned whether the oil used in the study was new or had been sheared down with a break in procedure. The data made the reviewer wonder if there were light ends evolving during the testing. The reviewer added that the Nowack volatility of the oil can be determined very easily, and is typically a value to rate oils; also, the distillation curve of the oil may help to explain why there was an increase in PM mass, either from the light ends or from the high volatility oil. The reviewer remarked that it was very interesting that all the oils behave the same way, as shown in the chart on Slide 19, and asked whether we can conclude that the SPI issue is not a function of oil ignition quality. The reviewer also questioned whether it is the Sequence 6 D test that is referenced on Slide 21, saying that it was noted by the American Society for Testing and Materials (ASTM) number and by a Sequence test, but the reviewer wanted to confirm. The reviewer commented that on Slide 26 and during the presentation, it was mentioned that Boron in oil would be evaluated. The reviewer did not think that this metallic additive could be used because of emissions control devices, and asked for the presenters to confirm and let the reviewers know.

Reviewer 4:

The reviewer commented that this work and the stated objectives are a positive step forward in contributing to the understanding of lubricant effects on combustion and emissions control. The reviewer stated that work in developing an understanding and correlation of lubricant properties to PM characteristics is important, and provides information to advance the understanding of how to optimize the choice of lubricants to be compatible with emissions control. The reviewer stated that the impact on LSPI is also contributing in a similar fashion. The reviewer added that the fuel economy study is interesting, and using several vehicles to get better statistical information is excellent, but it will be challenging to conclude the impact on fuel economy, because there are so many different factors and powertrain designs that have an impact on fuel economy. The reviewer stated that it will be important not just to evaluate the fuel economy over a sample of vehicles, but to identify some of the key vehicle characteristics (i.e. oil temperature, overhead design, oil consumption rate) that directly impact the fuel economy, and to develop correlations against the modal fuel economy, with the goal of providing models that can allow for system optimization. Overall, the reviewer found the project to be well designed, with all of the elements fitting well together into a central scope and goal. The reviewer commented that the work is feasible, the deliverables are realistic, and it will provide useful information to the industry.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that it seems that a lot of progress was made this year and the work is on track to deliver against the stated milestones. Further, the results seem to have strong conclusions and there is sufficient statistical confidence over multiple experiments.

Reviewer 2:

The reviewer commented excellent progress to date.

Reviewer 3:

The reviewer commented that technical accomplishments have been excellent thus far, and the project has developed and employed engine-based test stands and vehicle tests to explore the emissions and fuel economy impacts of lubricants. The reviewer stated that the work performed this year has allowed the project to meet several milestones and be on track to complete others in the future.

Reviewer 4:

The reviewer stated that the work is directly relevant and needs to be prioritized and accelerated; this will help to support the reviewer’s company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer suggested that the authors try to accelerate the accomplishments of the work, forego the LSPI work on the oil, focus on the fuel, and let the oil industry uncover these issues. The reviewer also recommended conducting a test with the low-viscosity oils, and a bad fuel, to determine the impact of the fuel and the oil viscosity grade. The reviewer expressed skepticism about a finding of the Sequence 6D test to the vehicle fuel economy; however, the work is important to highlight that the test does not accurately account for real world results, and to show the difficulty in measuring small impacts of oil on FE.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project has pulled together an excellent set of collaborators and partners, including national laboratories, OEMs, lubricant manufacturers and academia.

Reviewer 2:
The reviewer suggested that it might be helpful to review these data with someone from the oil industry, to help focus some of the testing on the oils, and to help explain the data so that it is of more value. The reviewer added that the data on Slide 9 could use further inspection of the oil, and perhaps a DOE set of oils to determine if the effect is from the Nowack volatility or from the oil viscosity itself. The reviewer suggested that it would be helpful for the project managers and engineers to attend one of the oil industry programs that teaches the background of engine oil technical specifications; this would help to provide the researcher with additional technical training and technical background, and networking with technical contacts in industry.

The reviewer found that, overall, there is a good mix of collaborators on the project, and they can help to guide the research with appropriate technical questions.

Reviewer 3:
The reviewer stated that there is an impressive collaboration among multiple labs, and there also appear to be good industry collaborations and input from vehicle manufacturers. The reviewer voiced surprise, however, that there is not more direct collaboration with a fuel or oil industrial partner. The reviewer noted that Driven Racing Oil is involved and that they are providing samples, but stated that this seems like a very small subset of this industry that is supplying the component at the heart of this project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project has identified proposed future research that will address the remaining challenges identified by the presenter. The reviewer found that there has been an excellent use of input from the partners in the project to provide guidance into the future research.

Reviewer 2:
The reviewer made multiple suggestions for the proposed future work. The first suggestion is to test the oils that were used in the PM evaluation and provide these data to help explain the test data already collected. Specific to the LSPI work, the reviewer recommended minimizing the majority of the work on the oil, and accelerating the work on the thinner weight oil and bad fuels. This, the reviewer explained, will help to show if the mechanism of the oil or the fuel, or both together, is causing the issue. The reviewer noted that there is great need to study the fuel effect, so this work needs to be pulled ahead. The reviewer observed a need to understand why boron can be used in oil, as the reviewer thought this was not allowed for emission control devices; if this is not an issue for the devices, then this is important work that should be completed. The reviewer recommended an LSPI test with the boron containing oils as well.

Reviewer 3:
The reviewer found that the proposed future research is on-track to deliver against the stated objectives, although there was not much in the planning about decision points, which is partially due to the nature of the

project, which is more of a survey and developing critical functions. The reviewer suggested that the authors address on Slide 26 is the fact that future work depends on funding levels, and there may need to be a mechanism to set priorities. The reviewer noted that this mechanism may exist, but there may have been insufficient time to include it in this review.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said that emissions problems could prevent more efficient lubricants so this project meets the goals as an enabler for better lubricants.

Reviewer 2:
The reviewer found the work to be very interesting and relevant, and directly related to fuel economy improvements from today's and tomorrow's (near term) vehicle technology, which focuses on displacing petroleum. The reviewer commented that it is important to make sure that there is adequate understanding of the test methodology for measurements of the metrics, and that there is understanding of the impacts of thinner weight oils, as well as LSPI on engine technology that improves fuel economy. The reviewer indicated that this research will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer stated that there is important research going on in this project that needs to continue.

Reviewer 3:
The reviewer commented that the goals of this project will guide the industry in determining the properties that will drive more efficient use of lubricants, and that understanding the emissions properties will guide efficient burning of the fuel to meet emissions requirements. The reviewer noted that the fuel economy vehicle measurements show the potential benefits of new lubricants to reduce the fuel consumption of existing vehicles as well as those being developed.

Reviewer 4:
The reviewer found this project to be extremely relevant to the DOE objective of petroleum displacement, as a major component of the project is to develop and demonstrate vehicle-based protocols to screen lubricants for improved fuel economy, which will directly impact the petroleum displacement objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that the budget for this project appears to be adequate for the project to complete milestones.

Reviewer 2:
The reviewer stated that this is significant and relevant work that needs to be completed. The reviewer voiced concern that this work might not be completed with the proposed budget cuts, and emphasized that this work is relevant for current and near-term propulsion systems.

Reviewer 3:
The reviewer commented that it seems that the national laboratories' capabilities and expertise are being well utilized to meet the stated objectives. The reviewer questioned the vehicle testing and evaluation, however, as being able to get a large enough sample to capture all of the variations and properties of different vehicles

available on the market can be challenging. The reviewer suggested that there is a potential opportunity to widen the scope of that work, although a reasonable balance is being applied here to get valuable work with a reasonable utilization of resources.

Presentation Number: ft050
Presentation Title: Power-Cylinder Friction Reduction through Coatings, Surface Finish, and Design
Principal Investigator: Arup Gangopadhyay (Ford Motor Co.)

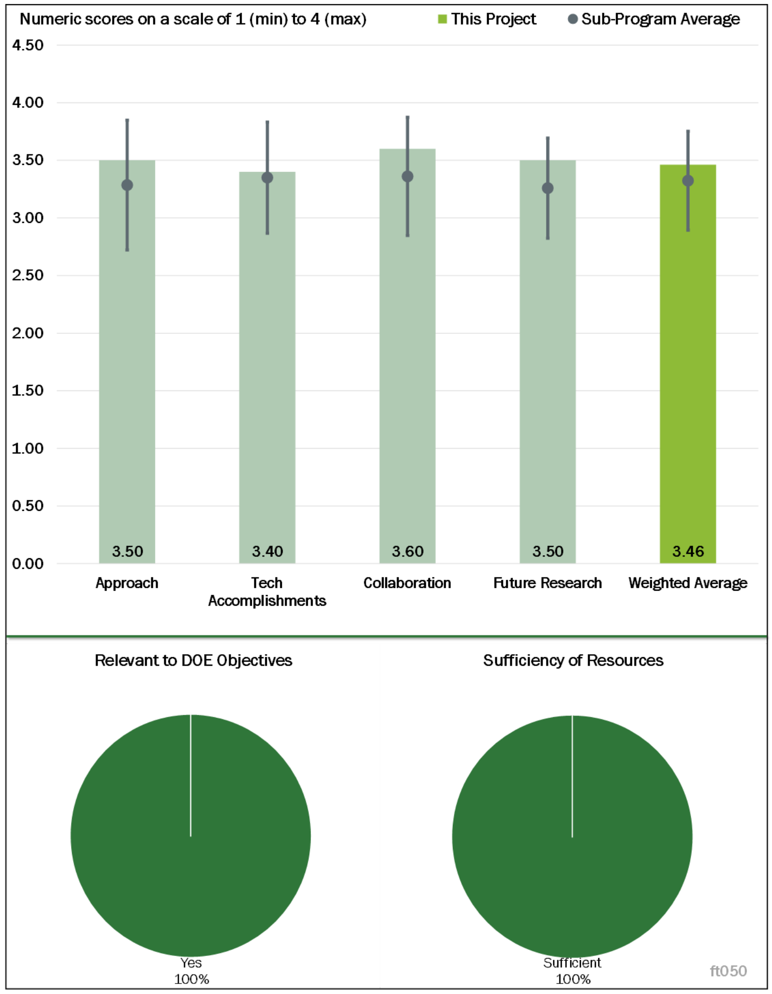

Figure 5-8 - Presentation Number: ft050 Presentation Title: Power-Cylinder Friction Reduction through Coatings, Surface Finish, and Design Principal Investigator: Arup Gangopadhyay (Ford Motor Co.)

Presenter

Arup Gangopadhyay, Ford Motor Co.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project is working on a comprehensive set of approaches to reduce friction, and that the methodology is well-designed and logical. The methodology included a study of relevant variable for coating deposition, a detailed characterization of the coatings and performance evaluation of the coatings.

Reviewer 2:

The reviewer found the project had a well-designed project plan addressing a unique approach to develop and understand an impact of protective coating porosity and oil film interactions.

Reviewer 3:

The reviewer commented on the good technical plan and collaboration with coating suppliers, and noted that deposition feasibility, then bench testing, all the way to chassis dynamometer testing was very complete.

Reviewer 4:

The reviewer remarked that the PI has considerable experience with the proposed technology of plasma transfer wire arc (PTWA) coatings, and noted that the proposed project will allow for variability of porosity of these coatings and will proceed with quantifying their tribological performance. The reviewer commented that porosity seems to be adequately characterized and monitored; evaluation of coatings seems to be sufficient as well, and it will be interesting to see how ANL proposed coatings will be implemented alongside the PTWA coatings. This reviewer has many questions as to the commercial viability of the ANL proposed coating and if that was considered in Ford’s approach.

Reviewer 5:

The reviewer commented that the approach is logical and systematic for completing research, and is likely to result in project completion. The reviewer found that the project has a good mix of bench and engine tests with final verification on a chassis dynamometer, and addresses fuel economy benefits and evaluation of wear. The reviewer noted that long term durability is not demonstrated. The reviewer commented that the project combines three technologies to achieve results: porous cylinder liner; low friction piston rings; and low viscosity lubricant.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that there has been overall good progress after some delays in setting up a new wear testing laboratory, and good development of the PTWA process and coating characterization protocol.

Reviewer 2:

The reviewer commented that there has been good progress in achieving a consistent porous coating and determining the optimum amount of porosity. In addition, friction reductions have also been demonstrated for polished crankshaft, piston ring coating, and PAG oil. The reviewer noted that the next phase will be to combine these technologies and evaluate total improvements.

Reviewer 3:

The reviewer noted that coating deposition method, characterization and initial assessment of the frictional properties have been completed, and that friction reduction benefits in bench and full scale motored rigs have been demonstrated.

Reviewer 4:

The reviewer stated that good technical progress is being made, and it is good to see a very well-planned testing strategy. The reviewer questioned why the authors selected API GF5 5W-20 (low viscosity grade) oil as a baseline for their studies. Since PAG base stocks offer unique challenges in overall performance of engine oil lubricants, the reviewer suggested that the authors reconsider using another futuristic GF-6 formulation based on conventional synthetic base stocks to optimize their novel coatings performance and achieve DOE target goals.

Reviewer 5:

The reviewer commented that the project is an interesting study of different bar stocks to use with PTWA coatings. The reviewer stated that it looks as though the 7% PTWA liner with DLC ring has very similar performance to the normal production ring for higher u*V shown on Slides 11 and 12, and commented that this would make sense as the lubrication condition moves away from boundary. The reviewer noted that the data are on two separate plots with different scales, so it is difficult to see. The reviewer stated that Slide 11 does not successfully demonstrate a clear performance trend with varying percentages of PTWA coatings, and it seems as though the lower concentration tested is detrimental to performance. This reviewer would recommend further benchtop tribological studies with varying PTWA porosity and thorough post-test analytical data to understand the mechanisms governing the performance.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented on the excellent collection of real, production auto suppliers who are each contributing in their respective areas of expertise, and who should have a good chance of commercially developing and releasing these technologies, if warranted. The reviewer stated that the coating and honing companies, in particular, appear to be very competent.

Reviewer 2:
The reviewer noted a very good collaboration with important partners in this area.

Reviewer 3:
The reviewer stated that, given the large number of collaborators, coordination among partners can be quite challenging; however, the project team has continued to make good progress, indicating that coordination among the partners is going well.

Reviewer 4:
The reviewer observed that it seems several partners acting as suppliers are providing the hardware components necessary to demonstrate the chosen technologies. The reviewer noted that ANL's nanocomposite coating seems promising as well, but it will be interesting to see how it plays in the future progress of this project, as it is a separate thrust area to the primary PTWA coating technology.

Reviewer 5:
The reviewer commended the authors on the impressive list of collaborating organizations that are contributing to this project, but questioned why there no lubricant additive supplier included in any activity, as additive supplier can offer key technical knowledge regarding formulating approaches.

The reviewer also requested clarification of the distinction between contributions from collaborating organizations and from supplier organizations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the key steps to complete the project have been well documented.

Reviewer 2:
The reviewer commented that several detailed and realistic future testing strategies are identified, including friction reduction on motored cranktrain rig with PTWA coated blocks (at various porosity levels); friction reduction on motored cranktrain rig with PTWA coated blocks with low friction rings; friction benefits on pressurized single cylinder friction rig; and friction benefits of piston skirt and ring nano-composite coatings against PTWA coated liner in laboratory bench rigs. The reviewer noted that there is also an impressive plan to conduct durability examinations in engines and vehicles.

Reviewer 3:
The reviewer commented that future work is following the project plan as written and is logical to achieve overall deliverables.

Reviewer 4:
The reviewer observed that the group has a large go/no-go decision point rapidly approaching, as they move from benchtop validation of the PTWA coating technology to rig testing. The reviewer expressed hope that this will elucidate some of the mixed performance results demonstrated in benchtop tribological testing. The reviewer noted that both friction and wear/durability performance will be quantified over the next year to year and a half.

Reviewer 5:
The reviewer stated that we really need to see the fired engine testing benefits, eventually progressing to chassis testing.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied yes, based on a well-planned project structure, this project definitely supports overall DOE objectives.

Reviewer 2:
The reviewer originally surmised that the porous coating might be hard to control or expensive; however, after reviewing the coating and honing supplier websites, the reviewer was impressed by their apparent competence. The reviewer added that the project will stimulate further interest in this approach to an oil retention bearing surface, if results add up as it appears they will.

Reviewer 3:
The reviewer found that preliminary results appear to support the reduction of petroleum usage.

Reviewer 4:
The reviewer stated that coatings are becoming vital to lubricated systems as lubricants move to lower viscosities, and the proposed PTWA coating technology could work exceptionally well with these low-viscosity lubricants. The reviewer concluded that there is high relevance overall to reducing friction and increasing fuel efficiency.

Reviewer 5:
The reviewer stated that the project aims to reduce friction by development and use of advanced coatings on engine components, and this goal is directly related to the DOE objective of reducing petroleum dependence; however, the project team is grossly over-estimating the size of the FE benefit that will accrue from this work. The reviewer remarked that the team should be requested to provide a rational basis for their assessment of the benefit.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the funds allocated for 2017 appear adequate to complete the remaining tasks identified by the project team.

Reviewer 2:
The reviewer replied yes, all proposed resources are sufficient to make this project successfully reach DOE specified goals.

Reviewer 3:
The reviewer commented that resources appear to be adequate to achieve end results, as long as planned funding is maintained.

Reviewer 4:
The reviewer stated that the project team has been performing on budget. In the reviewer’s opinion, it is good to see a cost share by Ford to investigate the chosen technology; the strong mutual interest should help the success of this project.

Presentation Number: ft051
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction
Principal Investigator: Robert McCormick (National Renewable Energy Laboratory)

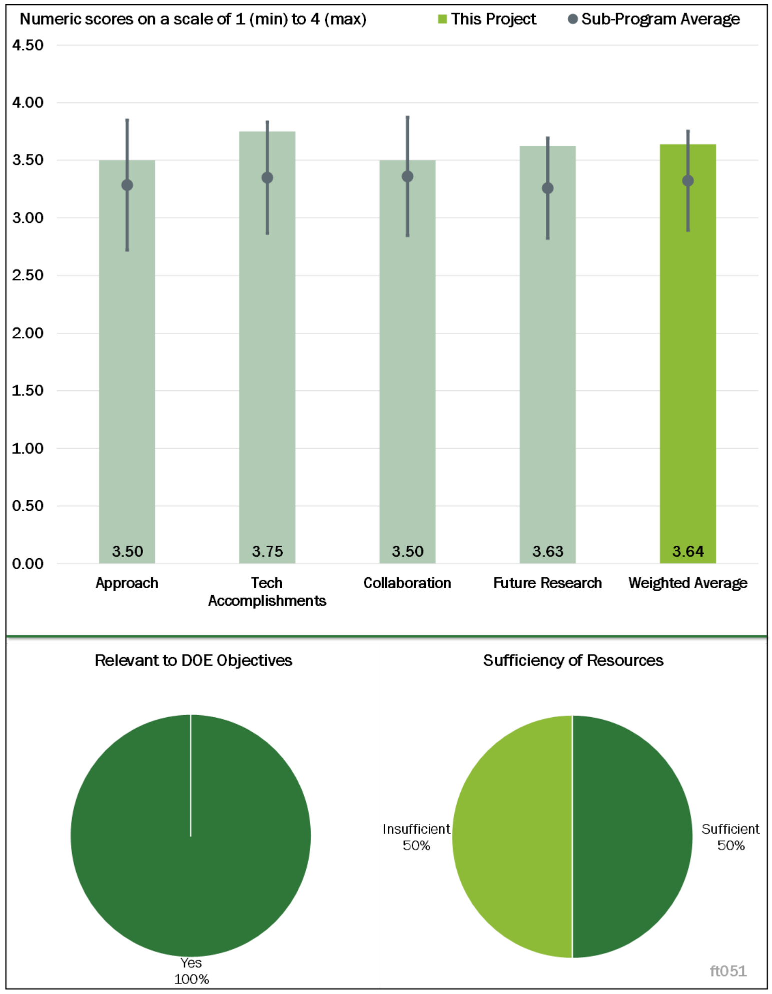

Figure 5-9 - Presentation Number: ft051 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction Principal Investigator: Robert McCormick (National Renewable Energy Laboratory)

Presenter

Robert McCormick, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer found that the work being conducted under this project is critical for establishing the Central Fuel Hypothesis that if pertinent fuel properties that enable higher engine efficiency are identified, then fuels that have those properties will be able to provide the expected improvement in engine performance. To this end, the reviewer commented that this project is generating new information and developing analytical/computational tools to help define the relevant fuel properties for improved engine efficiency.

Reviewer 2:

The reviewer noted that there are a number of different projects contained within the "umbrella" of this presentation topic of "Fuel Property Characterization and Prediction," and each of those has its own merits and debits. The reviewer stated that the overall concept/approach of understanding the impact of fuel properties on engine performance has a lot of merit, and assessment of potential fuel component candidates requires measurement of accurate prediction of the candidates' properties. The reviewer commented that the presentation raises some confusion about the performance characteristics that the Merit Function is developed to address. The reviewer elaborated by saying that in previous Co-Optima presentations, the Merit Function has been proposed as a way to predict the efficiency of SI, boosted engines based on fuel properties; however, in this presentation, the Merit Function comes immediately after the statement of the Central Fuel Hypothesis that "If we identify target values for the critical fuel properties that maximize efficiency and emissions performance ..." Further, the Merit Function has a term for particulate matter index (PMI), but lacks terms for other important emissions components. The reviewer added that this leads to confusion as to whether the Merit Function is solely focused on efficiency, or if it also tries to account for some, but not all emissions. The reviewer stated that the ultimate key to the value of the Merit Function is validation through comparison of predictions versus actual results in engines that are representative of downsized, boosted production engines. The reviewer commented that the focus of the fuel blend property testing appears to be oxygenates (based on data presented in Slide 9); however, in the spirit of true "Co-optimization" of fuels and engines, hydrocarbon candidates (regardless of whether they are bio-derived or not) should also be included to identify the best potential candidates. In the reviewer's opinion, the work to measure the heat of vaporization of multicomponent mixtures characteristic of "real" fuels has a lot of merit. The reviewer added that the development of small volume testers to measure key properties of fuel components that are not available in large enough quantity for conventional analytical devices (such as Cooperative Fuel Research [CFR] engines for octane determination) would be very valuable. The reviewer stated that the use of those devices for quantitative measurement will require that they have repeatability and reproducibility values consistent with the larger instruments.

Reviewer 3:

The reviewer said that emissions problems could prevent more efficient lubricants so this project meets the goals as an enabler for better lubricants.

Reviewer 4:

The reviewer praised the work as being very interesting and relevant, and said it will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer added that there is important research going on in this project that needs to continue. The reviewer did not see flame speed (SL) or PMI in the dataset, and commented that it was part of the merit function. The reviewer questioned whether that is being completed under a different part of the project or perhaps had not been prepared yet in this project. The reviewer commented that the decision point presentation followed the final Co-Optima presentations, and this seemed to help clarify why some factors of the merit function were not addressed. However, the reviewer stated that it is still imperative to look at Flame Speed (SL) and PMI as part of the merit function for the final blended fuels, as there are some effects to be understood with the blended fuels.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said excellent progress to date.

Reviewer 2:

The reviewer remarked that in 2016-2017, this project made excellent progress towards defining the fuel properties most relevant for increasing engine efficiency, and added that, in addition to generation significant new information on properties of various biomass based fuel components, new analytical and computational tools were also developed to help estimate the properties of finished fuels. The reviewer noted that the fuel property information was used to refine the merit function. The reviewer observed that, because 97% of the light-duty vehicles sold in the U.S. are powered by SI engines, fuels that can help improve engine efficiency even modestly can have a significant impact on the national energy consumption as well as expenditure on transportation. The reviewer concluded that defining properties of the fuel that can enhance engine performance is a critical step towards realizing the DOE goals of reduced energy consumption and petroleum displacement.

Reviewer 3:

The reviewer remarked that lots of work has been completed on predicting fuel component and blend properties, and the ultimate value of the work will need to be validated in tests in representative engines.

Reviewer 4:

The reviewer observed that the presentation demonstrated significant technical accomplishments and was well organized and very detailed. The reviewer really appreciates the attention to detail and the technical team that put this presentation together, and complimented them on a job well done. The reviewer stated that this work will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer commented that there is critical research going on in this project and believes that it needs to continue to support improvements in fuel selection and efficiency in the near term and within the next 10 years.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that there is a good list of collaborators on this program and they are coordinating at a high level, and added that this is demonstrated in the significant work accomplished and the valuable work being completed with a small budget. The reviewer offered praise for this highly efficient team.

Reviewer 2:

The reviewer stated that the collaboration between the various national laboratories and PIs has been excellent and is evident from the improved alignment of activities across various facilities, as well as the significant enhancement of the knowledge base related to properties of various fuel components.

Reviewer 3:

The reviewer remarked that the collaborations for this work that are mentioned on Slide 18 are predominantly within the national laboratories and universities, and no mention is made about collaborations with industry. The reviewer also noted that the Coordinating Research Council (a consortia of energy companies and automakers) is mentioned, but that was for the specific work on diesel fuel surrogate solidification and some heat of vaporization measurements. The reviewer suggested that sharing more technical details with industry and obtaining input on a timely basis (i.e., in developing fuel matrices and test conditions and as the results are obtained) would likely improve the ultimate relevance and potential for commercial deployment.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the proposed future research, particularly reducing uncertainty of the Merit Function for light-duty (LD) SI engines, as well as relevance of SI fuels for Advanced Compression Ignition combustion concepts, is in line with the goals of the project as well as the DOE goals. According to this reviewer, formalizing the Merit Function and finalizing the most relevant fuel properties for LD SI engines would be a substantial contribution to the existing body of knowledge and this effort should be provided all the support it requires.

Reviewer 2:

The reviewer said that including some non-biofuel streams would be beneficial and is being considered at least. This would help to frame how the biofuels compare to other exotic fuel sources.

Reviewer 3:
The reviewer praised the list of proposed work as excellent, and highly recommended that continued funding be spent on the list of work proposed, as these are critical for the success of this program and future fuels for our current and industry product mix.

Reviewer 4:
The reviewer stated that the proposed future work mostly makes sense, but it is unclear how decisions will be made regarding which work to continue if budgets are reduced. The reviewer recommended including the properties and effects of various hydrocarbon components to improve the value of the work.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this project supports the DOE objective of petroleum displacement. The reviewer added that it specifically addresses all technical issues involved with the fuels, and validating the technical issues with fuels, thus preparing them to be brought to the market place.

Reviewer 2:
The reviewer commented that engine and fuel combinations that lead to higher engine efficiencies will lead to lower fuel consumption.

Reviewer 3:
The reviewer responded yes, that clearly identifying and defining the properties of fuels that can help enhance engine efficiency is in line with the overall DOE objective of petroleum displacement.

Reviewer 4:
The reviewer commented that the project should save petroleum in both new vehicles and legacy vehicles due to efficiency improvements if successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that resources seem sufficient at the current funding level, but presumably work in some areas will have to be reduced if budget cuts are made, and it is unclear how that prioritization would be done within DOE.

Reviewer 2:
The reviewer stated that there is significant technical work being completed in this program, and expressed surprise at the funding level, considering some of the other AMR projects the reviewer has seen and reviewed, and compared their funding levels. The reviewer complimented the team as being highly efficient and effective, in comparison to some other projects. In the reviewer’s opinion, this is such an important project that it should be funded at a higher level and with more resources to ensure that it will be completed.

Reviewer 3:
The reviewer found that the funds allocated to this effort are insufficient and can be expected to impede progress at a critical juncture, which would be unfortunate, especially in view of the progress made over the past year.

Presentation Number: ft052
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Topic 7 - Fuel Kinetics and Its Simulation
Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Presenter

Matthew McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

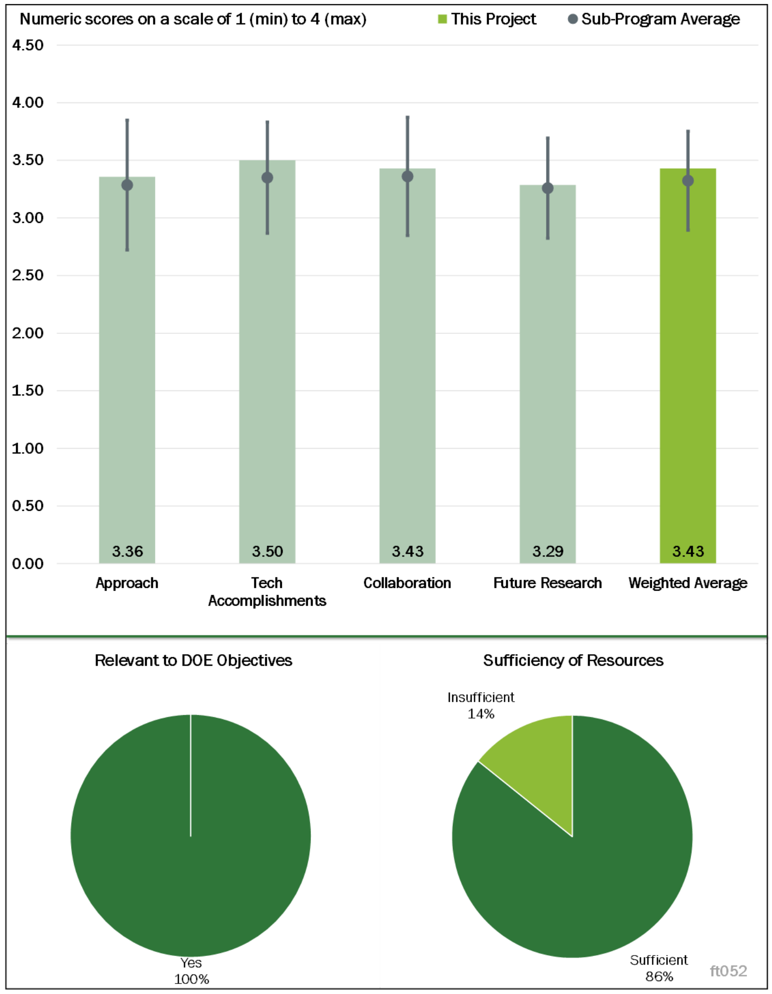

Figure 5-10 – Presentation Number: ft052 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Topic 7 - Fuel Kinetics and Its Simulation Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer found that the effort is well-focused on improving predictive capabilities regarding key fuel properties and is coordinated with a comprehensive and complimentary team.

Reviewer 2:

The reviewer found the overall approach to be very good, and stated that evaluating the impact of fuel properties on ignition and kinetics is a critical aspect of fuel and engine optimization.

Reviewer 3:

The reviewer indicated that, based upon this review, this appears to be very strong technical work. The reviewer added that if the Co-Optima project is to be successful, then it needs a strong technical understanding of the kinetic properties of the fuels, so that models can be developed to support and guide the merit function and reduce the burden of testing through screening methods via simulation. The reviewer found that the project is well designed and scoped, and praised the goal of addressing the efficiency of finding solutions. The reviewer stated that the project has a very aggressive goal, but expressed concern that there are sufficient resources to complete the work. The reviewer expressed the opinion that the work need not be completed in its entirely to improve the industry knowledge gap, and commented that even sub-sets of this work will be of high value.

Reviewer 4:

The reviewer stated that the approach presented is adequate to provide information to achieve the Topic 7 goals for fuel kinetics and its simulation, and to ultimately eliminate the barriers that need to be addressed.

Reviewer 5:

The reviewer praised the work as being very interesting and relevant, and said it will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer added that there is important research going on in this project that needs to continue. The reviewer questioned how the authors will determine if the model properties match the engine results, and asked for evidence that the simplified kinetic model and fuel set matches the engine output for a fully formulated fuel that is multi component. The reviewer also requested that the parameters at the top of Slide 11 be updated in the version of the slides that will be posted on the web.

Reviewer 6:

The reviewer complimented the project on being very well designed, feasible, and integrated with other efforts. The reviewer suggested that Task F2.2.2 should put more effort toward developing a computational fluid dynamics (CFD) model for the Advanced Fuel Ignition Delay Analyzer. The reviewer added that the ignition quality tester (IQT) uses an obsolete injector and the spray model is not very well studied, and was not very confident of using IQT to validate fuel combustion kinetics.

Reviewer 7:

The reviewer commented that development of a kinetic model to rapidly simulate and predict kinetic effects of various fuel properties and blends can be very useful in reducing the research needed for downselection of fuel candidates, as well as impacts with different combustion conditions. The reviewer indicated, however, that much of the actual approach to developing the model is difficult to understand from the presentation and slides.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that there is significant work that has been done in the project to provide fundamental data to support the modeling efforts. While always skeptical of models versus real-world data, the reviewer expressed the view that this effort is worthwhile and will provide a good set of tools for use in fuel selection and optimization for near term and long-term products for the market.

Reviewer 2:

The reviewer found that the technical accomplishments have been adequate to provide information to allow the project to meet FY 2017 milestones and continue to be on track for future milestones. The reviewer added that the project has significantly improved pressure dependence in the kinetic model with work done at ANL in FY 2017, and it has created virtual fuels to test the hypothesis in CFD. The reviewer expressed the view that success in these areas will move the project toward meeting the DOE goals.

Reviewer 3:

The reviewer commented that, considering co-optima relative newness, progress is impressive.

Reviewer 4:

The reviewer stated that the project has made very good progress toward overall project and DOE goals.

Reviewer 5:

The reviewer stated that it appears that excellent progress is being made towards the project goals, information is being provided that is helping to support and validate the Central Fuel Hypothesis, and predictions being done from the tools which are utilizing the kinetic information developed are showing strong correlation with conducted experiments.

Reviewer 6:
The reviewer remarked that progress is on track.

Reviewer 7:
The reviewer observed that the presentation says that work has been completed predicting blend behavior for high performance blend stocks in base fuels at LD conditions and compared to ethanol blend behavior, but no such results appear to be reported in the slides. The reviewer added that, apart from reporting that various "tools" have been developed, it is not clear from the presentation what work has been completed and what is yet to be done with regard to the model.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that, in reviewing the list of national laboratories involved in the project, it seems that there is a good mix of technical talent in collaboration. Also, it seems that the project has extended to collaborators outside of the government labs, to incorporate additional technical coordination in support of the overall goals.

Reviewer 2:
The reviewer commented that the project has very good coordination and collaboration through the work of four national laboratories and academia; in addition, the project coordinates with the Coordinating Research Council (CRC) which helps bring industry input to the project.

Reviewer 3:
The reviewer remarked on the overall excellent collaboration among national laboratories, and indicated that the project was well coordinated with other activities such as Advanced Engine Combustion (AEC) and CRC.

Reviewer 4:
The reviewer commented that the collaborations described in Slide 6 seem to be very successful and working well to meet the project objectives. The reviewer was particularly impressed with the collaboration with John Dec from Sandia National Laboratories, and the comments that his work was identifying desirable properties of the fuels to optimize efficiency, and was showing some promise in how to blend the fuels to meet those objectives and then demonstrate the expected performance.

Reviewer 5:
The reviewer notes that, apparently, this project has been criticized in the past as needing more collaboration, and agrees that this is still true. The reviewer pointed out that there are many places where researchers are looking at ignition delay/quality and kinetics, including (beyond those already working on this project) Jim Cowart at the Naval Academy, who has an IQT, Josh Bittle at the University of Alabama, who has a Cetane ID, Andre Boehman at the University of Michigan, who also has a Cetane ID, possibly with optical access, and others. The reviewer postulated that perhaps there is room for more extensive collaboration.

Reviewer 6:
The reviewer noted that four labs and 46 organizations are shown as participating in the Task 7 kinetic work, and periodic meetings and conference calls are held. The reviewer stated that the nature of the collaboration to date, however is shown only in Slide 6, which provides only the last names of researchers, not their affiliations; it does identify a breakdown of future work for the four participating labs, but does not do so for work to date.

Reviewer 7:
The reviewer commented that a comprehensive team has been assembled, but, if anything, the team is almost too large, with capabilities perhaps spread too widely. The reviewer stated that it was nice to see a new ignition quality rig brought to the team.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the future work here is critical to the success of this program, and to providing needed basic fundamental fuel property data for industry. Further, the reviewer noted that this is an outstanding list of future work that will be highly supported by industry. The reviewer stated that this work needs to have sufficient funding for completion because of the relevance and significant need.

Reviewer 2:
The reviewer stated that the proposed future work appears to be adequate and addresses the remaining challenges and barriers.

Reviewer 3:
The reviewer noted that the future work is outlined clearly, and apparently will contribute to understanding by predicting fuel behavior within the co-optimizer tool for different combustion modes, although the explanation of that is not as clear as it might have been.

Reviewer 4:
The reviewer suggested that other collaborators be considered in future work.

Reviewer 5:
The reviewer commented that the future work description should consist of a short set of two or three central outcomes of this part of Optima, not by just showing a distribution of work across the Labs. The reviewer suggested taking a diagram, such as Slide 22, and showing a clear path toward a couple of key outcomes, as it is not quite clear, as currently shown.

Reviewer 6:
The reviewer found that, overall, the future work is well planned. The reviewer did question what the plan is to address the barriers and challenges, however.

Reviewer 7:
The reviewer stated that this work is on track to meeting the stated objectives; the only thing that is not clear, however, is the pathway to mitigate risk. The reviewer commented that it seems there is a very large scope and it is not clear that there are sufficient resources to meet the desired goals. The reviewer added that it appears that the overall Co-Optima project has some mechanisms to manage this, but it would be nice to see that the most critical aspects of the project are able to be met, and that it is clear what the secondary objectives would be if the work takes more resources than allocated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that the work is relevant to supporting the need to more easily model the impact of fuel properties, in support of petroleum displacement. The reviewer added that the future work here is critical to the success of this program, and to provide needed basic fundamental fuel property data for industry.

Further, the reviewer noted that this is an outstanding list of future work that will be highly supported by industry. The reviewer stated that this work needs to have sufficient funding for completion because of the relevance and significant need.

Reviewer 2:
The reviewer stated that this work has a high potential for success in improving engine efficiency because it is a piece of work which considers total system optimization. The reviewer noted that this specific part of the Co-Optima work is providing fundamental building blocks for modeling efforts and determining the properties of various blended fuels. Further, according to this reviewer, beyond the scope of the Co-Optima work, the integration of the tools and functions gained in this work can be integrated into engine modeling tools for performance predictions, which are critical to the industry in order to run large screening studies and determine system optimums.

Reviewer 3:
The reviewer stated that the project definitely supports the overall DOE objective of petroleum displacement by predicting the impact of fuel properties and bridging the gap of efficient, low-emissions engine knowledge.

Reviewer 4:
The reviewer stated yes, this project supports the overall DOE objectives of petroleum displacement.

Reviewer 5:
The reviewer commented that this project (Task 7) is apparently useful to the overall Co-Optima project, which could result in much higher combustion efficiencies, hence increase fuel economy.

Reviewer 6:
The reviewer replied yes, presuming the fuel and auto/engine organizations will work together, and more efficient fuel-engine systems can be implemented.

Reviewer 7:

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that there are sufficient resources for the project to achieve the stated milestones in a timely fashion.

Reviewer 2:
The reviewer commented that the funds expected to be provided for this project appear to be adequate to complete the planned work.

Reviewer 3:
The reviewer stated that the budget is sufficient for now, but wondered what will be the impact of likely upcoming cuts, and if it will significantly impair progress.

Reviewer 4:
The reviewer found that there is a good level of investment of resources into this work, perhaps not is sufficient to meet all of the desired goals, but it is a good balance to meet a fundamental knowledge gap within the industry.

Reviewer 5:
The reviewer indicated that some of the participating Labs are a bit below the funding level needed to stay dedicated to their tasks; however, they should consider whether some subtasks are really critical or could be consolidated.

Reviewer 6:

The reviewer stated that it seems that this program has sufficient funding for completion; however, it is alarming that for future FYs, the funding will be reduced drastically. The reviewer added that this is important work that will provide fundamental technical support for industry to produce fuel efficient and reduced emissions products, in the longer term. The reviewer further commented that the research provides design tools that will allow for decision making regarding future fuels for engines, and it is imperative that this work be completed with the sufficient funding.

Presentation Number: ft053
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 1: Research Octane Number, Sensitivity, and Heat of Vaporization
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

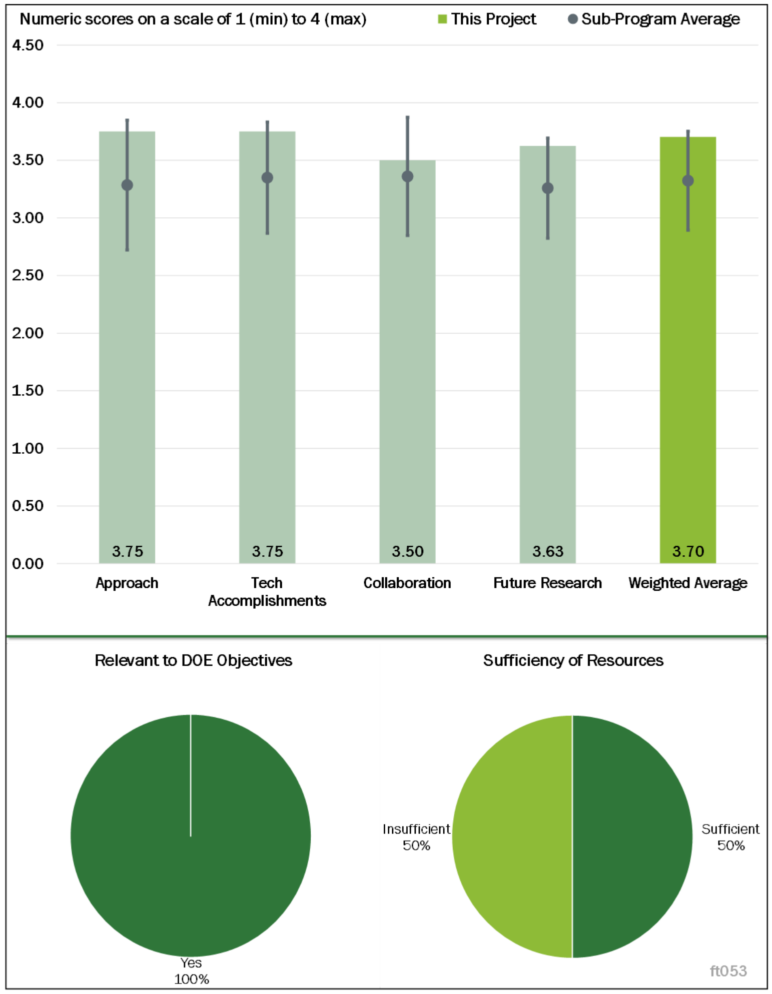

Figure 5-11 - Presentation Number: ft053 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 1: Research Octane Number, Sensitivity, and Heat of Vaporization Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter
Jim Szybist, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that the systematic and thorough experimental approach adopted in this project is crucial for establishing Co-Optima's Central Fuel Hypothesis. The reviewer added that the fundamental studies conducted under this project have helped develop a better understanding of the limits of the most relevant fuel properties for engine efficiency such as Octane Index, Sensitivity, and Heat of Vaporization. In addition, according to this reviewer, the engine experiments being performed as part of this project augment and complement the work being conducted under the Fuel Characterization and Prediction project being led by Bob McCormick.

Reviewer 2:
The reviewer noted that there are five different projects contained within the umbrella of the topic of this presentation, "Fuel Property Impacts on Spark Ignition Efficiency," and that each of those has its own merits and debits. The reviewer commented that the overall concept/approach of understanding the impact of fuel properties on engine performance and "Co-Optimizing the fuels and engines" has a lot of merit; the focus of the work in this program area is SI combustion, which limits potential "co-optimization" because the engine design is largely defined/fixed. Further, according to this reviewer, the almost exclusive focus of fuel blend component candidates is on those perceived by the DOE researchers to be producible by biofeedstocks, predominantly oxygenates. The reviewer suggested that a more robust, fundamental R&D program that would be of even greater value to fuel producers should also include an understanding of the performance of blends with various hydrocarbon molecule candidates (regardless of whether they can be bio-derived or not). The reviewer commented that the presentation generates some confusion about the performance characteristics that

the Merit Function has been developed to address. The reviewer elaborated that in previous Co-Optima presentations, the Merit Function has been portrayed as a metric for predicting relative SI engine efficiency based on fuel properties; that implies that other metrics are needed and will be used to evaluate other key parameters such as emissions and cold start performance. The reviewer noted that in the current presentation, however, no mention is made that the Merit Function pertains to engine efficiency, and it comes immediately after a statement of the Central Fuel Hypothesis that "If we identify target values for the critical fuel properties that maximize efficiency and emissions performance..." Further, the PMI has a term for PMI, but lacks terms for other important emissions components. This leads to some confusion as to whether the Merit Function alone will be used to assess the potential of the various components in engines or whether the intent is still to include other important engine performance parameters in assessing candidate components. The reviewer commented that the specific approach of coupling engine experiments with modeling and simulation is a good approach. The reviewer added that it will be critical to validate that the Merit Function does correlate very well with efficiencies obtained in SI engines that are representative of what will be in the market in the near future.

Reviewer 3:

The reviewer praised the work as being very interesting and relevant, and said it will help to support the reviewer's company in producing products that meet not only the current portfolio for today, but also a balanced portfolio for the future. The reviewer stated that the project directly contributes to the understanding of the use of energy in an efficient and clean manner. The reviewer thanked the project managers for the support of this project and efforts, and appreciated that they are open to some coaching support and advice from reviewers. The reviewer added that there is important research going on in this project that needs to continue. The reviewer is in complete agreement with the approach and eagerly awaiting the significantly important results of the project. The reviewer had two questions: whether the material on Slide 8 was CA10-CA90; and, referencing Slide 21, what LFV150 is and how it relates to SPI.

Reviewer 4:

The reviewer liked the quest to quantify how octane could actually be used on drive cycles. The reviewer wished the PI could also develop a correlation to say how it would behave with a newer engine, e.g., downsized and/or higher compression ratio (CR).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said great progress to date.

Reviewer 2:

The reviewer commented that, due to the sheer number of light-duty vehicles in the United States powered by SI engines, even modest efficiency gains can go a long way towards accomplishing DOE's overall project goal of displacing petroleum and consequently improving national energy security. Consequently, the reviewer added, the fundamental research being conducted as part of this project to better understand the impact of fuel properties on engine efficiency is critical for achieving a substantial market impact. The reviewer added that excellent progress has been made over the past year, and the constant volume ignition delay experiments and the completion of the engine test campaign evaluating knock propensity of the core Co-Optima fuel matrix were significant achievements. The reviewer stated that continuation of the ongoing efforts, aimed at quantifying and finalizing the ideal fuel properties for enhanced engine efficiency, is crucial for delivering an output that can provide immediate value to the various stakeholders and the society at large.

Reviewer 3:

The reviewer stated that the project has made significant progress and accomplishments so far. The reviewer is looking forward to continued good work in the future, saying that this is the kind of work and research that we are looking for from the industrial perspective that aid us in making critical and necessary design decisions.

Reviewer 4:

According to this reviewer, the projects shows very good technical progress. The reviewer commented that Sluder's experimental results in a multi-cylinder engine coupled with Autonomie vehicle modeling showing that at higher compression ratios (of 11.4) there is still 6% lower fuel economy for a gasoline turbocharged direct injection engine in the US06 drive cycle for E20 blends is very interesting. The reviewer added that the results of the effects of fuel heat of vaporization on load (indicated mean effective pressure) versus intake manifold T are interesting, but assessment/information on the projected actual values of intake manifold Ts in near future production engines would help to put the results in perspective. The reviewer stated that the desire to prove that the Central Fuel Hypothesis is correct seems to be the driver for making the statement on Slide 19 that the "Data validates the Central Fuel Hypothesis," despite the fact that it did not hold for two of the seven fuel blends tested.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer praised the significant collaborations within the national laboratories and within industry, and was pleased by the interactions on this project with the team.

Reviewer 2:

The reviewer stated that the fact that this project involved contributions from nine national laboratories and 13 universities is testament to the excellent level of collaboration and coordination between the various partners. In addition, according to this reviewer, the project leaders did a good job of apprising the various stakeholders of the progress being made in the project through periodic updates during the monthly conference calls.

Reviewer 3:

The reviewer noted that there is some engagement with industry through occasional stakeholder teleconferences, although the collaboration would be significantly improved by more timely release and discussion of detailed results.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the proposed future research is critical for refining the Merit Function for light-duty SI engines. In addition, according to this reviewer, completing the ongoing work to quantify and finalize the desired fuel properties for improving engine efficiency is critical for providing an output that provides immediate value to the various stakeholders, including society at large, and consequently helps accomplish DOE's goals.

Reviewer 2:

The reviewer expressed full support of the proposed future work for this project, but indicated some concern that with the proposed budget cuts, this work might suffer or not be completed. The reviewer cautioned DOE budget cuts on this particular project, as the issues being addressed will enable further fuel economy and reduced emissions for current vehicles being designed, as well as future short-term engine solutions. The reviewer added that the project is showing some interesting impacts of fuels that have not been known before, and expressed thanks to the researchers for their continued pursuit of this work.

Reviewer 3:

The reviewer commented that the proposed plans look reasonable, but they could be improved by including more fundamental work on hydrocarbon components, to truly identify components that are optimal and commercially realistic for these near future engines.

Reviewer 4:

The reviewer said that to optimize the merit function and see how RON matters, the PI might try partnering with someone familiar with LP optimization in refineries. Adjusting the LP tool to optimize the merit function instead of profit might give some insights.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

In this reviewer's opinion, out of the various Co-Optima activities, this project has perhaps the greatest potential to have an immediate impact on the current production technology, and in the process, achieve DOE's overall goal of petroleum displacement. The reviewer added that, due to the potential of this project to have a positive impact on the society at large, it should be afforded all the support it requires.

Reviewer 2:

The reviewer stated that the project is critical to understanding the role of fuel properties on efficiency. The reviewer added that this is needed so that the various fuel properties can be established by the value of their contribution to efficiency improvements.

Reviewer 3:

The reviewer commented that improved engine efficiency and lower emissions are consistent with DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that resources are currently sufficient, although they may not be sufficient to cover all areas if the budget is reduced.

Reviewer 2:

The reviewer stated that the researchers did not indicate that the funding was not a factor for this project; however, due to the nature of the LSPI work, there may be a need for additional hardware to repair engines and testing equipment for continued testing and longevity of the project. The reviewer recommended making sure that this project has sufficient funding for a successful completion, as the data are relevant and of high value to industry.

Reviewer 3:

The reviewer stated that the resources allocated to this project for 2017-2018 are grossly insufficient, and this project cannot be expected to reach a successful conclusion with the allocated funds. The reviewer added that, as the expected deliverables of this project are extremely relevant for the current and near future production technology, and the success of this project would go a long way in accomplishing DOE's overall goals, this project should be provided all the support possible.

Presentation Number: ft054
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 2
Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

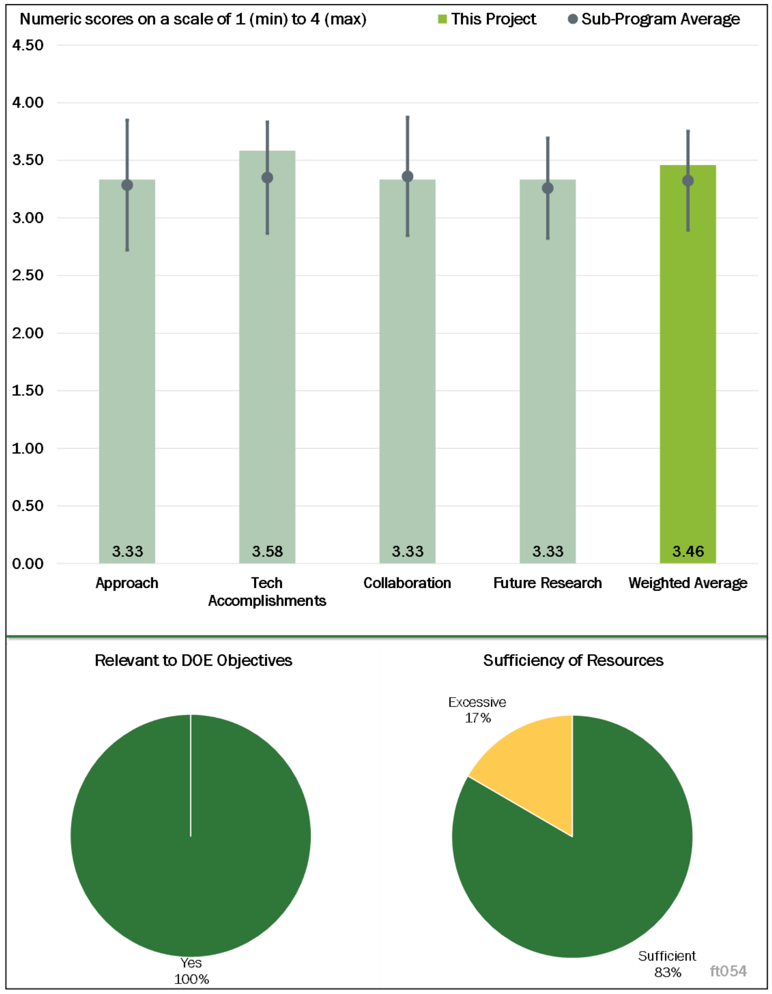

Figure 5-12 - Presentation Number: ft054 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel-Property Impacts on Spark Ignition Efficiency, Part 2 Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

Presenter
Chris Kolodziej, Argonne National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the approach taken in this project, using engine experiments and simulations to provide information regarding how fuel properties affect engine efficiency, is excellent and will help in addressing the barriers identified in the project.

Reviewer 2:
The reviewer stated that the approach to each of the three (broadly defined) tasks undertaken to date is well explained in the task slides. Moreover, according to the reviewer, the overall "approach," i.e. how the work tasks fit directly into the development and testing of the SI Merit Function and ultimately, the Co-Optimizer, is very clear. The reviewer noted that how the other terms of the Merit Function are being tested and defined is less clear, but this is apparently outside the scope of this task.

Reviewer 3:
The reviewer commented that the project is well conceived, plays an important role in Co-Optima, and addresses critical technical barriers. The reviewer's only small concern at this point is that collaborations could be expanded to include others with CFR engines and/or modified CFR engines. The reviewer mentioned a group led by Andre Boehman, at the University of Michigan, that has modified a CFR engine to eliminate the carburetor entirely and use a port-fuel injection system and heater upstream of the engine to produce the desired fuel/air mixture at the desired temperature.

Reviewer 4:
The reviewer indicated that, overall, this project is very well designed to better understand the fundamentals of fuel properties on downsized, boosted SI engines, which is important to achieve the overall Co-Optima goals.

The reviewer added that the project is feasible and integrated with other efforts, but stated that one area that can be improved is how to better quantify the fuel effect on low-speed pre-ignition (or superknock).

Reviewer 5:

The reviewer commented that the project approach focuses on fuel property impacts on engine efficiency and on developing models for predicting fuel properties and characteristics for boosted SI engines. The reviewer added that the approach uses the Merit Function to validate the Central Fuels Hypothesis. The reviewer noted that the statement on the barrier does not seem pertinent to this sub-project of Co-Optima. According to this reviewer, all the topics, fuel effects on dilution tolerance, RON and HoV effects, and development of the virtual CFR engine, address downsized boosted engines, which are very pertinent for light-duty OEMs.

Reviewer 6:

The reviewer praised the project's excellent work to understand the effect of various fuel properties on SI engine performance characteristics. The reviewer added, however, that it was not entirely clear from the presentation how the engine performance, like the lean dilution limits and exhaust gas recirculation (EGR) limits, feeds back into the merit function and co-optimizer. The reviewer recognized these to be critical to optimizing the engine efficiency while meeting emissions limits. The reviewer stated that the overall approach is very good, and understanding the performance aspects of critical fuel properties is at the core of this work, and added that this knowledge will be critical to determining the impacts of fuel/engine system optimization. The reviewer liked the fact that uncertainty is captured in the Co-Optimizer tool, and added that it is important that the output is capable of producing distributions and space plots rather single curves, although in that case additional guidance will likely be required to ensure the results can be interpreted. The reviewer commented that one thing that did not come across clearly from the presentation is the approach that is being taken to capture all of the engine efficiency aspects, i.e., the identification and prioritization part, and then a schedule of how those will be addressed. The reviewer commented that perhaps this was part of previous reviews, but it seems an important step to understand the context of where things stand with the current progress.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the PIs have made significant progress on all 5 tasks.

Reviewer 2:

The reviewer indicated that work to date has been successful in showing the relationship to HoV, as well as intake air, to RON ("equivalent RON") at least for carbureted engines. The reviewer commented that it also has a well-determined relationship of laminar flame speed (LFS) to lean and EGR tolerance. The reviewer added that future research will be facilitated by the development of a "virtual CFR Engine" to predict RON and S, which also provides potentially valuable kinetic information for the Merit Function and Co-Optimizer directly. The reviewer praised the slides and presentation for being very clear.

Reviewer 3:

The reviewer stated that the project's technical accomplishments continue to move the effort toward meeting the DOE goals of petroleum displacement. The reviewer added that accomplishments include validation studies at RON/motor octane number (MON) conditions to show that the CFD setup can capture fuel sensitivity to knock propensity, and a co-optimizer tool for mathematical analysis of fuel cost and engine efficiency has been developed for stakeholder use.

Reviewer 4:

The reviewer stated that everything is completed or on track for completion.

Reviewer 5:
The reviewer commented that all the accomplishments contribute towards understanding the tradeoffs in selecting fuel blends that have high Merit Function scores.

Reviewer 6:
The reviewer commented that the work shows excellent capability of making progress against identifying the parameters of the Merit Function and the development of the Co-Optimizer tool. The reviewer questioned whether a comprehensive set of parameters has been addressed to generate charts like that on Slide 19, and indicated that it is not entirely clear if there is a master list that is being considered as data are available, or if the most critical parameters are being addressed and then other effects will be considered later. The reviewer added that the modeling capability with the virtual CFR engine results was impressive, and the capability of prediction shown on Slide 14 seems very powerful, even beyond the scope of this project. The reviewer stated that only one project milestone is highlighted, and it is very broad, so it is difficult to get a good sense of the planned goals. Overall, the reviewer noted excellent progress, but indicated that it is not clear how the scope is being managed to ensure the Co-Optimizer tool captures the correct trends.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that there is evidence of excellent collaboration between a wide group of partners, and it seems that there is good cross-functional input into the project. The reviewer added that working within the scope of the Co-Optima project, having an advisory board reviewing the direction and gathering industry input are important aspects of this work.

Reviewer 2:
The reviewer stated that the project has excellent collaboration and coordination with nine national laboratories, as well as with Ford and Marathon Oil; the project also is working well with universities and an external advisory board.

Reviewer 3:
The reviewer stated that good collaboration exists among the national laboratories.

Reviewer 4:
The reviewer suggested that the authors consider expanding collaborations to work with other appropriate researchers, but added that budget cuts may make this difficult.

Reviewer 5:
The reviewer observed that, while utilizing a limited number of collaborators, the work to date had obviously done successfully, although most of it has been performed by a single laboratory (ANL) working with a major oil company participant. The reviewer added that NREL is shown as a key collaborator, but mainly for integrating the results of this work into the Co-Optimizer; similarly, reference is made to team of nine laboratories and monthly stakeholder meetings, but that apparently refers to the overall Co-Optima project, not to this task.

Reviewer 6:
The reviewer noted excellent collaboration within DOE laboratories, but hopes this project can create better collaboration with the oil and auto industries.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that it appears that the planned work will continue to provide valuable information about the impact of various fuel properties on SI combustion performance. The reviewer added that the goal of reducing uncertainty in the Co-Optimizer output is important, as is being able to guide the user in how to interpret the output based upon the known uncertainties.

Reviewer 2:
The reviewer stated that the proposed future work is a logical extension of the results achieved to date: applying relationships identified to top Co-Optima fuel blend/BOB compositions; further verification of the virtual CFR engine; and integrating results into the Co-Optima Merit Function.

Reviewer 3:
The reviewer stated that, assuming the funding levels are appropriated, the future research will continue to provide much needed information to address the barriers identified in the project.

Reviewer 4:
According to this reviewer, overall, the future research was very well planned, although one area that can be improved is how to better integrate the results from the five tasks to refine the Merit Function.

Reviewer 5:
The reviewer recommended that the top candidate fuels be tested as soon as possible in a typical downsized boosted gasoline engine.

Reviewer 6:

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer expressed the view that the Co-Optimizer tool is a good way to show that the combination of fuel properties and their capability to optimize engine performance is an important aspect to improving engine efficiency. The reviewer commented that this system approach has a high probability of identifying a means to improve engine efficiency.

Reviewer 2:
The reviewer stated that, by conducting engine, fuels and combustion experiments, this project provides information as to how fuel blends can help increase engine efficiency, which will definitely support the overall DOE objective of petroleum displacement.

Reviewer 3:
The reviewer commented that this task provides key information for the overall Co-Optima project, which could result in major improvements in engine efficiency, with attendant increases in fuel economy.

Reviewer 4:
The reviewer responded yes, this project supports the overall DOE objectives of petroleum displacement, and added that engine fuels and combustion experiments and simulations are necessary to improve understanding of how fuel blend characteristics can unlock increased engine efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer expressed the view that, with the project about 60% complete, it appears that resources are sufficient to complete the project as planned.

Reviewer 2:

The reviewer stated that the PIs have sufficient resources to achieve the stated milestones in a timely fashion; for example, the RCF engine has been well modified and instrumented for this project.

Reviewer 3:

The reviewer commented that the work proposed here has a very large potential scope and needs to be refined based upon the available resources. The reviewer added that there are sufficient resources to make a strong advancement of the understanding of fuel properties and develop the Co-Optimizer tool.

Reviewer 4:

The reviewer stated that, as with all DOE projects, the concern is what will happen when expected budget cuts take place, how will cuts affect this project and will it be able to continue moving forward effectively?

Presentation Number: ft055
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Multimode Lean Spark Ignition: Experiments and Simulation
Principal Investigator: Magnus Sjoberg (Sandia National Laboratories)

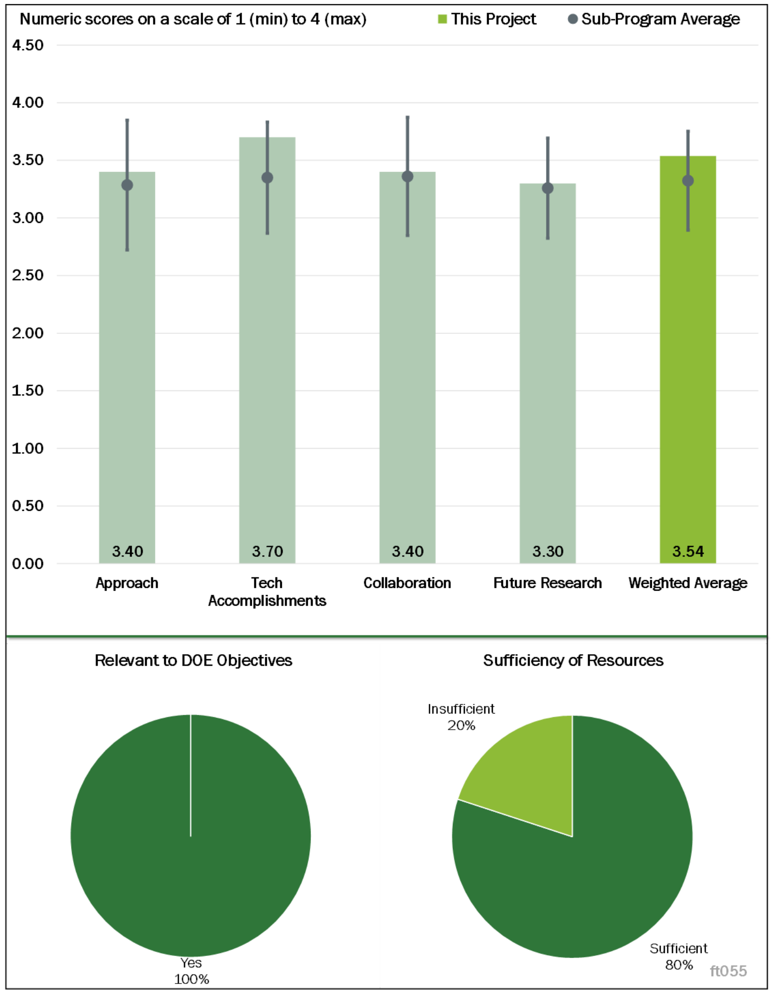

Figure 5-13 – Presentation Number: ft055 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Multimode Lean Spark Ignition: Experiments and Simulation Principal Investigator: Magnus Sjoberg (Sandia National Laboratories)

Presenter

Magnus Sjoberg, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer expressed the view that the approach taken, of running both metal and optical engine experiments with CFD modeling, is very good.

Reviewer 2:

The reviewer said that the testing hypothesis is well thought out and critical for future work.

Reviewer 3:

The reviewer commented that the approach adopted in this project not only supports refinement of the Merit Function for LD SI engines, but is also supporting development of diagnostic techniques that can help evaluate and troubleshoot engine operation for mixed-mode combustion regimes. The reviewer stated that it is encouraging to see that the Tier 3 fuels that were primarily intended for direct injection SI engines are also being tested as part of this project, thereby providing a link between the near and long-term efforts. The reviewer added that reviewer feedback from the 2016 DOE AMR was appropriately addressed and used to adjust the technical approach, with the goal of making the project more relevant for production applications. The reviewer indicated that, while the evaluation of particulate emissions is extremely valuable for current and near future production engines, it is not clear if the observed PM emissions were a consequence of the differences in the fuel properties or in the operating procedure. The reviewer suggested that isolating the fuel properties from operating strategy (e.g. fuel injection timing) may provide further insight into engine out PM emissions and how they relate to fuel composition.

Reviewer 4:

The reviewer noted that the researchers combine modeling, metal engine and optical engine experiments to develop a broad understanding of combustion changes due to fuel properties in direct injected spark ignited engines. The tests compared E30, high aromatics, high alkylate, high olefin and high cycloalkane fuels.

Reviewer 5:

The reviewer noted that the focus is on boosted advanced spark ignited gasoline combustion, like homogeneous and stratified charge lean combustion, and added that complementing the metal engine tests with optical engine tests and with CFD support at ANL is a good approach.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer remarked excellent progress, and that the PI is doing an excellent job as usual.

Reviewer 2:

The reviewer observed good progress, as demonstrated by completion of measurement of knock limits for five fuels; evaluation of applicability of PM index; and the discovery that pool fires cause E30 blends to have higher PM emissions than PM index predicts. The reviewer commented that this latter discovery has important potential implications for use of gasoline containing higher levels of ethanol than E10.

Reviewer 3:

The reviewer commented that this project has made excellent progress over the past year. In this reviewer's opinion, some of the notable accomplishments of the project include experimental data, in conjunction with CFD results used to refine the Merit Function; development of semi-quantitative wall-wetting diagnostic technique; evaluation of the impact of fuel composition on particulate emissions; and the use of Global Sensitivity Analysis to identify the most influential fuel properties. The reviewer added that the aforementioned accomplishments are in line with the overall goals of the Co-Optima program and have augmented the existing body of knowledge, particularly with respect to LD SI engines.

Reviewer 4:

The reviewer stated that the knock limits of the five fuel types have been related RON and MON at stoichiometry for both steady state and transient conditions. The reviewer added that demonstrating the role of low-temperature heat release for poor performance associated with low sensitivity fuels and determining some of the pitfalls of PMI are significant accomplishments, not to mention the myriad of other accomplishments like examining the wall wetting using E30 and its causes.

Reviewer 5:

The reviewer complimented the PI and team on the amount of relevant progress made this past year, saying that the results on S and knock are very pertinent. The reviewer added that the study on PMI versus soot for both well mixed and stratified designs at two operating conditions is interesting, and the wall wetting aspects of E30 and effect on soot are very pertinent. The reviewer commented on the good progress made on Mixed-mode combustion and transition.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented on the excellent collaboration between participating national laboratories, as well as industry partners. The reviewer added that it is worth noting that coordinating the activities across multiple teams and researchers requires a lot organization and the effort is worth applauding.

Reviewer 2:

The reviewer stated that the national laboratories are collaborating extremely well.

Reviewer 3:

The reviewer noted some collaboration mentioned with industry (GM, Toyota) and some of the other national laboratories (Lawrence Livermore National Laboratory [LLNL] and ANL).

Reviewer 4:

The reviewer complimented the team on good collaboration with the CFD at ANL and links to other ignition work at ANL and SNL.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the project has made good progress thus far, and continuation of several of the ongoing efforts is encouraged. The reviewer added that, in particular, continued development and use of optical diagnostic techniques in conjunction with CFD modeling is encouraged, as these activities can help develop a fundamental understanding of the underlying physics associated with advanced combustion modes. The reviewer cautioned that, while the scope of work is limited to low TRLs, practical considerations such as aftertreatment requirements and transient controls should be kept in mind while analyzing results and assessing the feasibility of the combustion concepts being proposed.

Reviewer 2:

The reviewer stated that the work plans seem reasonable.

Reviewer 3:

The reviewer stated that the proposed future research makes sense, as it is to finish up and further investigate the work they are doing.

Reviewer 4:

The reviewer suggested that perhaps updating the injectors and playing with injection pressure and timing would show how pool fires can be controlled. The reviewer acknowledged that this adds complexity but it might be interesting for future work.

Reviewer 5:

The reviewer stated that the interaction between an advanced SI engine (e.g., lean strat or multi-mode) and fuel type (say E30) and engine calibration variables like single and double pulsing is complex, and questioned how a Merit Function will be developed for such a situation. The reviewer also asked what would happen if the Merit Functions of an SI boosted engine and an advanced combustion engine predict the need for very different fuels.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that this is exceptional work that couples engine efficiency with emissions, and added that you cannot sell engines that do not meet emissions requirements.

Reviewer 2:

The reviewer stated that the information generated from this program should lead to the development of higher efficiency engines with better fuel economy.

Reviewer 3:
The reviewer commented that the investigations being undertaken as part of this project are in line with the overall DOE goal of petroleum displacement.

Reviewer 4:
The reviewer said that the project should save petroleum in new vehicles due to efficiency improvements if successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the very good progress in meeting milestones suggests that resources have been sufficient.

Reviewer 2:
The reviewer cautioned that the resources allocated to this project may not be sufficient for competing the proposed future work.

Presentation Number: ft056
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Exploratory Advanced Compression Ignition Combustion Tasks
Principal Investigator: John Dec (Sandia National Laboratories)

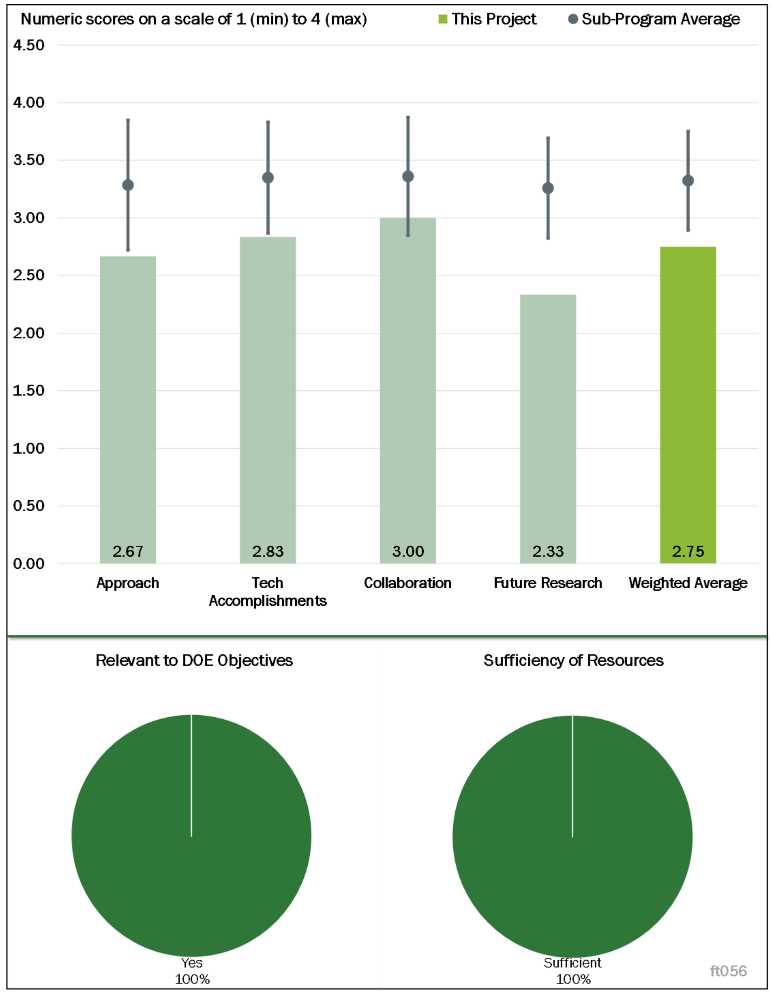

Figure 5-14 - Presentation Number: ft056 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Exploratory Advanced Compression Ignition Combustion Tasks Principal Investigator: John Dec (Sandia National Laboratories)

Presenter
John Dec, Sandia National Laboratories

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that generating data to support the fuel figure of merit is good, and investigating Thrust I SI boosted fuels in ACI engines and processes is good; however, the objectives of many of the ACI studies are too vague, and imply continuing to research a wide range of ACI recipes without a clear end point. The reviewer commented that Optima needs a finite timeframe for delivering data and answers to questions, and added that most of the ACI recipes have a long history already. In this reviewer's opinion, the sub-projects need to have more explicit outcomes and titles regarding questions being answered about fuels and combustion recipes. The reviewer added that the ducted combustion concept is interesting, but does not seem to fit well in the Co-Optima structure; it is more device development, rather than providing data for decision making and policy considerations. The reviewer recommended perhaps continuing it as a separate project.

Reviewer 2:
The reviewer appreciates the authors testing boosted-SI fuels in ACI combustion concepts, as requested in past reviews, and other responses to previous reviewer feedback. The reviewer stated that barriers should include higher fidelity, and the authors should more accurately describe the barriers to low temperature combustion concepts. The reviewer offered the following as examples of barriers: a lack of adequate CA50 control; challenges in transient control; challenges in switching between combustion modes; high combustion noise; high HC and CO emissions; the need for a lean-NO_x exhaust aftertreatment system; challenges in cold operation; limited speed and load range; and low exhaust temperature. The reviewer questioned whether, given this daunting list of challenges, the fuel is really being looked upon to solve all these issues. The reviewer opined that high engine fuel efficiency is the least of the worries; it has been shown numerous times over the past 15 years that the efficiency is very high.

Reviewer 3:

The reviewer stated that the presentation and slides are extremely confusing and difficult to follow. The reviewer commented that the presentation is apparently intended as an overview of various ongoing advanced compression ignition projects, but rather than giving a real overview, explaining the overall thrust of the research and how the different projects relate to each other, it seems to simply pick out what the presenter believes are the most salient features of each of the projects, and presents them outside of the context of other explanations. The result, according to this reviewer, is that both what is shown in most of the slides, as well as the significance of each, is extremely difficult to discern; compounding the problem is that the slides introduce many unfamiliar acronyms without defining or explaining them. The reviewer added that the relationship of the work to the Co-Optima program is especially unclear; further, the response to reviewers' comments slide explains away similar comments from last year, but the author apparently has made no attempt to avoid such problems in this year's slides.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that technical accomplishments cannot be readily discerned from the presentation due to the problems discussed in response to the previous question. The reviewer added that a great deal of data are summarized in graphs and a few conclusions are stated, e.g., RON and MON–S are insufficient to determine reactivity, but what they mean in terms of actual progress is not clear. The reviewer noted that the presenter stated that there might have to be up to five separate Merit Functions rather than a single one, which appears to negate the concept of the Co-Optima program.

Reviewer 2:

The reviewer stated that Co-Optima is relatively new and the data generated are impressive, publications etc.

Reviewer 3:

The reviewer stated that OI and potassium correlations are probably dependent on the engine combustion recipe, and questioned whether we are expecting to develop correlations for each of the known low temperature combustion recipes. The reviewer also asked, by the same token, if we will have a Merit Function for each of the different engine recipes. The reviewer commented that it seems like we need to downselect the low temperature combustion recipe, but questioned who gets to choose the winner.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that collaboration among the national laboratories is very good.

Reviewer 2:

The reviewer commented that various slides do reflect apparent collaboration and interaction between the various labs, in which results obtained by one suggest additional research by another one, but the actual significance is not clear, so that there is little basis for evaluating the quality and relevance of such collaboration.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer questioned whether OEM input has been sought for future ACI work, and whether light-duty OEMs really think reactivity-controlled compression ignition (RCCI) is commercially viable. The reviewer commented that a lot of emphasis is being placed on Low Temperature Gasoline Combustion-Advanced Compression Ignition (LTGC-ACI) and asked whether Light-duty OEMs have given encouragement for this type of work. The reviewer also asked about part-load homogeneous charge compression ignition (HCCI) in a downsized boosted engine that otherwise employs flame propagation combustion.

Reviewer 2:

The reviewer commented that the future research shown in Slide 19 consists of 4 bullets, each of which appears useful, though vaguely stated and without clear explanations as to how such work would proceed from the work referenced in the presentation for 2016, apart from the testing DFI in the optical engine which needs no real explanation.

Reviewer 3:

The reviewer stated that the future research objectives and subjects are mostly too vague and open-ended.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that, overall, Co-Optima can identify more efficient sets (plural) of fuels and engines.

Reviewer 2:

The reviewer commented that the project is intended to research modes of more efficient engine combustion, which would result in higher fuel economy, though much of the presentation is unclear as to how the results presented do this.

Reviewer 3:

The reviewer indicated that the project is relevant, but the emphasis is probably misplaced, per comments in other sections of this review.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer was not sure there is justification for the conspicuously higher investment in ducted combustion within the Co-Optima portfolio, and added that this is not saying anything about the ultimate merit of the idea, but more that Co-Optima is not the best fit for a Cooperative Research and Development Agreement on a specific technology development.

Presentation Number: ft057
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Emissions, Emission Control, and Sprays
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

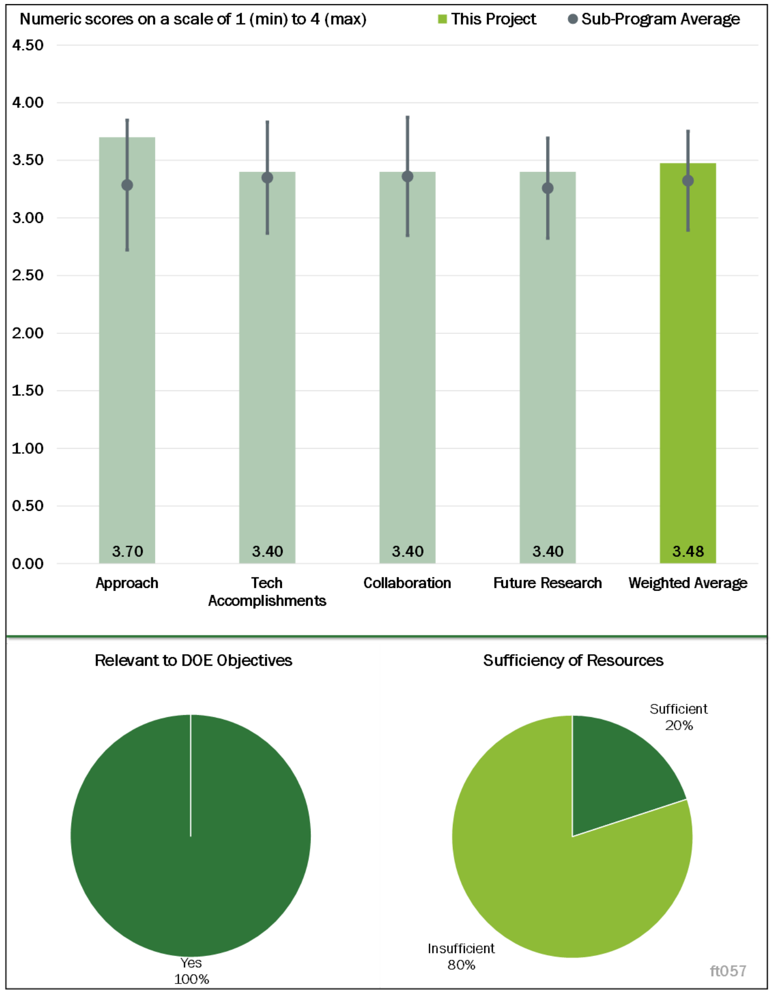

Figure 5-15 - Presentation Number: ft057 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Emissions, Emission Control, and Sprays Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter
Todd Toops, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked that this is a great project that is needed.

Reviewer 2:
The reviewer commented that there are five projects contained within the "umbrella" of this "Co-Optima Emissions, Emission Control, and Sprays" program, and each has its own merits and debits. The reviewer stated that evaluating the impact of candidate fuel components on injector sprays, emissions, and emissions control is very important to better assess the technical viability of the various candidates. The reviewer commented that it is unclear what the technical basis is for assuming that engine efficiency in the Merit Function is reduced by 0.7% if fuel PMI is less than 1.6, and added that it seems like that would be very dependent on the specific design of the engine and the engine operating conditions. The reviewer pointed out that one emissions aspect that appears to be missing is assessing the formation of toxics such as formaldehyde and acetaldehyde with the component candidates, which are predominantly oxygenates. The reviewer suggested that a robust evaluation of the candidates should include this aspect.

Reviewer 3:
The reviewer stated that engines with improved efficiency cannot be introduced in the market unless they meet stringent emissions criteria, and added that, in view of the importance of emissions criteria, the research being conducted as part of the current project is extremely relevant. The reviewer commented that the investigations being undertaken under this project address some of the most critical aspects of engine development, including fuel spray characterization, emissions, and aftertreatment. The reviewer concluded that the fundamental knowledge being generated here is pertinent to both near and long-term engine technologies.

Reviewer 4:

The reviewer stated that fuel sprays have a major effect on emissions, and found it encouraging that DoE has not forgotten that, and has allocated some of its most sophisticated spray measurement equipment to this task.

Reviewer 5:

The reviewer stated that Co-Optima is proposing eight fuel candidates for SI-intended blendstocks, many of them with oxygenates. The reviewer commented that fuel effects on exhaust aftertreatment performance (both catalysts and particulate filters) are an important part of the Co-Optima project aimed at future downsized boosted SI gasoline engines, especially as the PMI is expected not to correlate for oxygenated fuels. The reviewer added that fuel effects on fuel spray atomization, entrainment, vaporization and penetration characteristics need to be understood.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that a lack of funding is holding back some progress but the team is doing very well given the circumstances.

Reviewer 2:

The reviewer observed very good progress in several areas, and commented that the higher than expected PM values relative to PMI values, for fuels containing oxygenates, is very interesting, and suggests that higher levels of ethanol and/or alternative oxygenates may be detrimental. The reviewer stated that this calls into question the validity of the existing PMI term in the Merit Function. The reviewer also noted that the results of catalytic light-off temperatures for pure components are interesting, but we will need to see how that correlates to light-off behavior in blends. The reviewer observed that in some areas, such as the high throughput spray chamber, progress consists of equipment procurement and setup, and that some work apparently was delayed or postponed, such as X-ray studies of baseline fuel under flash boiling and non-flashing conditions in the new high-pressure fuel system.

Reviewer 3:

The reviewer stated that the findings of this project are applicable to current, near future, and long-term engine combustion concepts. The reviewer noted that some of the notable accomplishments include enhancement of optical measurement techniques for characterizing fuel sprays (SNL and ANL), an improved understanding of particulate emissions from oxygenated fuels, cold start performance of oxygenated fuels, and the impact of fuel composition on emissions control and durability.

Reviewer 4:

The reviewer noted that there is a significant amount of information generated from the accomplishments in this study. The reviewer commented that the accomplishments are excellent, however, in the reviewer's opinion, the researchers need more time to analyze and evaluate the data that have been generated.

Reviewer 5:

The reviewer stated that a good amount of work on understanding PM emissions during cold start, silver (Ag) selective catalytic reduction (SCR) catalysts, and catalyst light-off behavior has been accomplished. The reviewer commented that a Merit Function for emissions control or performance is a great idea and should be developed further.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked on the excellent collaboration between the various project partners, and noted that significant effort has been made to coordinate the various activities addressing fuel sprays and emissions, with the objective of ensuring that they complement each other.

Reviewer 2:
The reviewer was impressed with how well coordinated the work between the national laboratories has been.

Reviewer 3:
The reviewer commented that collaboration among laboratories is getting more seamless, but the project needs more involvement from aftertreatment suppliers.

Reviewer 4:
The reviewer observed that while there may be good collaborations between the various national laboratories doing the work in this area, collaboration with industry appears to be very limited, or light. The reviewer noted that collaborations with the External Advisory Board are listed, but those are very infrequent (only a couple of times a year) and tend to be high level. The reviewer commented that the authors also mentioned stakeholder engagements, which presumably include the monthly teleconferences, but topics are discussed on a rotating basis (so not very often for any given area) and tend to be a summary of some results, not a timely in-depth review and discussion of results and near-term plans.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that continuation of the ongoing investigations is vital to the success of both current and future combustion concepts; in particular, improving the fundamental understanding of fuel sprays and particulate emissions is critical for improving engine efficiency, while meeting the stringent emissions requirements.

Reviewer 2:
The reviewer noted that the proposed future research is to continue and finish the outstanding research that has been performed.

Reviewer 3:
The reviewer commented that additional work on low-temperature catalysts is critical for future low-temperature combustion engines and should be expanded.

Reviewer 4:
The reviewer stated that the list of future work (Slides 17 and 22) on PM response to cold start conditions is extremely important, and commented that the Ag-Cu SCR NO_x-catalyst work is very interesting and should be pursued.

Reviewer 5:
The reviewer stated that the future work seems reasonable; however, as mentioned earlier, the authors need to consider the effects of the candidate components on toxics emissions.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that reducing emissions is consistent with DOE goals.

Reviewer 2:
The reviewer commented that the investigations being undertaken as part of this project are crucial for the accomplishment of DOE's overall goal of petroleum displacement.

Reviewer 3:
The reviewer noted that the overall goal of this research is to displace petroleum with biomass based fuels.

Reviewer 4:
The reviewer commented that this project, especially the emphasis on fuel effects on exhaust aftertreatment, is extremely relevant. The reviewer noted that it is assumed that high-octane, high sensitivity fuels (fuel properties, not molecules) will yield high efficiency in SI, downsized, boosted gasoline engines, but what are unknown are the fuel effects on aftertreatment performance, because they are molecule dependent. The reviewer added that it would be a shame to let this project end due to budget restrictions.

Reviewer 5:
The reviewer said that emissions are the biggest threat to improved internal combustion (IC) engines, and that more work should be done on emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that several tasks and milestones, such as catalytic light-off behavior, apparently were delayed, but stated that presumably this was due to insufficient resources, rather than poor project planning. The reviewer added that this will likely become more of an issue if DOE program budgets are reduced for FY 2018.

Reviewer 2:
The reviewer stated that the resources allocated to this project for 2017-2018 are insufficient, and it would be unreasonable to expect timely completion of the proposed work with the funding allotted to this project.

Reviewer 3:
The reviewer suggested that the project scope be expanded to include more exhaust aftertreatment issues, like catalyst efficiencies, and to speed up the pace of work.

Reviewer 4:
The reviewer said that additional work on fundamental combustion is great and useful, but the engines will be illegal without proper emissions controls. This area may be getting shorted on funding because both the advanced combustion engine and fuels groups own it (and disown it as well). The reviewer said please increase the funding or at least do not cut it much if the Trump budget becomes anything close to reality.

Presentation Number: ft058
Presentation Title: High-Efficiency Cost-Effective Natural Gas Engine
Principal Investigator: Alexander Freitag (Bosch)

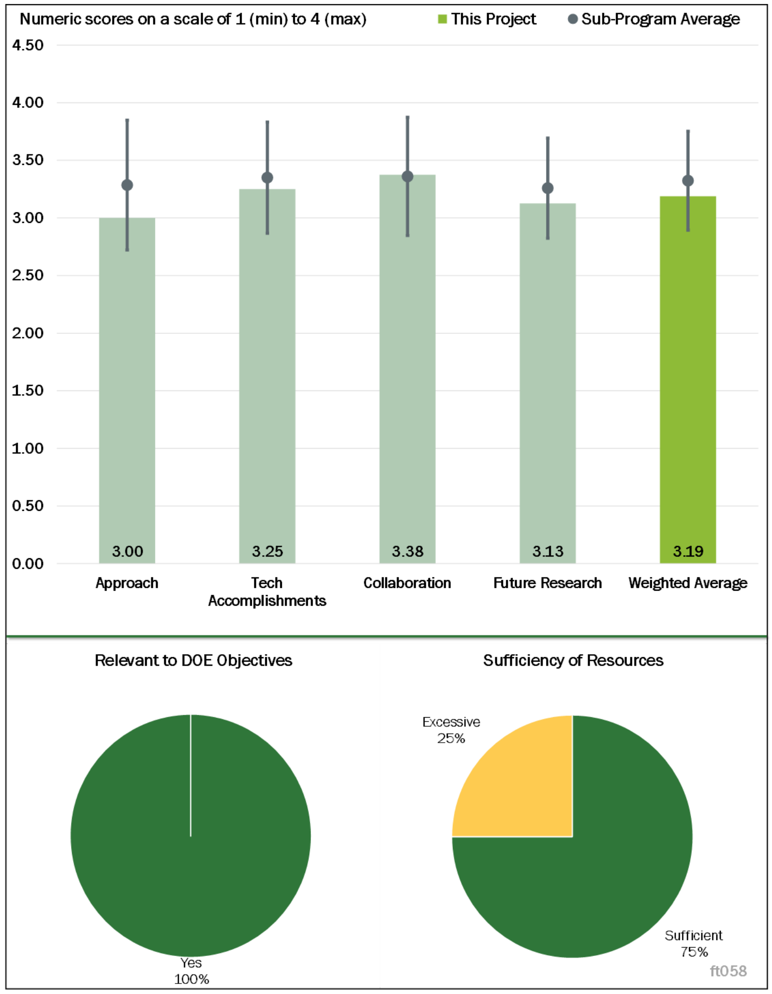

Figure 5-16 - Presentation Number: ft058 Presentation Title: High-Efficiency Cost-Effective Natural Gas Engine Principal Investigator: Alexander Freitag (Bosch)

Presenter

Steve White, Bosch

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that efficiency is to be achieved by high EGR dilution/lean CDI combustion enabled by ammonia (NH_3) generation in catalyst aftertreatment feeding passive SCR. The reviewer stated that hardware was selected from existing systems from diesel engines and installed, and engine combustion modes are being tested.

Reviewer 2:

The reviewer stated that the program is justified based on achieving a 20% increase in efficiency from a stoichiometric natural gas engine by extending lean limit with a high-energy ignition system and with lean / rich cycling of aftertreatment to utilize passive ammonia SCR NO_x reduction. The reviewer commented that the intent of using proven hardware where possible strengthens the project, while not allowing any changes to the base engine weakens it. The reviewer remarked that the base engine is a non-U.S. certified industrial engine and may not be suitable for extreme lean burn operation. It is not apparent to this reviewer that cost savings will be achieved over an active SCR system because two catalysts and a very complex control system will be required. The reviewer added that it is not apparent that fuel savings will be achieved, because rich cycling is needed to generate ammonia for passive SCR, and it is not apparent that technology will function over a wide range of transient operation, duty cycles, and ambient conditions.

Reviewer 3:

The reviewer expressed surprise that the project had been funded, as there is a lot of research and work available that has already been done through universities. The reviewer did not see how this project was new and unique and would require DOE funds to be used, and added that it would help if the researchers could further explain how this research work is providing something of R&D value to the area of NG engines. The reviewer commented that it is not clear that the project will meet the goals, and the items that are “out of scope” may need to be used to meet the efficiency targets.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer stated that good progress has been achieved in both hardware configuration and in identifying operating mode for maximum lean operation with adequate rich operation to provide NH_3 to SCR. The reviewer noted that 39% brake specific fuel consumption has been achieved to date, out of a target of 42% (versus base engine of less than 37%).

Reviewer 2:
The reviewer commented that the authors have made good progress in evaluating ignition system improvements, and in EGR and aftertreatment development, and added that they have achieved some efficiency improvements in base engine efficiency, but have not met their goals yet and have not done cycle simulation to determine losses from rich cycling.

Reviewer 3:
The reviewer stated that it looks like this project may not meet the efficiency targets, given the current progress. The reviewer noted that there is a plan to try to work towards the goals, but added that there is uncertainty in meeting the targets, and it seems like there is further process that needs to be made to complete the project, and a little over a year to do this in.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that Slide 16 shows substantial and appropriate division of research between 3 project partners and 2 suppliers/support organizations.

Reviewer 2:
The reviewer noted that the program included involvement of an OEM engine company and a tier 1 supplier for ignition systems, and that a national laboratory is contributing the aftertreatment technology.

Reviewer 3:
The reviewer commented that there is a good list of collaborators and good coordination with the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed future research is a logical progression of the work to date, so as to bring about successful conclusion of the project.

Reviewer 2:
The reviewer found that there is a good plan for future work to complete this project, but questioned whether the authors are optimizing the aftertreatment size of the three-way catalyst (TWC) and SCR for the project to run lean more often, which will enable the efficiency targets. The reviewer expressed the hope that the authors provide information on the cost of this system to enable the efficiency, and the cost trade-offs.

Reviewer 3:
The reviewer commented that it is not specifically stated, but researchers need to compare this engine concept to an engine running stoichiometric with a three-way catalyst, and to an engine concept of continuously lean

operation with urea SCR NO_x control. The reviewer noted that only then will gains and tradeoffs be clearly demonstrated. The reviewer added that it also appears that the engine and aftertreatment control strategy will be very complex, and it is not clear how far this development will be carried.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that the program is relevant because it promotes the use of natural gas as a fuel and because it seeks to improve engine efficiency while maintaining emissions at the required level. The reviewer added that the project is relevant because it seeks to study a "high risk" advanced concept of engine and emissions control.

Reviewer 2:

The reviewer responded yes, this project is relevant to meeting the DOE objectives of petroleum displacement. The reviewer wondered, however, about the use of natural gas in the United States, and why we would want to work on this project, as there is limited infrastructure to supply natural gas (NG) for vehicles. The reviewer was not sure why this project would be funded, and added that it seems like this kind of research work has been completed before, so it is unclear what is new and unique with this.

Reviewer 3:

The reviewer stated that by enhancing the efficiency of NG engines, this project has the potential to increase their cost-effectiveness and overall deployment as substitutes for petroleum-burning engines. The reviewer added that greater efficiency and reduced use of natural gas is an additional benefit, in terms of overall energy security and greenhouse gas reduction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources seem adequate to complete the project as planned, providing current funding levels are maintained.

Reviewer 2:

The reviewer expressed the opinion that the resources for the project are excessive, and added that based on projects with which the reviewer has been involved in the past, this could be accomplished for much less. The reviewer added that, given that the base engine hardware was being used for the project and there was no combustion system development, it was a struggle to figure out what the costs of the project are. The reviewer recommended that, if there is some control system development to run the engine and the project, it would be good to highlight that and the developed capability to run the system.

Presentation Number: ft059
Presentation Title: High BMEP and High Efficiency Micro-Pilot Ignition Natural Gas Engine
Principal Investigator: Jeffrey Naber (Michigan Technological Institute)

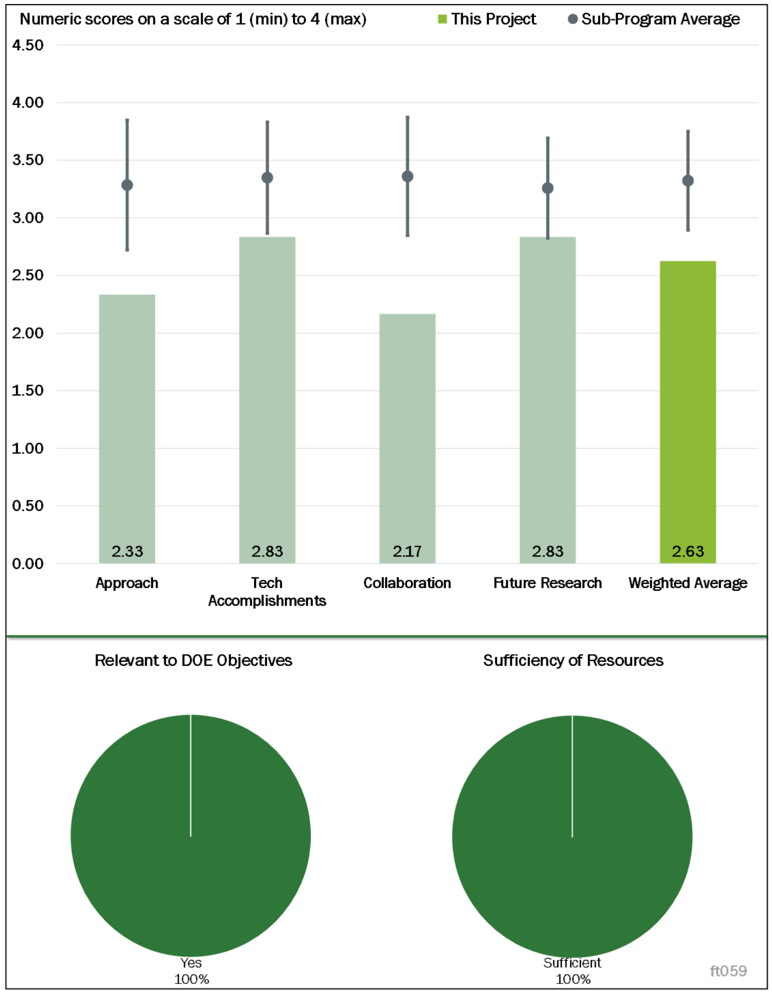

Figure 5-17 – Presentation Number: ft059 Presentation Title: High BMEP and High Efficiency Micro-Pilot Ignition Natural Gas Engine Principal Investigator: Jeffrey Naber (Michigan Technological Institute)

Presenter

Jeffrey Naber, Michigan Technological University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that this seems like a very detailed study looking at aspects of the project- mixing of the fuels with a micro pilot. The reviewer does not believe that this is new research, and is aware of some that has been previously published. The reviewer recommended checking Penn State work with Andre Boehman, and expressed the hope that this is in the literature review. The reviewer further recommended checking Southwest Research Institute (SwRI) research work. The reviewer suggested looking at the impact of the Cetane number of the fuel on the pilot ignition, by spanning the Cetane number from 40 to 80 with different kinds of fuels. The reviewer also suggested looking at the fuel distillation curve of the pilot injection, and stated that this would be an interesting aspect of the research and would make it more relevant and new. The reviewer also stated that the data for the fuel, shown on Slide 4, should be based on an energy basis of the quantity of the fuel injected; this would make it easier to understand the efficiency improvement and brake mean effective pressure (BMEP) change based on the energy density of the fuel. The reviewer commented that it appears that the authors are just getting started on the engine testing. The reviewer is looking forward to seeing the results of the improved fuel efficiency.

Reviewer 2:

The reviewer commented that, with its high-pressure direct injection (HPDI) 2.0 injector, Westport already has dual fuel (compressed natural gas [CNG] plus diesel) technology in production, and the presentation did not establish how the current dual fuel approach is different than, and superior to, Westport's HPDI 2.0 injection system. The reviewer stated that modern diesel engines are already capable of achieving and exceeding 44% brake thermal efficiency (BTE); thus, it is not clear how the 44% BTE target mentioned in the presentation addresses DOE's goal of reducing fuel consumption. The reviewer noted that stoichiometric fueling is presented as a positive, as it enables use of a three-way catalyst for exhaust aftertreatment; however, the presentation also mentions ultra-lean operation at low load conditions, and it is not clear how the aftertreatment for ultra-lean conditions will be accomplished without the use of lean aftertreatment systems. The reviewer also noted that use of CNG as the primary fuel has been presented as a benefit, as it provides a lower carbon dioxide (CO_2) and lower cost solution than diesel; however, the use of CNG also implies additional hardware cost due to the need for a second fuel injection system and fuel storage capability. The reviewer stated that it would be beneficial to present a cost-of-operation benefit that also considers the cost of the additional hardware. The reviewer also stated that switching from diesel to CNG should perhaps yield an improvement in CO_2 emissions greater than 10-15%, as mentioned in the presentation.

Reviewer 3:

The reviewer's impression, based on the information provided by the slides and PI, is that this project set up an objective that is too ambitious. The reviewer stated that the major challenges of the NG-diesel dual fuel engine at different loads are different; at low load, it is high HC and CO emissions and thus the engine needs to use a high amount (percentage) of diesel, whereas at high load, it is the high thermal load, due to the thin flame quenching distance. The reviewer expressed the view that the PI did not propose solutions significantly different from the other studies to address these challenges.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that satisfactory progress has been made and the project is in line with the proposed plan. The reviewer noted that accomplishments over the past year included baseline engine testing, combustion vessel modeling, and spray characterization under different operating conditions.

Reviewer 2:

The reviewer stated that, overall, the PIs made decent progress to study NG-diesel dual fuel combustion.

Reviewer 3:

The reviewer commented that, based on the schedule, it looks like the PIs are just getting started with the engine testing, but the program looks like it is almost halfway complete. The reviewer expressed the hope that the PIs can get the data they need to show the improvement by the end of the program, given the challenges. The reviewer added that there is a lot of work to do to make this system work, and that getting control in the system, measuring the fuel injection quantity, and determining the metrics of the energy basis will be challenging.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that Westport is the principal partner and has been supporting the project with CFD modeling, engine hardware, and pertinent test data, and suggested that perhaps Westport can provide additional insights and help make comparisons against their HPDI 2.0 fuel injection system.

Reviewer 2:

The reviewer commented that it appears there is only one partner on this project, and it would be helpful in completing the project to have more than one collaborator who might help and assist in making the project successful, unless the current project sponsors are comfortable with continuing with only the shared responsibilities. The reviewer suggested that it would be nice to see if any of the national laboratories could be consultants, or perhaps Charlie Roberts from SwRI.

Reviewer 3:
The reviewer stated that Westport is the only collaborator, and recommended that the PIs also work with other HD engine OEMs such as Volvo truck, who actually commercialized NG-diesel dual fuel engines for medium-duty (MD) trucks.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed research is in line with the goals of the project.

Reviewer 2:
The reviewer commented that, overall, the proposed future research is fine, but added that it appears the PIs underestimated the barriers.

Reviewer 3:
The reviewer commented that the future work for FY 2017 and FY 2018 looks interesting and challenging, and expressed the hope that this can all be completed in the next 2 years. The reviewer added that there is quite a bit to do to get the system working.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer responded yes, with abundant NG in the U.S., advancing NG engines will support the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer responded that, yes, this supports the overall DOE objectives of petroleum displacement; however, it was unclear to the reviewer what the future of natural gas is in the United States. The reviewer stated that there is not the infrastructure in place for NG refueling; however, the success of this project could provide the impetus for increased NG locations.

Reviewer 3:
The reviewer stated that displacing diesel with CNG as the primary fuel supports DOE's goal of petroleum displacement; however, the presentation has not clearly established how the work being conducted under this project is advancing the state-of-the-art and surpassing the dual fuel technology already in production.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that there are enough resources to perform the tasks proposed by the PI.

Reviewer 2:
The reviewer commented that resources appear to be sufficient for the proposed scope of the project.

Reviewer 3:
The reviewer noted that this project is only 25% completed, so it is unclear if the resources are sufficient. The reviewer added, however, that it seems that there is a plan in place to complete the program within budget.

Presentation Number: ft060
Presentation Title: Single-Fuel Reactivity Controlled Compression Ignition Combustion Enabled by Onboard Fuel Reformation
Principal Investigator: Ben Lawler (Stony Brook University)

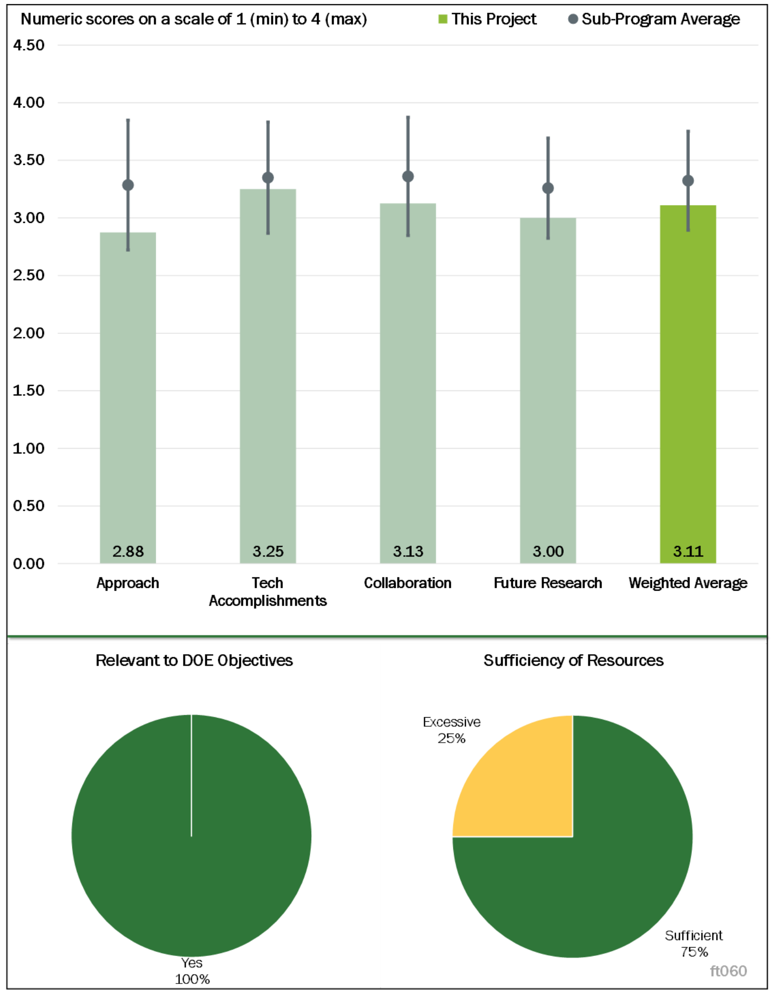

Figure 5-18 – Presentation Number: ft060 Presentation Title: Single-Fuel Reactivity Controlled Compression Ignition Combustion Enabled by Onboard Fuel Reformation Principal Investigator: Ben Lawler (Stony Brook University)

Presenter
Ben Lawler, Stony Brook University

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that this project provides research into one possible concept for controlling advanced combustion, and should provide sufficient information to allow evaluation of the concept. The reviewer added that the concept is using on-board reforming so that a single fuel can be “split” into a high reactive and a low reactive fuel for regulation of RCCI; the fuel is “split” by reforming a portion of it using catalytic partial oxidation.

Reviewer 2:
The reviewer commented that the three-step approach outlined is logical, apart from the deferring of the development of the actual on-board reformer, which is outside the scope of the project. The reviewer added that production and characterization of reformate from NG, gasoline and diesel, and subsequent modeling, paves the way for actual testing of a viable parent fuel.

Reviewer 3:
The reviewer commented that, after hearing the presentation, it was unclear what the value of this project was. The reviewer added that there is a lot to be understood on the fuel reforming and the reformer, and this is not a mainstream technology that is being pursued in the industry for application within the next 10 years. The reviewer suggested that what might be better is to understand the types of fuel molecules that provide the reactivity that is needed for a particular flame speed required in the engine for a given condition, or rate of reactivity needed. The reviewer requested clarification on the fuels used in the project, i.e., was it a certification diesel and not a production fuel? The reviewer also inquired about the biodiesel content of the fuel. The reviewer suggested that the PI may need to evaluate better reforming technology, knowing that it will lose energy and becomes an inefficient solution.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that reformate has been produced and characterized, with modeling run on reformate, resulting in down-selection to a single parent fuel (diesel). The reviewer added that the test engine was configured and operational.

Reviewer 2:
The reviewer commented that the researchers have successfully reformed diesel fuel, gasoline, and natural gas with catalytic partial oxidation, and were successful in measuring the reactivity of the reformate as equivalent octane, as measured with a CFR engine. The reviewer stated that this method seems well adapted for this type of measurement, and somewhat novel; unfortunately, the reformate became less reactive than the parent fuel (for gasoline and diesel), resulting in the need for reforming the majority of the RCCI fuel with resulting larger energy loss in the catalytic partial oxidation (CPOX). The reviewer added that, for gasoline and especially for natural gas, the separation of the octanes between the parent fuel and the reformate does not appear to be large enough to allow effective RCCI. The reviewer commented that it appears that enough information has been taken to allow modeling any potential efficiency benefits from RCCI and energy losses from the CPOX process.

Reviewer 3:
The reviewer stated that this project is 50% complete, but seems to still have some technical challenges. The reviewer added that there is a very detailed plan to follow, but some significant technical issues were brought up to address. The reviewer suggested that it would be helpful for the researchers to have a fuel analysis, so that the fuel properties can be used to help to further elucidate the energy content and efficiency of the reformer, as well as the fuel chemistry and reactions. The reviewer commented that it was still not clear why diesel use was chosen over the use of gasoline, as it seems that the gasoline fuel would have been easier to ignite, given its distillation characteristics and lower octane value. The reviewer postulated that this is due to the use of HCCI as the diagnostic, which would indicate that a diesel fuel will have autoignition characteristics. The reviewer referenced other issues noted on Side 12.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that, although the project has only three partners, two of which are essentially subcontractors, the work division is appropriate for the scale and nature of the project.

Reviewer 2:
The reviewer commented that it appears that the reformer technology supplier is well equipped to provide hardware and technology for the project, and inclusion of a university for chemical analysis of the reformate provides an important contribution to the project. The reviewer stated, however, that having no collaborations with engine or auto companies, fuel companies, or tier 1 suppliers weakens the project.

Reviewer 3:
The reviewer noted that there is good collaboration and coordination on the project, but suggested that it might help to have some national laboratory participation in the project so that some of the technical issues can be elucidated with the consultation of experts in the area.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that actual experiments with the parent fuel/reformate mixing in an engine configured to RCCI will proceed after further validation of the CFD model.

Reviewer 2:

The reviewer noted that the project has a very important go/no-go decision point (decision point two) coming in a few months, i.e., can the engine achieve better efficiency operating on a single fuel and its reformate in RCCI than it can operating conventionally? The reviewer stated that this decision needs to be very rigorously evaluated to determine the value of this concept. The reviewer observed that the project does not appear to have additional fuels in the plan, and does not appear to include development of a transient control strategy. The reviewer commented that this is probably appropriate, because this research is definitely exploratory and high risk, and added that any problems with the CPOX, such as coking or catalyst deactivation, also need to be documented.

Reviewer 3:

The reviewer stated that this is a very challenging set of experiments, and it will be hard to model CFD and engine conditions with fuels that are multicomponent. The reviewer suggested using some simple primary reference fuels for some initial tests, and then a multicomponent fuel to show how the models and experiments compare, but added that this is not a trivial task. The reviewer commented that the results will demonstrate how difficult this is for RCCI and control of a system, which is why this technology is very far away from implementation. The reviewer added that, until a system can be demonstrated to use a market multi component fuel, this type of research will be needed to investigate this methodology, and it demonstrates the challenge for OEMs.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that the development of more efficient engine concepts and modification of fuel to make it more compatible with advanced combustion concepts definitely supports DOE's goal of energy efficiency.

Reviewer 2:

The reviewer stated that the project could pave the way for RCCI without the need for storage of two separate fuels on board, assuming an on-board reformer can be designed, and noted that other companies are working on that in hydrogen engine related research. The reviewer commented that this could make RCCI a more viable and attractive option, with its enhanced efficiencies and increased fuel economy.

Reviewer 3:

The reviewer commented that, for this project, if some efficiency gains can be demonstrated, and natural gas can be used, then this would meet the stated goals; however, at present, the project is also using diesel and gasoline, and there are some issues with the efficiency in the system. The reviewer responded yes to this question, but added that it was a stretch to do so.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that resources appear to be sufficient to complete the project if funding levels are maintained.

Reviewer 2:

The reviewer noted that there is a lot of money being spent on this project by the DOE, and expressed the view that it is imperative that several national laboratories be involved to support in consultation, to make sure that the value in this project is accomplished in support of the project goals. The reviewer expressed uncertainty about the project's ability to meet it stated goals, and noted that there seem to be a lot of resources involved in the work.

Presentation Number: ft061
Presentation Title: Methods to Measure, Predict, and Relate Friction, Wear, and Fuel Economy
Principal Investigator: Steve Gravante (Ricardo)

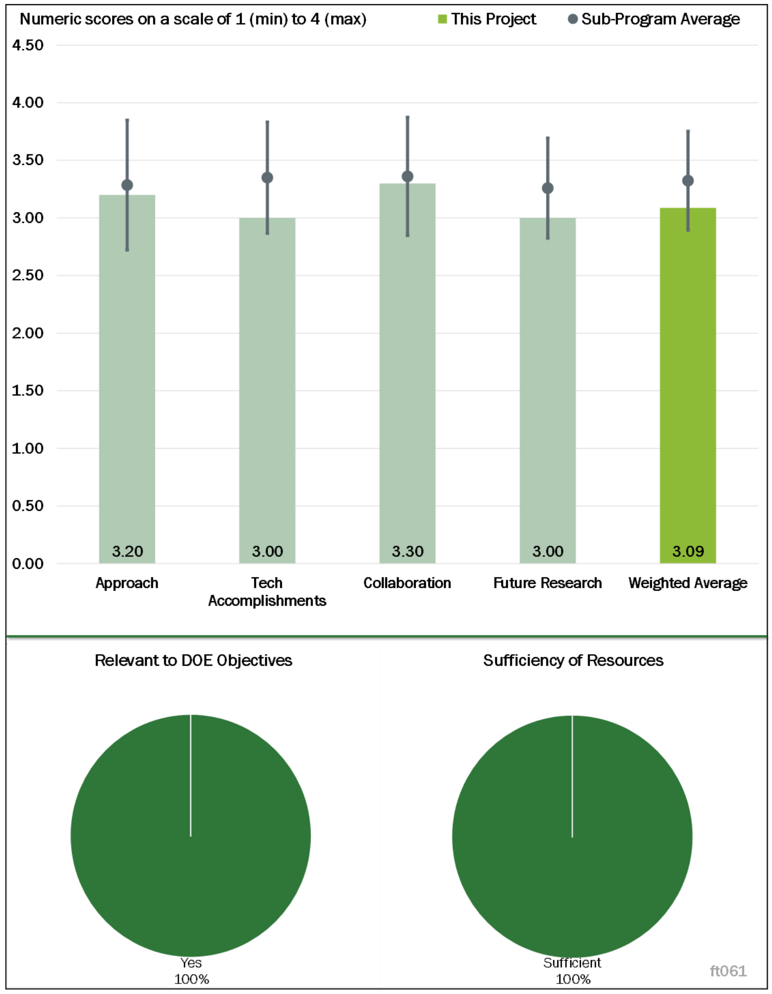

Figure 5-19 - Presentation Number: ft061 Presentation Title: Methods to Measure, Predict, and Relate Friction, Wear, and Fuel Economy Principal Investigator: Steve Gravante (Ricardo)

Presenter
Steve Gravante, Ricardo

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that combining a benchtop test, rig test, modeling and simulation to develop a tool to predict system changes seems feasible, and noted that the PIs are using established experimental tests and models to help mitigate some risk.

Reviewer 2:
The reviewer commented that the project took a very interesting and unique approach to developing methods capable of predicting the impact of friction reduction technologies on engine fuel economy and wear, and noted that the methods of prediction are supposed to be both empirically and analytically based.

Reviewer 3:
The reviewer liked the linkage to real engine friction measurement.

Reviewer 4:
The reviewer stated that the project seeks to correlate bench measurements of friction and wear to various motored single cylinder engine tests, and develop correlations which can be used to predict potential effects of new technologies. The reviewer noted that the project uses a matrix of oils and materials to evaluate viscous and boundary friction and wear, and the expected deliverable is an empirical model which can relate basic lab measurements to engine friction and wear. The reviewer observed that the project is developing a methodology, not proving or selecting improvements for power cylinder rings and skirt.

Reviewer 5:
The reviewer expressed a number of reservations about this project. The reviewer stated that there has been a good deal of prior work done by the project leader’s own company in the last 5-6 years, and added that this project should have described the current state-of-the art, and explained how the project would advance the

current state-of-the-art, but this has not been done. The reviewer commented that, as such, it is difficult to know if the current project is justified in the base case. The reviewer noted the limited amount of engine testing envisioned in this project, using very few test oils, and engine hardware that is not representative of the prevalent engine designs in the U.S. market, and concluded that it is unlikely to yield models that are sufficiently reliable or relevant to the U.S. market.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that the test oils, hardware and test matrix have been finalized; however, the main body of the work which involves actual engine testing has not begun.

The reviewer questioned what the kinematic viscosity of synthetic OIL C which is currently being used in all studies is. The reviewer found it surprising that the authors selected not to summarize and present their experimental data collected on the original matrix of eight (8) oils, as it was proposed and tested during the 2016 program's presentation. The reviewer noted that it is advisable that technical knowledge gained from DOE sponsored programs be shared and communicated to the general public. The reviewer added that the proposed approach to separate out the impact of lubricant changes on engine friction and fuel consumption realized through other components, e.g., main bearings and valve train, has not been fully developed and reported.

Reviewer 2:
The reviewer noted that the coating of piston skirts and rings with friction reducing materials was unsuccessful, so the researchers formulated a third motor oil to develop their procedures and correlations. The reviewer observed that the results in Slide 12 also indicate that DLC and honing variations have been or will be evaluated. The reviewer added that it also appears that the authors have developed a fairly simple method for quantifying wear; however, the researchers admit that it will not work on surfaces with durable tribofilms, so it may not be applicable to all situations.

Reviewer 3:
The reviewer noted good progress, and expressed the hope that the experimental portion will stay on track.

Reviewer 4:
The reviewer stated that it seems there is some correlation between the project team's lab-scale test correlations, but noted some deviation that should be investigated further. The reviewer commented that the authors developed a good way to quantify wear on complex geometries by focusing on how surfaces change relative to the deepest valleys; white light interferometry has a sensitivity to surfaces with an oil film or tribological film, thus surface preparation becomes critical. The reviewer state, however, that this approach can only be quantitatively used for bare metal surfaces.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that a well-balanced team of technical collaborators are contributing to this project.

Reviewer 2:
The reviewer commented that the program includes Ricardo, ANL, ElectroChemical Associates (EMA), Isuzu, ZYNP, and Infinium, so that all aspects of the engine industry relative to power cylinders have been included. The reviewer noted that bench tests were conducted at both ANL and EMA for ring and liner friction and wear.

Reviewer 3:

The reviewer commented on the good use of an industry partner.

Reviewer 4:

The reviewer observed that no apparent issues with respect to coordination among the partners have emerged.

Reviewer 5:

The reviewer observed that the PI has had some issues receiving parts on schedule and having the parts surface prepped for testing; however, the reviewer found this understandable when dealing with novel coatings. This reviewer would recommend focusing only on proven technologies to prevent schedule delays, as the focus of this project is to develop a tool to predict fuel efficiency, not increase the technical readiness level of novel coatings/additives.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer expressed the hope that this project is successful, and stated that often the linkage between friction reduction agents and actual engine efficiency is not determined. The reviewer stated that, if successful, this could greatly enhance the ability to introduce these agents to manufacturers.

Reviewer 2:

The reviewer noted that there is still a lot of work to be conducted in the final year of the project's period of performance, and commented that the work seems to align with the logical progression to develop a model for fuel economy predictions.

Reviewer 3:

The reviewer stated that the future work is well described; however, future work constitutes the main body of the work, and it is difficult to predict what new barriers might be encountered and how the team will resolve them.

Reviewer 4:

The reviewer observed that the authors are planning a very long list of tests to be carried out within the next 6 months: perform motored and fired friction tests; perform long-term wear measurements to obtain wear rate coefficients; develop a model-of-a-model for fuel economy predictions; and demonstrate that the model can be exercised over a real-world usage profile to quantity fuel economy benefits for the different oils considered in this project. The reviewer added that other theoretical case studies can or will be performed, and offered the example of quantifying wear over a reference usage profile and demonstrating that trade-offs between fuel economy and durability can be understood prior to any field or durability testing. The reviewer stated that it is unrealistic that all these activities can be carried out in timely fashion. The reviewer also questions why there were no technical publications or presentations given on this work over the duration of this project, which started in 2015 and is funded at a $1.3 million level.

Reviewer 5:

The reviewer noted that the authors admit that their results will not be universally applicable to different engines or new technologies, but that successful results can be applied as a methodology to develop further correlations for different engines and technologies. The reviewer commented that correlation of motored engine tests and models to bench tests is highly dependent on local temperatures and temperature distributions in an engine, and, unfortunately, temperatures change based on operating condition and viscous and boundary friction. The reviewer stated that there is a lot of "noise" in this system, and a robust correlation will probably not be reached. The reviewer also found that the number of variables being exercised and the range over which they are being exercised are also not broad enough to develop a broad correlation procedure. The reviewer commented that the presentation also states that they might not be able to complete modeling if Isuzu does not supply the required information, and questioned why this was not worked out ahead of time.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that, based on the well-planned project structure, this project definitely supports overall DOE objectives.

Reviewer 2:
The reviewer commented that the development of laboratory methods, models, and correlations to predict real world fuel economy changes supports DOE energy efficiency goals.

Reviewer 3:
The reviewer stated that the ability to predict performance based on hardware, lubricant and coating, material is a lofty goal; however, as technology advances, it seems to enter more into the realm of possibility. The reviewer commented that Ricardo's approach could be adopted for other systems if successful, which would be a huge accomplishment and very worthwhile.

Reviewer 4:
The reviewer stated that the availability of reliable models for FE and wear can be helpful in reducing barriers to adoption of advanced FE technologies; however, the critical issue here is the reliability and credibility of such models. The reviewer commented that the current project does not instill much confidence in the reliability and credibility of the models that might come out of this work.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that all the projected aspects of the work seem to be well resourced.

Reviewer 2:
The reviewer commented that all the proposed resources are needed to make this project successful.

Reviewer 3:
The reviewer stated that the resources appear adequate to complete the project, providing that funding level is maintained.

Reviewer 4:
The reviewer found that the team has been allocating resources appropriately as they come to the end of their project period of performance, and they provided good cost sharing; however, they had some schedule issues that are being corrected presently.

Acronyms and Abbreviations

ACI	Advanced compression ignition
AEC	Advanced Engine Combustion
Al_2O	Aluminum oxide
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	American Petroleum Institute
ASSERT	Analysis of Sustainability, Scale, Economics, Risk, and Trade
ASTM	American Society for Testing and Materials
BOB	Blendstock for oxygenated blending
CFD	Computational fluid dynamics
CN	Cetane number
CPOX	Catalytic partial oxidation
CR	Compression ratio
CRC	Coordinating Research Council
Cu	Copper
DOE	U.S. Department of Energy
E10	10% ethanol blend with gasoline
E20	20% ethanol blend with gasoline
E30	30% ethanol blend with gasoline
EDAX	Energy-dispersive X-ray spectroscopy
EGR	Exhaust gas recirculation
EMA	ElectroMechanical Associates
GDI	Gasoline direct injection
HCCI	Homogeneous charge compression ignition
IQT	Ignition quality tester
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition

MON	Motor octane number
NH_3	Ammonia
NO_x	nitrogen oxides
NP	nanoparticles
NREL	National Renewable Energy Laboratory
NU	Northwestern University
OCP	Olefin copolymer
OEM	Original equipment manufacturer
OI	Octane index
ORNL	Oak Ridge National Laboratory
PAG	Polyalkylene glycol
PAO	Polyalphaolefin
PI	Principal investigator
PM	Particulate matter
PMI	Particulate matter index
PTWA	Plasma transfer wire arc
RCCI	Reactivity-controlled compression ignition
RON	Research octane number
SD	Standard deviation
SI	Spark Ignition
SiO_2	Silicon dioxide
SwRI	Southwest Research Institute
TRC	Transportation Research Center
TRL	Technology readiness level
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle Efficiency and Energy
VM	Viscosity modifier
VN	Vanadium nitride

VTO	Vehicle Technologies Office
ZrO_2	Zirconium dioxide

6. Grid and Infrastructure

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Grid and Infrastructure (GI) subprogram identifies systems pathways and conducts research to develop and harmonize a robust, interoperable electric vehicle (EV) charging and grid infrastructure that incorporates advanced charging technologies and distributed energy resources. The GI subprogram includes four focus areas. EV/Electric Vehicle Supply Equipment (EVSE)/Grid Interoperability and Control efforts focus on technologies and tools to enable seamless interoperability and control that maximizes charging convenience and minimizes grid impacts. EV Grid Integration and Services R&D identifies system requirements and researches V1G and vehicle-to-grid (V2G) technologies that optimizes vehicle charging efficiency, minimizes systems disruptions, and facilitates integration of distributed energy resources. Extreme Fast-Charging activities identify and assess system requirements and conduct research to enable extreme fast-charging while minimizing grid impacts. Finally, High-Power Static/Dynamic Wireless Charging focuses on conducting feasibility studies and technology R&D of high-power static and dynamic wireless charging to enable additional consumer charging options and greater vehicle autonomy.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 6-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
gi001	Medium- and Heavy-Duty Vehicle Field Evaluations	Kenneth Kelly (NREL)	6-5	3.25	3.25	3.63	3.25	**3.30**
gi029	Advanced Vehicle Testing and Evaluation	Jeremy Diez (Intertek)	6-9	3.50	3.33	3.33	3.33	**3.38**
gi030	Advanced Technology Vehicle Lab Benchmarking (Level 1 and Level 2)	Kevin Stutenberg (ANL)	6-12	3.60	3.60	3.70	2.90	**3.53**
gi095	EV-Smart Grid Research and Interoperability Activities	Keith Hardy (ANL)	6-16	3.30	3.50	3.70	3.30	**3.45**
gi096	Wireless and Conductive Charging Testing to Support Code and Standards	Barney Carlson (INL)	6-20	3.58	3.75	3.67	3.50	**3.67**
gi115	Zero Emission Drayage Truck Demonstration (ZECT I)	Matt Miyasato (SCAQMD)	6-24	3.50	3.13	3.38	3.38	**3.28**
gi116	Hydrogen Fuel-Cell Electric Hybrid Truck and Zero Emission Delivery Vehicle Deployment	Andrew DeCandis (Houston-Galveston Area Council)	6-28	2.33	2.08	2.17	1.92	**2.14**
gi157	UTEMPRA—Unitary Thermal Energy Management for Propulsion Range Augmentation	Sourav Chowdhury (Mahle Behr USA, Inc.)	6-35	3.00	3.00	3.08	2.83	**2.99**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
gi158	Zero Emission Cargo Transport II: San Pedro Bay Ports Hybrid and Fuel Cell Electric Vehicle Project	Joseph Impullitti (SCAQMD)	6-41	2.88	2.88	2.88	2.50	**2.83**
gi161	Multi-Speed Transmission for Commercial Delivery Medium-Duty Plug-In Electric Drive Vehicles	Bulent Chavdar (Eaton)	6-45	3.50	3.30	3.40	3.20	**3.35**
gi165	Design and Implementation of a Thermal Load Reduction System in a Hyundai PHEV	Cory Kreutzer (NREL)	6-48	3.25	3.08	3.08	3.08	**3.13**
gi187	Comprehensive Assessment of On- and Off-Board Vehicle-to-Grid Technology Performance and Impacts on Battery and the Grid	Sunil Chhaya (EPRI)	6-53	3.00	3.08	3.33	2.83	**3.06**
gi188	Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-Grid Connectivity	Mike Ippoliti (CALSTART)	6-58	2.75	2.50	3.08	2.83	**2.68**
gi189	Electric Truck with Range-Extending Engine (ETREE)	John Kresse (Cummins)	6-62	2.79	3.07	3.00	2.86	**2.96**
gi190	Medium-Duty Urban Range Extended Connected Powertrain (MURECP)	Alexander Freitag (Bosch)	6-69	3.36	3.29	3.64	3.50	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
gi191	Medium-Duty Vehicle Powertrain Electrification and Demonstration	Wiley McCoy (McLaren)	6-73	3.60	3.60	3.80	3.50	**3.61**
gi192	Hybridization of Class 8 Line Haul And Regional Refrigeration Trucks CRADA	Dean Deter (ORNL)	6-78	3.60	3.30	3.30	3.20	**3.36**
Overall Average				**3.19**	**3.14**	**3.29**	**3.04**	**3.16**

Presentation Number: gi001
Presentation Title: Medium- and Heavy-Duty Vehicle Field Evaluations
Principal Investigator: Kenneth Kelly (National Renewable Energy Laboratory)

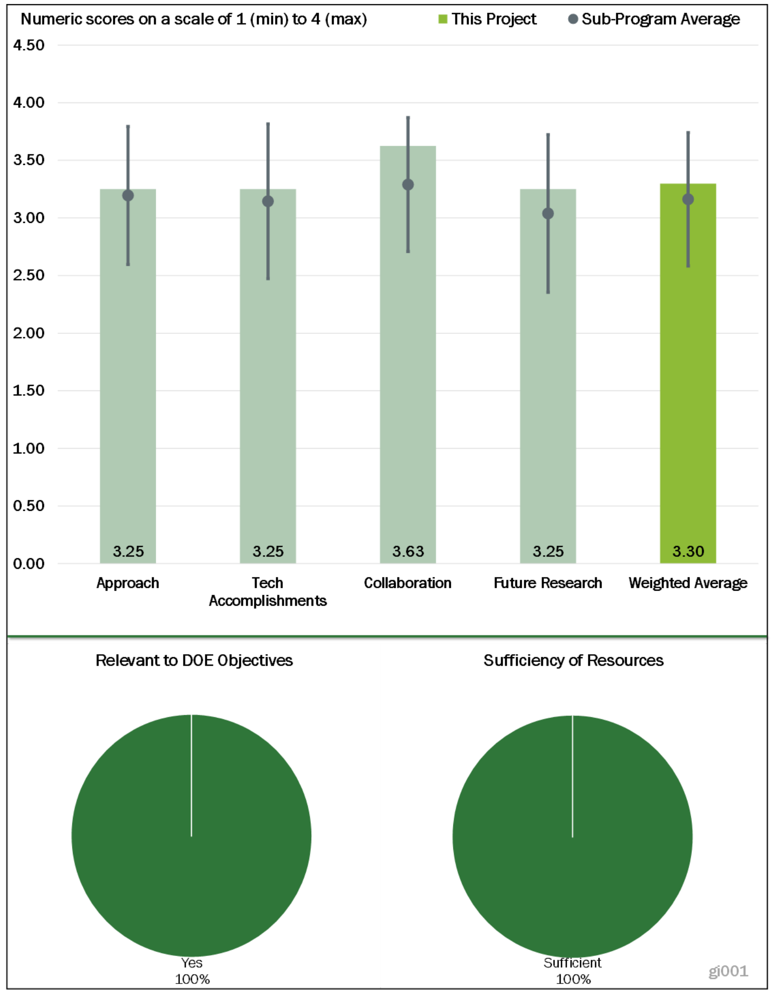

Figure 6-1 - Presentation Number: gi001 Presentation Title: Medium- and Heavy-Duty Vehicle Field Evaluations Principal Investigator: Kenneth Kelly (National Renewable Energy Laboratory)

Presenter

Robert Prohaska, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the National Renewable Energy Laboratory (NREL) has consistently addressed a critical advanced vehicle technical barrier of a lack of unbiased data by using real-world examples and robust data collection protocols. The team is approaching the problem with a logical process to identify fleets and vocations and to collect appropriate data for sufficient time periods. Selection criteria for new fleets are very thorough and appropriate, and make good use of limited time and resources to address most important vocations. The reviewer observed a good mix of NREL-collected and original equipment manufacturer (OEM) provided data, and opined that the focus on disseminating information to the community is critical. The team's ability to expand the use of the data set to support funding opportunity announcement (FOA) activities and external work such as U.S. Environmental Protection Agency fuel efficiency regulations maintains the relevance of the data set.

Relative to project selection, it appeared to this reviewer that there has been more of a push for zero emission vehicles and electrified vehicles recently as a result of the general "feel" of the industry and U.S. Department of Energy (DOE) priorities. The reviewer suggested it is important for the team to focus on technologies that show significant fuel efficiency savings and to represent technologies that are of most interest to the community. Additionally, it was clearly understood by the reviewer that the selection process is somewhat subjective.

Reviewer 2:

The reviewer stated this project is a comprehensive demonstration project of advanced powertrains in a variety of applications where the potential for reduced petroleum consumption is pronounced. The previous year's reviewer comment that methods for determining changing payload weight is still relevant and needs to be addressed. Otherwise, this reviewer opined that the fuel economy data are not all that useful. The reviewer commented that in addition to dynamometer testing, real-world driving emissions (RDE) testing with a portable emissions measurement system (PEMS) unit could be a useful method for understanding both fuel economy and emissions in real-world driving. RDE testing could be used to help quantify differences in fuel economy based on payload weight, and modeling could be used to estimate fleet vehicle payload based on the fuel economy that the vehicles are achieving.

The reviewer said the project team did a good job addressing all the issues in its approach.

Reviewer 3:

The reviewer observed a good project, but it is not well integrated with other efforts. Instead of a straight across-the-board comparison, the reviewer opined that it is a mish-mash comparison of apples and oranges. The reviewer said hybrid-hydraulics are compared with diesels but it is not clear if they are the same size running on the same duty cycle and same route. The reviewer indicated that battery-electric buses (35 foot) are compared with compressed natural gas buses (40 and 42 foot).The reviewer said maintenance costs are a major factor in fleets deciding which alternative fuel vehicle to go with, yet all the data presented was solely on fuel economy or fuel efficiency. The reviewer questioned if the data actually show that there is less wear and tear on brakes and tires with hybrids. The reviewer also questioned how hybrid-hydraulic refuse trucks compare with electric-battery refuse trucks or natural gas refuse trucks. The reviewer suggested that all these alternative fuel trucks and buses should be compared against one standard (e.g., diesel).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said the project team has demonstrated an extensive set of very detailed advanced vehicle characteristics that expand the understanding of how these vehicles perform in real-world service and how fleets are using these vehicles, including how the vehicles are generally used. The reviewer noted the Miami-Dade work included some independent verification of the manufacturer fuel efficiency improvement claims for the hydraulic hybrid system and this independent assessment is a very important aspect of the project. The reviewer stated the team is showing its results in ways that are very visual and demonstrate major findings. The creative use of existing data channels to derive fueling maps that illustrate conventional and hybrid vehicle engine operation is helping inform future research. The reviewer indicated it is important to collect maintenance data for the advanced vehicles that are in use as there may be benefits or drawbacks from a cost standpoint here.

The reviewer said the Foothill Transit work includes very detailed route and drive cycle analysis that shows the benefit of an extensive data collection activity. The team has demonstrated several interesting data interactions here (e.g., acceleration rates versus number of stops to highlight how different vehicle types are used differently). The reviewer opined that creativity of the team in analyzing the data sets and picking these data cross-references is essential to success.

The reviewer said the V2G school bus project is helpful as it is addressing areas of interest to many people in the industry, specifically the potential for electric-drive school buses and the opportunity for V2G services to increase the business case value for these vehicles. The reviewer indicated it is good to see the data being used to support an ongoing FOA award with Blue Bird to leverage DOE funding.

Reviewer 2:

The reviewer stated the project progress appears to be on schedule despite having multiple deployments and fleets to monitor. The tasks beginning in Fiscal Year (FY) 2017 should be able to be completed in FY 2018.

Reviewer 3:
The reviewer noted the goals were all addressed and progress is acceptable.

Reviewer 4:
The reviewer commented that fuel savings have been shown, but as previously indicated, fleets make choices based on total life-cycle costs rather than just fuel. The reviewer explained that life cycle costs include maintenance and operations, and these must be considered. The reviewer pointed out that nothing on maintenance costs was presented.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated this project would be impossible without collaborators and the project team has the right ones. The project team showed an extensive list of collaborators that covered the range from participation with vehicles and data to direct funds-in for activities. The reviewer commented that in a project such as this, which has applicability beyond the VTO, research work should include external collaborators; the project team has done so. The funding from several California agencies is important to include as these agencies are very involved in deploying and testing these vehicles. There is opportunity for getting this data into the broader fleet DNA database. The reviewer noted the industry participation is a testament to the trust that these organizations have in the project team for collecting and protecting data while reporting useful results.

Reviewer 2:
The reviewer opined that the collaborations are the strength of this project. The various consortia indicate strong industry representation. The reviewer commented that collaborations with academia could allow for more extensive modeling and analysis and could strengthen the outcomes of this project.

Reviewer 3:
The reviewer stated the project team has all the correct players to be successful on this project's goals.

Reviewer 4:
The reviewer noted that battery suppliers and other energy storage system (ESS) providers are not included in the collaboration and coordination.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated the future research plan appears feasible and significant challenges have been identified. The reviewer remarked the overall project outcome should include as much overarching conclusions on the various technologies, including cross-comparisons, as possible, in order to inform future projects that will use these conclusions in developing proposals.

Reviewer 2:
The reviewer stated it looks like the project team covered all contingencies for future research.

Reviewer 3:
The reviewer noted the team has picked an interesting set of future vehicles to study, but pointed out that they are all electric drive. The reviewer suggested it may be useful to consider other vehicle types, and offered that there may be an opportunity to examine trucks with SuperTruck technologies and determine the real-world fuel efficiency improvements to connect back to DOE VTO R&D. The reviewer noted the results of the off-cycle

fuel savings from the plug-in hybrid electric vehicle (PHEV) bucket truck will be interesting as this is the area where this technology should demonstrate benefits.

Reviewer 4:
The reviewer commented that future work needs to include collection of maintenance cost data, mean time (or miles) between failures due to alternative fuel technology, and information on the duty cycle. The reviewer pointed that use of alternative fuel for power take-off (e.g., in automobile carriers, booms, bucket trucks, cherry-pickers, etc.) needs to be considered separately and that fuel economy (miles per gallon [mpg]) or fuel efficiency are completely inappropriate measurement tools.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that data collection and analysis products directly support DOE objectives for petroleum displacement. This occurs through assisting fleets in making decisions about new technology deployments and refinement of upcoming technologies via work with external partners on FOA awards.

Reviewer 2:
The reviewer noted deployment projects are always useful to obtain real-world data on usage and performance. The variety of technologies incorporated into this project is laudable and the outcomes should provide meaningful insight into these technologies.

Reviewer 3:
The reviewer asserted that improving MPG and idle reduction are addressed.

Reviewer 4:
The reviewer remarked it is important to ascertain how much petroleum is displaced by alternative fuels.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that the project team has developed a robust data collection protocol, a systematic approach for identifying and working with partners, and a set of tools that allow for storage and analysis of data collected. Because of this groundwork, the reviewer indicated that resources identified for ongoing activities appeared to be sufficient to achieve stated goals.

Reviewer 2:
The reviewer stated the resources appear to be sufficient for this project. The industry partners provide significant cost share; this is another project strength in leveraging industry resources while also helping the project team develop novel technologies.

Reviewer 3:
The reviewer indicated that all the resources appear to work well.

Reviewer 4:
The reviewer commented that the resources may be slightly excessive and was generous in marking that they are sufficient. The reviewer explained that for this kind of money, a larger sample size and more data on maintenance costs would have been expected.

Presentation Number: gi029
Presentation Title: Advanced Vehicle Testing and Evaluation
Principal Investigator: Jeremy Diez (Intertek)

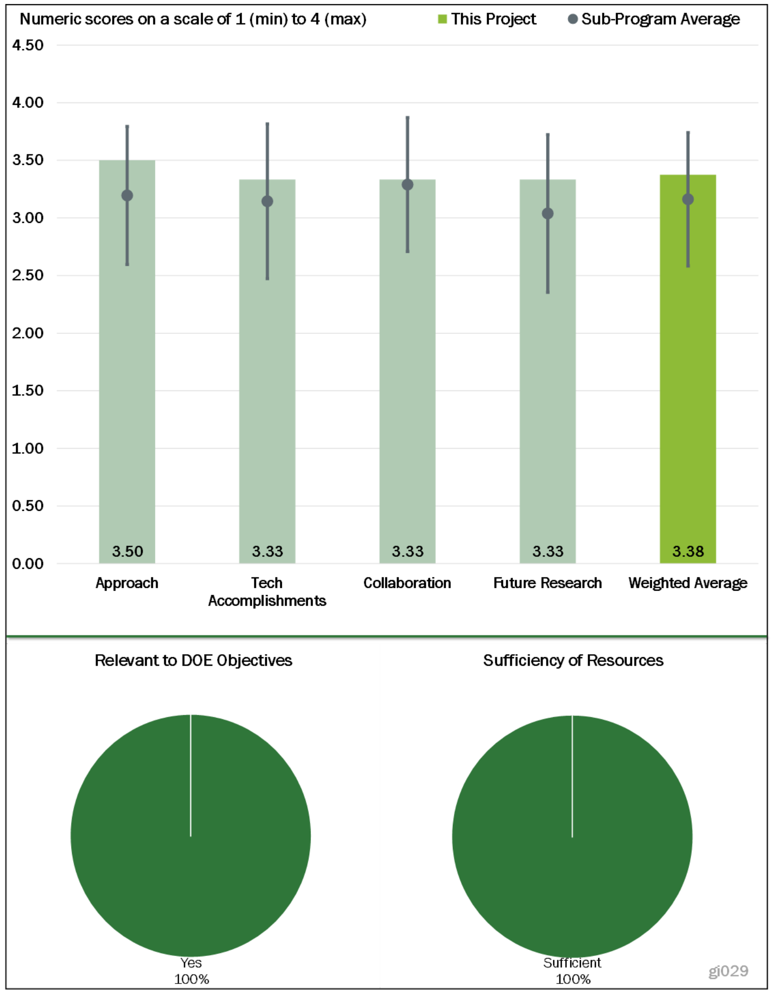

Figure 6-2 - Presentation Number: gi029 Presentation Title: Advanced Vehicle Testing and Evaluation Principal Investigator: Jeremy Diez (Intertek)

Presenter

Jeremy Diez, Intertek

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted this project attempts to gather data and performance trends for advanced technology vehicles and their fueling infrastructure. In such, multi-vehicle and real-world fleet information is necessary to support the data collection. The reviewer indicated this project has well defined objectives and appears to be successful thus far in completing its goals.

Reviewer 2:

The reviewer remarked the project needs a certain number of identical vehicles of a type in the fleet to produce enough data to make analysis meaningful. With the recent inadequate levels of funding, which allowed for one vehicle purchased in 2016, this is apparently less and less likely to occur. The reviewer stated that the de-emphasis and lack of support by top-level DOE leadership of this type of vehicle testing also would seem to make it difficult to continue even if alternative sources of vehicles can be developed (e.g., OEM donations).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said that given the resources available, technical progress has been very good. Fleet results were able to confirm engineering hunches (e.g., poor performance of non-liquid cooled electric vehicle (EV) batteries in a hot environment) as well as surfacing other issues. The reviewer noted that the data collected is useful to the public generally and to the OEMs for certain studies for which data collection is not extensive enough (e.g., real-world driving accessory load data).

Reviewer 2:
The reviewer indicated that per a prior comment, this program appears to be meeting the defined objectives and is gathering quality data for analysis.

Reviewer 3:
The reviewer noted that some of the evaluated vehicles (smart vehicles) include additional smart charge communication features. If evaluated, these features might further support project objectives, particularly those related to charging/maintenance cost evaluation and advanced vehicle charging technologies benchmarking.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that collaboration was necessary to execute the work and there was a well-organized and coordinated division of labor between Intertek, Idaho National Laboratory (INL) and Argonne National Laboratory (ANL).

Reviewer 2:
The reviewer stated that collaboration with three separate national laboratories and EZ Messenger is solid in skill diversity and describes each function well. Intertek appears to be somewhat independent at this time in driving the fleet activity

Reviewer 3:
The reviewer suggested to expand project integration to encompass other OEMs with advanced vehicle charging solutions such as higher power. The reviewer suggested adding direct current (DC) EVSE charging equipment from other major vendors to further support the fueling infrastructure benchmark objective.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated the proposed work is a reasonable attempt to grapple with the changing direction of DOE research and is highly contingent on future funding. It would seem to be imperiled because it does not meet the criteria of work at technology readiness level two or three. The reviewer questioned if non-DOE sources of vehicles and/or funding can be realized, and whether top management will support this work.

Reviewer 2:
The reviewer commented the proposed future work describes the general trends of the technology and is a logical and beneficial next step.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented this project supports DOE objectives by identifying performance/areas of improvements in vehicle technology and fueling infrastructure, as well as identifying interoperability issues that could result in a bad customer experience and reduce mass market adoption of new technology.

Reviewer 2:
The reviewer indicated the project is independent confirmation of benefits of advanced technology vehicles. At the same time, the project provides the public detailed information on real-world ownership experience and performance.

Reviewer 3:

The reviewer said though these fleet programs are very grinding in execution, they are necessary to quantifying data which support the overall goals of increased efficiency and electrification.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated resources are dwindling, but appear sufficient to meet the scaled-back goals.

Reviewer 2:

Though expensive, this reviewer opined that these long-term projects are worth the investment of capital.

Presentation Number: gi030
Presentation Title: Advanced Technology Vehicle Lab Benchmarking (Level 1 and Level 2)
Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

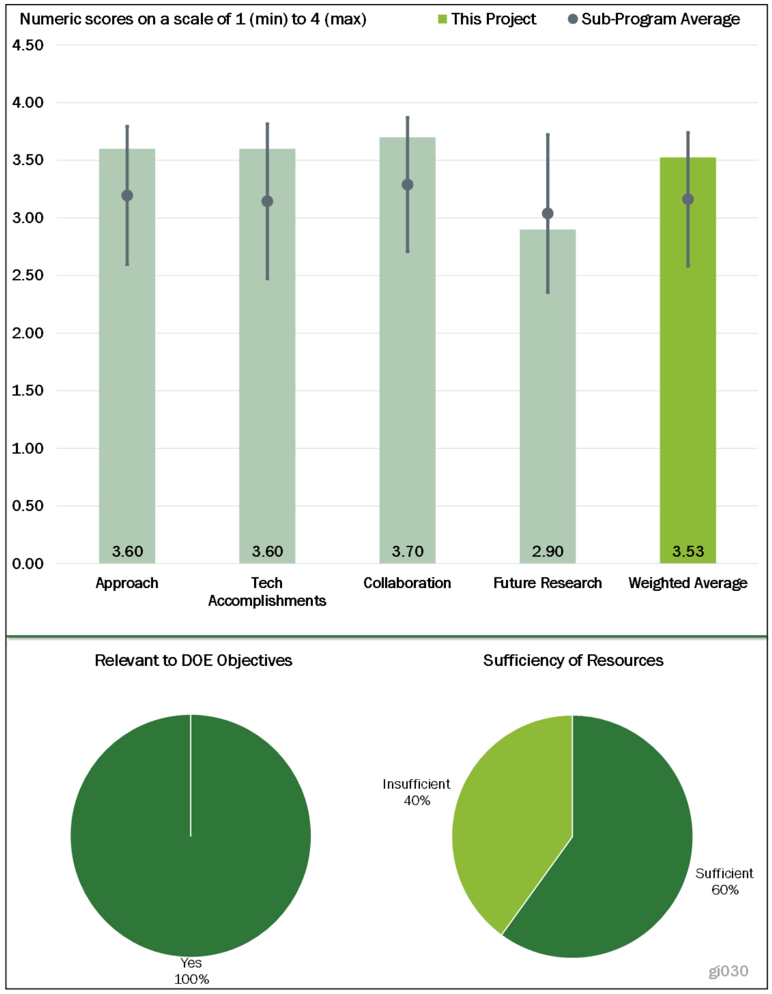

Figure 6-3 - Presentation Number: gi030 Presentation Title: Advanced Technology Vehicle Lab Benchmarking (Level 1 and Level 2) Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

Presenter

Henning Lohse-Busch, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer indicated this project is extremely important as it is the data input to the policy making, modeling and strategic decision-making process. The reviewer commented that when ANL goes through and generates these learnings it informs these folks to make decisions that are based on the actual capabilities and sensitivities of the vehicles.

Reviewer 2:

The reviewer stated the test facility, procedures and staff are well prepared for the task of vehicle benchmarking.

Reviewer 3:

The reviewer has been reviewing the Advanced Vehicle Testing Activity work for quite a few years , and stated the project team at ANL has been very good about incorporating feedback and improving their approach to the extent possible. The reviewer suggested one improvement that could be made is to perhaps track the usage of the Advanced Powertrain Research Facility (APRF) data more carefully to quantify the benefits in some fashion along the lines of the NREL Transportation Secure Data Center database, where users have to create a login before downloading the data.

Reviewer 4:

The reviewer noted it would be helpful for the review to be a little more specific as to the criteria for vehicle selection. The reviewer understood that this is a collaborative process but asked what the primary decision factors are for choice of vehicles. The reviewer suggested the project team provide the criteria for the specific choices for current review year and to explain why level one, two, and specific type of analysis was used.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented this area of review is generally excellent. The team has provided insights and data into advanced technology vehicles that would generally only be available inside OEM engineering staffs. The reviewer said the project team also provides another useful information source on competitor products to the OEM United States Driving Research and Innovation for Vehicle efficiency and Energy (U.S. DRIVE) partners. APRF work also helps to inform government regulators with useful, fact-based information.

Reviewer 2:
The reviewer stated, given the resource limitations, the technical accomplishments and progress are quite acceptable. One area that could perhaps be improved would be running the 'special' cycles that identify the limitations of the various powertrain elements. The reviewer noted these cycles tend to drive the sizing of various components and indirectly influence the fuel consumption and petroleum displacement.

Reviewer 3:
The reviewer underscored that the emphasis on off-cycle emissions and fuel economy (FE) benefits is the most important aspect of emissions control and fuel economy for these complicated vehicles going forward. This is something that this effort has done a great job of in terms of Heating, Ventilating, and air-conditioning (HVAC) loads, coolant thermal storage. The dynamometer is very important for doing this type of work, because of its ability to control the environment, but off-cycle emissions will be more important in the future. The reviewer inquired about the role for portable emissions measurement systems under these efforts. The reviewer continued that once connected vehicles become a real vehicle (next generation is this reviewer's expectation), then the on-cycle emissions and FE will become less relevant.

Reviewer 4:
This reviewer observed a track record of multi-year performance to data generation and archival for public and private use. The reviewer noted a good analysis of comparing a battery electric vehicle versus a PHEV.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted good cooperation with both INL for the hybrid fleet data, and with Oak Ridge National Laboratory (ORNL) on testing electric motors and power electronics, and with NREL on several other projects. The reviewer stated the recent report that NREL put out on real world light-duty (LD) vehicle efficiency, which was supported by APRF testing, was very informative.

Reviewer 2:
The reviewer wanted to see more coordination with other parts of ANL and DOE. The reviewer stated the D3 database is outstandingly transparent. The availability of these data makes validation of custom models very robust and respected. The reviewer also noted that, on the other hand, none of the models that are available from DOE include validation using the D3 database. The reviewer indicated that DOE does not publish the model and the validation data at the same time. Outside academia users interested in using Autonomie models of the Prius (for example) have to develop their own model and validate against D3. There is so much new emphasis on validation and verification (see American Society of Mechanical Engineers literature or work at Sandia National Laboratories/Lawrence Livermore National Laboratory). The reviewer expressed interest in having a quantification of Autonomie's validation error and predictive error, which is why a coordinated effort would be great, and would contribute to the rigor of ANL's modeling efforts.

Reviewer 3:

The reviewer stated there are collaborations and/or connections with most of the salient automotive entities and are generally excellent.

Reviewer 4:

This reviewer suggested evaluating how the ATVL work fits into the network of national laboratories doing other vehicle benchmarking and analysis with minimal redundancy, and acknowledged that this may be a more appropriate consideration for DOE. Further, the reviewer offered that a laboratory "matrix" of who focuses on what would be useful to those not integral to the resource allocation process.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented the future work appears to be gravitating towards connected and automated vehicles (CAVs) and smart transport. This is perhaps a longer-term strategy that, from an OEM's perspective, is perhaps not entirely justifiable. However, the reviewer believed that many of the changes that are likely to be brought about with the increasing presence of CAVs should be studied, and in the absence of a concerted effort on the part of the industry, and to ensure standards development and compatibility of technology, it is perhaps, at least in part, the responsibility of the national laboratories.

Reviewer 2:

The reviewer wanted to see more future research on off-cycle emissions including portable emissions measurement systems. This becomes even more important as DOE's emphasis on CAVs grows as these vehicles may be difficult to evaluate outside of the real-world.

Reviewer 3:

The reviewer commented the forecast was somewhat hazy, given the changes in VTO research direction. It is clear that the project focus must change from benchmarking but the nature and sources of future work streams are not clear.

Reviewer 4:

The reviewer noted there is not much insight here only talk about past accomplishments not the future work. A few categories appear highlighted on slide but no description of where this may, or should, be head in the short-to-intermediate term different from the past.

Reviewer 5:

The reviewer reported the proposed future work of vehicle to grid, vehicle as sensor and four-wheel drive CAVs upgrade is not clearly defined.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented the project supports the DOE objective with physical data and analysis. Data further enhances codes and standards and provides an independent petroleum displacement insight which is generally not published by OEMs.

Reviewer 2:
The reviewer reported the benchmarking activity is useful for educating regulatory authorities on the advantages and benefits of vehicles that reduce petroleum consumption through advanced technology deployment.

Reviewer 3:
The reviewer stated access to unbiased data of various vehicles with advanced technology helps the overall industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that it is great that this facility is being used by outside industry partners, which seem to be providing resources and support to the ANL facility.

Reviewer 2:
The reviewer said while the milestones are noted, they do not appear to have due dates, the funding resources seem insufficient to keep the APRF resources fully committed, relative to the volume of work done in the past.

Reviewer 3:
The reviewer observed that the nature of the work does not lend itself to specific milestones. The impression is that work will fit the funding level by definition. The reviewer said if there is less funding, there will be fewer tests and analyses.

Reviewer 4:
The reviewer commented that ideally, it should be unnecessary for the laboratories to rely on funding from commercial sources for survival. There should also be a continuity of funding maintained to ensure that the laboratories do not bleed all the talent that they have acquired and developed over several years.

Reviewer 5:
The reviewer noted the proposed future work and associated resources needs further elaboration.

Presentation Number: gi095
Presentation Title: EV-Smart Grid Research and Interoperability Activities
Principal Investigator: Keith Hardy (Argonne National Laboratory)

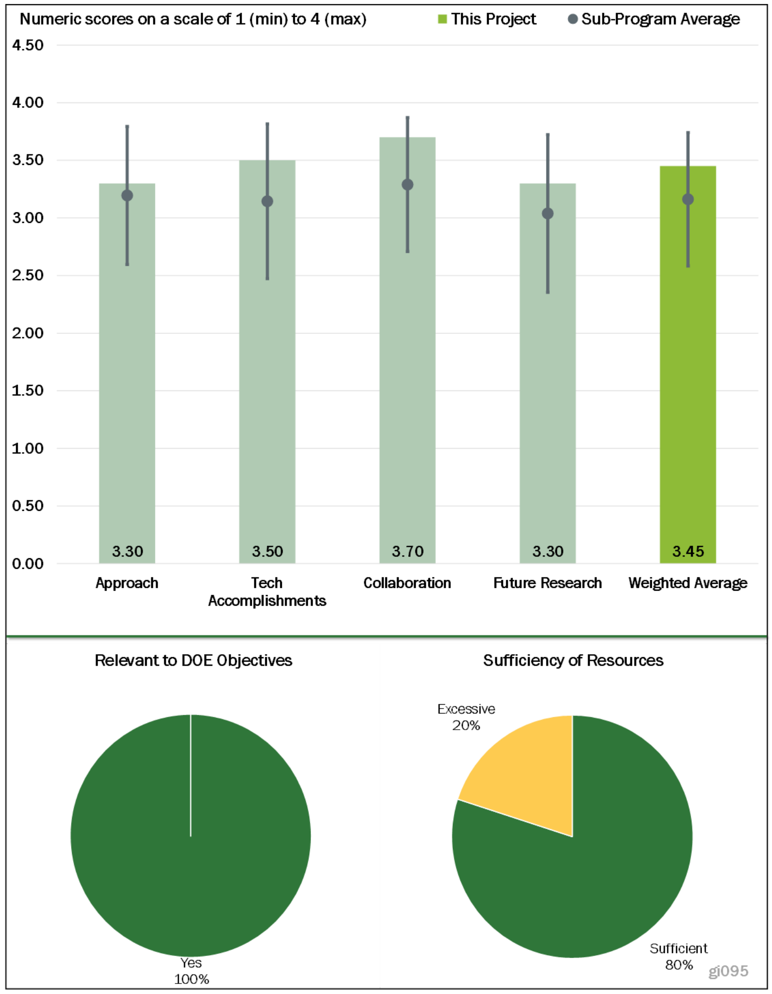

Figure 6-4 - Presentation Number: gi095 Presentation Title: EV-Smart Grid Research and Interoperability Activities Principal Investigator: Keith Hardy (Argonne National Laboratory)

Presenter

Keith Hardy, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated this project seems to interactively match its approach to the barriers and it is well-designed and feasible. This project seems to have a good approach.

Reviewer 2:

The reviewer acknowledged that overall, given the constraints, the project does a great job in addressing the barriers.

Reviewer 3:

The reviewer liked the approach. The reviewer definitely liked the vision of a universal interface for grid connected devices including the vision of the smart energy plaza. The “hands on” approach helped solidify the approach and application.

Reviewer 4:

The reviewer noted with such a broad project scope, it is difficult to truly access strategy and progress. The reviewer suggested focusing on led activities and goals and how those specific goals are met with R&D. This reviewer recommended showing alignment with other regions in R&D and E-mobility focus points, and the areas that have the best coordination. The reviewer encouraged the project team to highlight regions (e.g., China) that are not aligning and how support needs to be adjusted.

Reviewer 5:

The reviewer commented the approach slide restates activities and categories rather than an “approach.” The reviewer questions what the overall methodology to converge standards and interoperability is. The reviewer asked where the gaps are and how priorities are being set to address them.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer would have a lot of trouble trying to improve the approach. The reviewer stated this seems like great work.

Reviewer 2:
The reviewer said there is good progress in developing open source software and is well placed to coordinate with various organizations and across continents.

Reviewer 3:
The reviewer liked the cooperation of the industry and government in the U.S. and Europe, as well as with standardization bodies. Obviously, this still needs to have an outreach to Asia to make it truly global.

Reviewer 4:
The reviewer commented that progress for FY 2017 seemed good, but it is difficult to determine where funding was applied and to which efforts. The reviewer questioned why the temperatures did not line up (other than 23º C testing) to identify variations in test procedures or equipment, if it was supported through this funding and no other research.

The reviewer understood that hardware development is important to researchers. However, it would be great to see alternatives to making vehicle hardware cheap enough so that accurately measured EVSE energy data could be compared with EVSE value. The reviewer explained that this would provide "check" without needing someone running around with a meter to check every EVSE. If it is cost prohibitive, the reviewer suggested letting WATSON do it for a quick cost analysis to indicate why the lab should be making such a device. The reviewer indicated it is Important to show why wireless is needed at ANL and INL, and what were the different use cases. Although the Smart Charge adapter seemed like a good development, this reviewer recommended that it would be good to establish whether this is a significant U.S. issue. The reviewer questioned whether the cost for this effort was significant for petroleum displacement.

Reviewer 5:
The reviewer stated that much progress has been made with real open source hardware available (assuming all are highly relevant). The reviewer questioned what is the extent of the licensing interest mentioned and wondered if there are agreements in place or imminent with OEMs of significant scale. In addition, the reviewer questioned what the conclusion of the reference vehicle testing is as pertains to interoperability. It is not clear from the slide what the objective and relevant accomplishment was.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said collaboration is excellent but, the project team needs to get Asian cooperation to make it global. United States and Europe is a good start, but not good enough for automotive is a global marketplace.

Reviewer 2:
The reviewer stated collaborations appears the major strength of the effort by ANL.

Reviewer 3:
The reviewer indicated the project has extensive collaboration efforts, and is fundamentally well-integrated with other institutions.

Reviewer 4:

The reviewer noted there is no question that the project team has broad network of collaborators, but questions if there is a main focus point to assure prioritization of activities to increase market penetration or the use of EVs and EVSEs.

The reviewer suggested checking for repeated effort versus testing which needs to be repeated at multiple locations to validate procedure and equipment.

Reviewer 5:

The reviewer commented testing of the BMW i3 at both ANL and at Joint Research Center appears to have yielded dividends. The two sets of results compare quite well. The presenter stated that there has been good progress in harmonizing with Europe. However, according to the presenter, there has been less progress in harmonizing with China. Given that the regulatory environment in China will likely push towards electrification faster, it is perhaps worthwhile to invest extra effort in harmonizing with them as well.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented the proposed plan looks good. The reviewer asked if the 'ultra-fast' charging would require more effort or resources to look into the effect on the grid if more of these come online simultaneously, or, are the effects quite well understood.

Reviewer 2:

The reviewer remarked decision points and alternative plans were not discussed, but it seems obvious that this project evolves as the conditions change.

Reviewer 3:

The reviewer stated the project team needs the same enthusiasm for the future vision, as you have had up to this point.

Reviewer 4:

The reviewer said that High Power DC charging is noted in future work. The reviewer questioned if the relevancy of 400 kW charging been established. There seems to be a need for more definition prior to spending funding on standardization of technology. Tesla's 125-145 kW chargers were developed without government participation. The reviewer asked if that charging rate has been deemed a successful application. In addition, the reviewer wonders what effort has been done to understand the impact of these chargers and the required investment to populate an appropriate network and which OEMs have signed on to the 400kW.

It will be good to see the use of Energy Plaza for future research, and grid modernization efforts. The reviewer asked if there is a projected end date to this project.

Reviewer 5:

The reviewer observed the interoperability center appears to know where it wants to go but the logic of the future activities and priorities is not well defined. The reviewer asked where DOE needs to concentrate its limited funding for the biggest industry and global standards/interoperability impact. In addition, the reviewer inquired about what is the very top obstacle to break down.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated the project obviously supports the DOE mission thru expanded E-Mobility but the question is return on investment (ROI). The reviewer indicated that since it is sometimes difficult to understand the funding streams for the different activities, it is difficult to relate the accomplishments to increased E-mobility, and therefore hard to establish impact of effort.

Reviewer 2:
The reviewer stated increased electrification displaces petroleum use.

Reviewer 3:
The reviewer applauded the project since it shows how you can improve electrical charging if you move to standardization in the marketplace. The reviewer also liked this project due to the outreach to the European community and to ensure that worldwide standards can be chaperoned into application

Reviewer 4:
The reviewer understood the effort needed and the potential benefits in harmonizing procedures. The reviewer suggested it should make the products more affordable to the customer and encourage faster adoption.

The reviewer noted that the principal investigator (PI) did a good job of identifying key project attributes for interoperability and an excellent job of collaboration. It was suggested by this reviewer that some easy to follow bookkeeping needs to be done.

Reviewer 5:
The reviewer stated standards development is a particular enabler for the electrification advancements.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said as described, it seems that the program is appropriately funded.

Reviewer 2:
The reviewer noted the project team really needs to put a push onto Asia and questioned if it is resources that is hindering the project team.

Reviewer 3:
The reviewer remarked that issues of tracking funding to a specific activity and specific results, have been previously noted.

Reviewer 4:
The reviewer stated it is unclear how that much fiscal year funding focused on key priorities is consumed efficiently. This reviewer observed significant activity with some gems of advancement for the industry/DOE objectives, and questioned if too much funding goes to hardware and travel. This reviewer’s impression was that an actual budget review by DOE VTO is needed to be sure all the spending is used for greatest impact.

Presentation Number: gi096
Presentation Title: Wireless and Conductive Charging Testing to Support Code and Standards
Principal Investigator: Barney Carlson (Idaho National Laboratory)

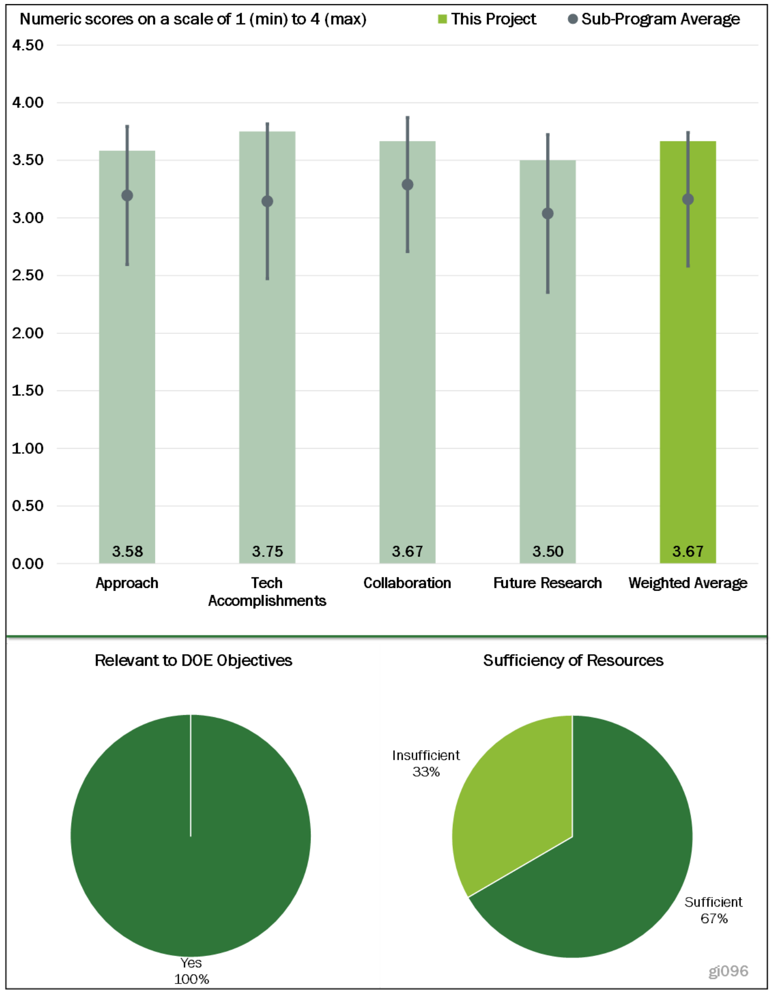

Figure 6-5 - Presentation Number: gi096 Presentation Title: Wireless & Conductive Charging Testing to Support Code and Standards Principal Investigator: Barney Carlson (Idaho National Laboratory)

Presenter

Barney Carlson, Idaho National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed the approach and execution of this project demonstrates superior engineering skills and resource allocations to a complicated enabling technology to vehicle electrification. Non-contact charging and the future of reverse flow are essential in technology acceptance and growth

Reviewer 2:

The reviewer indicated the project seems well-structured and uses feedback to adjust to technical barriers.

Reviewer 3:

The reviewer said the approach taken meets all the requirements for executing the objectives stated.

Reviewer 4:

The reviewer acknowledged INL has vast experience in testing to support standards and has the knowledge to establish a robust approach for testing new technology. This case is an example of their fully developed capability in this area.

Reviewer 5:

The reviewer commented the technical barriers are very well identified and addressed.

Reviewer 6:

The reviewer stated the approach is somewhat difficult to follow. The laboratory is highlighted and tasks and activities performed are listed. The reviewer noted the approach to the big picture problem and opportunity to be solved is not presented in a most organized way.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented the accomplishments of this project are excellent to the objectives pursued in charging system characterization and well supported in the collaborative efforts with Hyundai, TDK, and a host of competitors in the interoperability analysis.

Reviewer 2:
The reviewer said this project seems to have made excellent progress.

Reviewer 3:
The reviewer stated the project has made excellent progress, achieved all objectives planned to date and provided excellent support to standards activities.

Reviewer 4:
The reviewer said INL continues to advance their work in the measurement of wireless power transfer (WPT) and support Society of Automotive Engineers (SAE) standards committees. The reviewer noted the project has great insights on greatly varying behavior of charging systems in response to voltage sags.

Reviewer 5:
The reviewer reported that test results are very impressive.

Reviewer 6:
The reviewer remarked that in testing new technology for standards development there is always some risk in conducting a most complete array of tests to deal with the many varied conditions that a device may be subjected to. This approach and the accomplishments are very comprehensive but there is no way to assume that all barriers will be overcome.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted good collaboration with industry. The reviewer said it Seems there would be additional laboratories interested in collaborating and being involved with WPT. The reviewer suggested that additional vehicle OEM involvement seems a natural next step.

Reviewer 2:
The reviewer stated this project seems to be very collaborative.

Reviewer 3:
The reviewer observed all stakeholders are represented and communication has been effective.

Reviewer 4:
The reviewer noted collaborations cover all the necessary stakeholders and the testing is across a wide number of systems.

Reviewer 5:
The reviewer acknowledged that by leveraging efforts from competitors in the commercial markets and having success in an interoperability analysis, collaboration can meet the “needs” of the technology by supporting safe deployment of wireless charging.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted the project seems to have an excellent plan for future development.

Reviewer 2:
The reviewer reported the future work is well thought out, but highly contingent on funding. It appears that if DOE funding is unavailable, the project will be forced to shut down unless some of the standards committees being supported step up to the plate.

Reviewer 3:
The reviewer stated future proposed work, especially in cybersecurity, is extremely significant to the success of the EV technology. The reviewer noted the hope is that resources are allocated accordingly.

Reviewer 4:
The reviewer acknowledged the work is very comprehensive. The reviewer suggested it would be nice to see an expansion to characterize other environmental factors on charging performance and efficiency, such as ambient temperature.

Reviewer 5:
The reviewer commented the future work tied to continued standards development. The reviewer noted it is not too clear exactly where the technical frontier is and what are the next steps to address.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented the increasing the ease of electricity use will decrease petroleum consumption.

Reviewer 2:
The reviewer remarked that by furthering beyond the fundamental barriers for wide-spread acceptance of EVs (in this case convenient wireless charging), this project supports the premise for all DOE programs and will assist in the reduction of petroleum dependence for energy.

Reviewer 3:
The reviewer indicated that higher adoption rates of EVs can be fostered by availability of wireless charging systems to increase convenience of owning an EV. Higher transfer rates are required as greater energy storage capacity comes to new EVs. The reviewer said petroleum will be displaced with each added EV to the national fleet.

Reviewer 4:
The reviewer observed it is necessary to develop well informed EV charging codes and standards to ensure that our transition away from petroleum is well guided. This work serves as a fantastic guide for the current state of wireless and conductive charging technologies.

Reviewer 5:
The reviewer noted that clearly, as a key support for standards development, the work is relevant and not likely to be naturally led by industry without DOE prompting.

Reviewer 6:

The reviewer noted the project helps in the development of standards and technology for EV-oriented transportation and reveals issues that need to be addressed that impact the grid.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed the project seems to do a lot of work for the money. The project includes both complete and efficient test protocols which indicated a well-trained workforce.

Reviewer 2:

The reviewer commented though no shortage of resources was noted, the accomplishments of this project was very fruitful on the budget that it was provided.

Reviewer 3:

The reviewer said funding has been just sufficient to meet the promised work stream. The funding has been dwindling, which puts future work in jeopardy.

Reviewer 4:

The reviewer noted that resources look very light in the last fiscal year. The reviewer questioned if the forecast is to increase in this area. It appears the project is in wind down mode versus satisfying the procedure development in such unchartered territory as WPT.

Reviewer 5:

The reviewer noted that given the scope of work it looks like the funding is a limitation.

Presentation Number: gi115
Presentation Title: Zero Emission Drayage Truck Demonstration (ZECT I)
Principal Investigator: Matt Miyasato (SCAQMD)

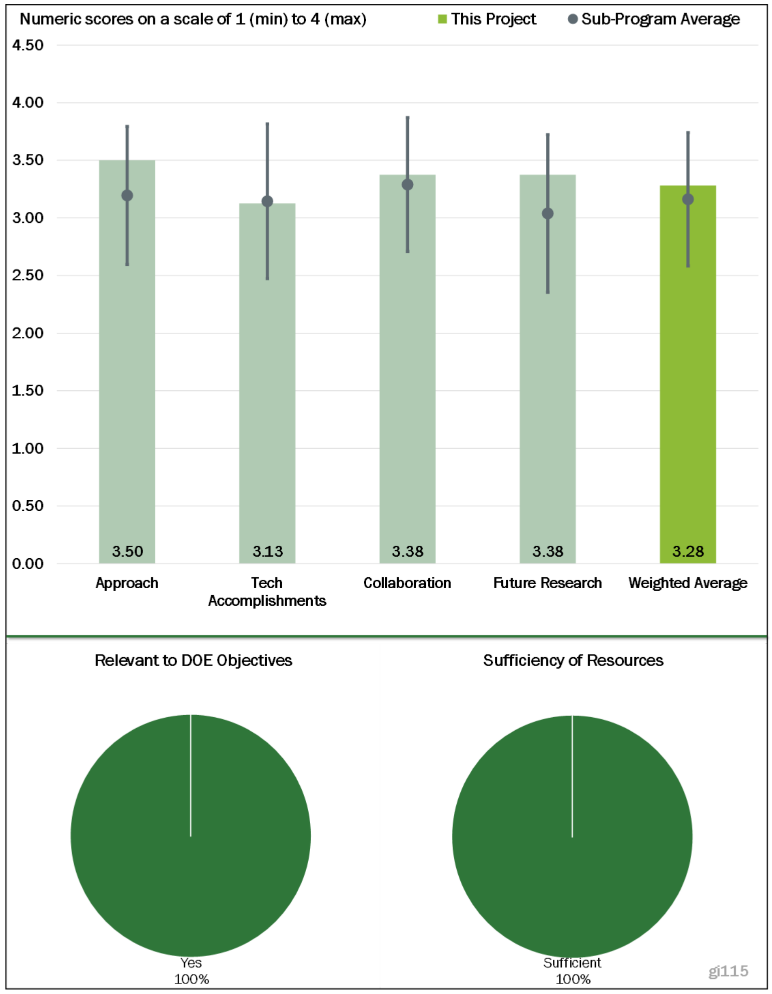

Figure 6-6 - Presentation Number: gi115 Presentation Title: Zero Emission Drayage Truck Demonstration (ZECT I) Principal Investigator: Matt Miyasato (SCAQMD)

Presenter
Joseph Impullitti, SCAQMD

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer remarked the project has a great approach addressing all barriers.

Reviewer 2:
The reviewer noted the project has a good scope of Class eight product with strong partners for fleet use. There is also good use of early data to help with market understanding of the application for the technology. The reviewer remarked the project still needs to devise an appropriate driver feedback process and produce reports that relate kinetic intensity to type of driving in the various clusters of driving types and benefits of technologies.

The reviewer is looking forward to seeing hybrid vehicle data, this is critical for this project.

Reviewer 3:
The reviewer said you cannot do better than putting something into operation and seeing how it works. It is unfortunate that the electric trucks were used in such limited service, because that makes head-to-head comparison harder. The reviewer hopes that when plug-in hybrid electric truck (PHETs) are put into service, their service will not be as limited.

Reviewer 4:
The reviewer acknowledged the work is feasible, and progressing with technical barriers being addressed. However, the project is not specifically integrated into the new modeling efforts that DOE started this year. It was noted orally that the data could easily be tied into those models in the future.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said the project is working in the right direction to accomplish all goals.

Reviewer 2:
The reviewer noted the trucks are out there running on the road in commercial service. There is no other way to actually test a concept.

Reviewer 3:
The reviewer commented that progress is good for initial battery electric trucks (BETs), although it would be great to convince fleet partners to plan truck use to maximize range. The project could use yard bulldog to move the trailer while cab is charging, this example should increase usage percentage of vehicle. The reviewer suggested a second BET will help to identify impacts of architecture and component sizing to performance.

Hybrid electric vehicle (HEV) Truck progress is vital, particularly in clusters three and four to better understand architecture, component sizing and selection.

Reviewer 4:
The reviewer observed the project did not have any stated project targets. The goal of the project was to demonstrate the vehicles and compare against baseline vehicles. The reviewer noted that fuel savings was shown. As a demonstration project, it should still compare fuel savings to the predicted models. It is not pass or fail, but a sanity check for the standard models and drive cycles when compared to an actual end user drive cycle.

The reviewer noted the data that was collected was a great start, as it shows there is fuel savings real world. The estimated cost for a kit should also be included in this study. The project appears to be steering away from presenting cost numbers (stated orally and in the written presentation), due to the fear the numbers would not represent production numbers. The reviewer remarked that without cost numbers, it will be difficult for the project to be successful, in the goal of promoting market acceptance. Fleet owners will not adopt without knowing what the investment cost will be.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated the project has a good mix of research institutions, vehicle manufacturer’s, and end fleet owners.

Reviewer 2:
The reviewer said there is a great group assembled to achieve the project goals.

Reviewer 3:
The reviewer reported there is good collaboration, which is required for a project of this size. Next phase of project should include some outreach with partners to expound on the benefits, both to the communities, the industry and the science.

The reviewer it was unfortunate about delays and component resourcing, but it was good recovery to be able to provide demonstration vehicles by separating partners.

There is a need to convert data into information to showcase the progress and technology opportunities for this type of logistics activity.

Reviewer 4:

The reviewer noted not much was said about other collaborators besides truck fleets. The reviewer suggested the project team be encouraged to run the electrics on some longer runs. It looks like the project team has range anxiety. The reviewer added that some influence over operation of the PHETs may be possible.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said the future research is properly addressed.

Reviewer 2:

The reviewer observed the project is planning on completing the data collection and the project over the next 16 months. Decision points, barriers and risk mitigation were not presented, but do not really apply. The reviewer noted the technology is already deployed and functioning. And the main task is waiting for the data to be collected.

Reviewer 3:

This reviewer observed what you would expect for a project in the process of extending, and indicated there is a need to pursue options to determine truck use scenarios that maximize the difference from a base truck, or HEV versus BET (when HEVs are ready). Also, emissions from series based hybrid electric truck (HET) should not be too difficult to project, and should be included as differential from base combustion to NG which should show the value to air quality with performance gain, and reduction in consumed energy based on HET technology. The reviewer also noted that it is really important to get specific cluster type data for each technology architecture. The reviewer suggested to be included in future work should be a baseline cost analysis of the various technologies showcased in this project; NREL has some experience in this type of analysis and should be consulted.

Reviewer 4:

The reviewer noted there was little detail provided on the architecture or operating method of the PHETs.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer reported this project supports the overall DOE objective of petroleum displacement. By demonstrating hybrid and battery vehicles side by side with conventional vehicles in a real-world business, a good apple to apples comparison can be seen. It helps promote the fuels efficiency gains past an engineering simulation to a real-world usage case, which should help lead to less resistance to adaptation. Fleet operators put more faith in real world business case return on investment data, then an engineering estimate.

Reviewer 2:

The reviewer said yes, hybrid and full EV supports the DOE goals.

Reviewer 3:

The reviewer said this project is one of the better projects reviewed in 2017. This project focuses technology advancement effort in an area that all business projects show an increase in energy consumption in the coming decade, that area is logistics.

Few projects have the opportunity to both learn as much, and demonstrate critical benefits in port operations efficiency improvements. Slide 12 is an indication of the importance of focused research in Cluster two and three, but Cluster four should also be examined, particularly around other port cities.

Reviewer 4:
The reviewer remarked that any substitution of electric vehicles for diesel is a win, but acknowledged having an issue with how big a win. This reviewer reported that electricity was converted to gallon equivalent on a 1-1 British thermal unit basis, but noted that really depends on the generation mix. As done, it assumes all renewable electricity.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed the project has sufficient resources to finish in a timely manner.

Reviewer 2:
The reviewer commented that though there were some delays in the development of some of the trucks, the project has shown good progress with the available funding. As indicated previously, cost analysis for technologies, petroleum displacement projections and emissions benefits are needed to ensure understanding the complete picture this technology might represent.

Reviewer 3:
The reviewer stated the project is on plan.

Reviewer 4:
The reviewer remarked doing stuff the first few times is expensive.

Presentation Number: gi116
Presentation Title: Hydrogen Fuel-Cell Electric Hybrid Truck and Zero Emission Delivery Vehicle Deployment
Principal Investigator: Andrew DeCandis (Houston-Galveston Area Council)

Presenter

Andrew DeCandis, Houston-Galveston Area Council

Reviewer Sample Size

A total of six reviewers evaluated this project.

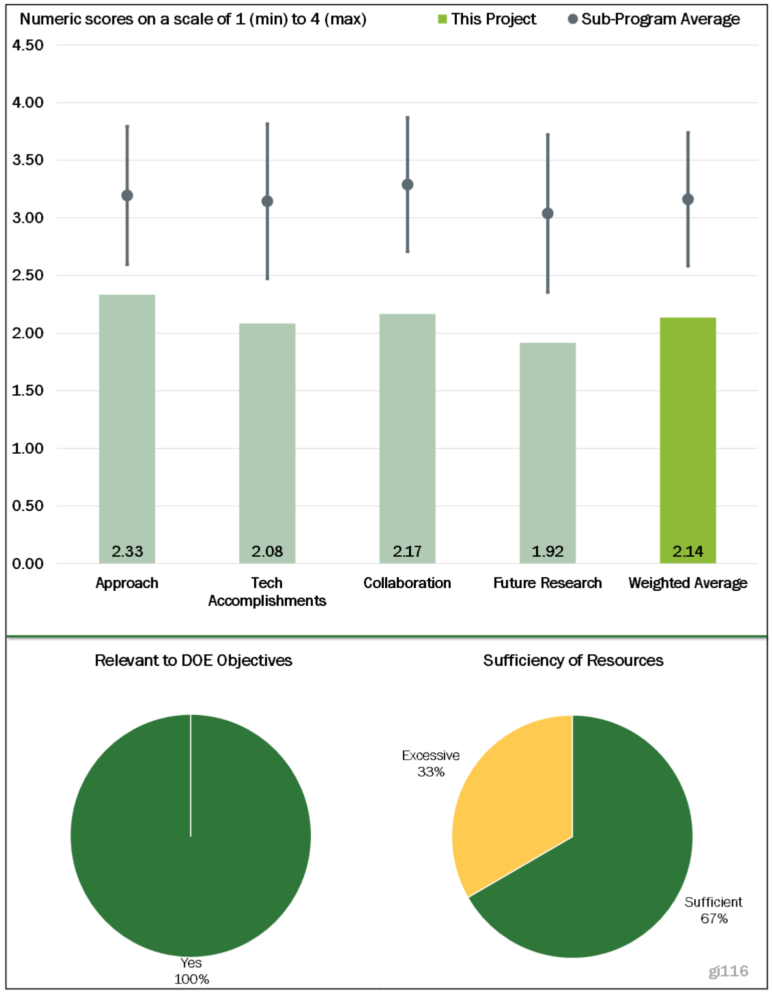

Figure 6-7 - Presentation Number: gi116 Presentation Title: Hydrogen Fuel-Cell Electric Hybrid Truck and Zero Emission Delivery Vehicle Deployment Principal Investigator: Andrew DeCandis (Houston-Galveston Area Council)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said the approach to this project is reasonable and it represents a relatively conventional development and deployment activity for advanced vehicle technologies. The project team is seeking to develop and deploy highly-advanced electric drive technology in applications for which the technology should be suited. The reviewer observed that because of the advanced nature of the technologies the team is working with smaller technology providers and this offers both challenges and benefits.

Reviewer 2:

The reviewer noted that for the fuel cell hybrid truck project, the initial approach made sense, but apparently funding issues and requirements resulted in departure of the demonstration fleet partner. It may have made sense to have included in the original approach a way of addressing this potential issue, which was not necessarily a surprise for this type of project. No such process was identified in the presentation as being part of the original approach.

The reviewer remarked that for the Zero Emission Delivery Vehicle Deployment, the approach included a solid demonstration partner in United Parcel Service (UPS).

Reviewer 3:

The reviewer commented the approach has some flaws given that it could not meet the original schedule and scope. It seems that the PI’s organization did not have full understanding of fleet operator’s decision-making criteria, appetite for new technologies, and how they are incentivized. The reviewer suggested that in future similar projects could adjust how they incentivize fleet operators to enter into a partnership.

Reviewer 4:

The reviewer stated the approach for this "demonstration" type project is fairly straight forward and has been used in other programs. However, this project has demonstrated what can go wrong with non-committing partners and technical issues beyond the skill set of the project managers at the Houston-Galveston Area Council.

Reviewer 5:

The reviewer commented it is difficult to give ratings for these two projects together as they are both substantially funded with varied success. The reviewer indicated the Hydrogen Fuel Cell Class 8 is a mess and that the project should not be extended. The reviewer said the project was flawed from on-set. It is understandable that partners leave projects and that makes them difficult to complete, but the lack of hydrogen infrastructure in the area is a pretty big oversight. Cost of trucks should have been projected better. The reviewer added that there should be a review of projected success prior to large spends in FY 2017. Electric Delivery trucks have had better success and data is available, but noted only 18 of the original 30 planned trucks to be built, due to re-scope. The reviewer suggested data collection could be extended to meet the 24-month initial project goal and an initial review of this project data vs other EV and HEV drayage truck projects should be performed to determine if both are required.

Reviewer 6:

The reviewer noted the approach for the Hydrogen Fuel-Cell Electric Hybrid Truck Project is completely unsatisfactory. The project has failed to secure a demonstration partner, which is the focus of the entire project. A more robust approach was needed from the start of the project to ensure a demonstration partner would be secured and follow through. Additionally, no plan for hydrogen fueling infrastructure has been set forth, which is critical to the success of a demonstration and the project.

The reviewer observed the approach to the Zero Emission Delivery Vehicle Deployment is fair to satisfactory. Vehicles were produced, put into service, and data is being successfully collected. However, the approach should include a data analysis plan that dictates what the data will be used for. Metrics should be defined that will allow comparison of operation of the Zero Emission Vehicles to their conventional internal combustion engine (ICE)-powered counterparts. The reviewer said the PI referred to reliability as a key concern, but no plan was described to measure and assess reliability.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer indicated the collection of the data on the UPS trucks is great progress. It would have been good to have a slide on the data analysis done so far with respect to utilization of the trucks. Lots of information was conveyed but it was all verbal.

Reviewer 2:

The reviewer reported the delivery project the team has already completed the deployment of an 18-truck fleet and is collecting data on them. The trucks were delivered over a reasonable schedule. The team has re-scoped the project to 18 trucks to ensure sufficient data collection time, which is a good decision. The team should consider working with NREL through the Fleet DNA project to contribute data to this VTO-funded project. The utilization rates for the vehicles appear to be reasonable but there is opportunity to use the vehicles more. It seems as though some of the challenges the team faced (chargers and DC/DC converter failures) could have been easier to resolve as these components are not necessarily cutting edge. The reviewer noted it took a long time to get everything started but progress seems to be speeding up and the demonstrations will still be over 2 years long. The team did a good job in addressing the reviewer comments, especially the truck specifications (especially now that vehicles are out in service).

The reviewer said the drayage truck project also seems to be moving slowly but progress is accelerating. The team has done a good job of addressing the challenge of project partner turnover and not allowing the setback to derail the project. The trucks have now been procured and the zero emission drayage truck demonstration (ZECT) drivetrains are being installed so the project is now back on track.

Reviewer 3:

The reviewer noted both projects are seeking extensions to complete demonstration elements. For the Fuel Cell project, a fleet partner has not been identified at this time, after departure of the original fleet partner. The PI indicated that the project team identified several other fleet partners along the way, only to have each of those back out. Obviously, efforts to obtain a fleet partner have been a significant focus of project efforts, there just has not been success yet. The project would possibly have benefited from including either a fully solid fleet partner (like UPS under the Zero Emission Delivery portion), or perhaps a clearer process for selecting a partner if the original one dropped out (or, a point at which the project would be revised if no partner had been obtained).

The reviewer remarked the Zero Emission Delivery project appears to be ready to go for demonstration using what is now a commercially-available product. Data is beginning to be generated now. The project team is also finding out some limitations of the technologies which is critical information before larger deployment. However, the project is still seeking additional fleets.

For both projects, however, the original timelines appear too long for at least the call for projects and partner selection process (2 years or more for each). Particularly when compared with the admittedly highly-accelerated timelines for the American Recovery and Reinvestment projects, this appeared overly long to get things moving (at least as far as the project call and selection processes). It is possible as far as the Fuel Cell project, this may have simply been the wrong location. Houston may simply not have a sufficient interest level for this type of project (hydrogen), particularly when compared to California. It may make sense to try to restructure things to focus more on the Zero Emission Delivery portion of the overall project, which seems to largely be moving ahead as planned.

Reviewer 4:

The reviewer remarked to expand on a prior comment, the performance at 5 years into the project is poor. Largely due to non-committing partners and technical issues, this project not only is suffering delays but a vehicle accident which may have ties to the program, and accumulating delays with issues in the chargers, converters, and battery management system (BMS) cell balance. The reviewer stated it may be preferable, sometimes, to end the project if funds are recoverable; if non-recoverable, DOE may have a great burden to micro-manage progression.

Reviewer 5:

The reviewer stated again that two projects are being reviewed, and suggested the hydrogen project would be less than one. The reviewer indicated that the Zero Emissions Delivery Vehicles have strong partners, but observed technical challenges with trucks in operation. The presenter noted that 80% of UPS routes are less than 100 miles, but these trucks only have 80-90 miles of range. The reviewer reported very large motor specifications for trucks that are usually cubed out versus maximum weight, in the flat area of the gulf coast. This reviewer described the drivetrain architecture selection as interesting. Additionally, only 7 of 18 vehicles have greater than 50% utilization, which does not support continuation of the project.

Reviewer 6:

The reviewer indicated accomplishments of the Hydrogen Fuel-Cell Electric Hybrid Truck Project are completely unsatisfactory. The project has failed to secure a demonstration partner, which is the focus of the entire project. Three trucks have been procured, but the conversion to fuel cell-electric hybrid drive has not been completed 5 years into the project. No plan for hydrogen fueling infrastructure has been set forth, which is critical to the success of a demonstration and the project.

The reviewer said the approach to the Zero Emission Delivery Vehicle Deployment is satisfactory. Eighteen vehicles were produced, put into service, and data is being successfully collected. However, this falls short of the project goal of 30 vehicles. Over a year of data was collected from the 18 trucks, but no report on vehicle utilization, efficiency, reliability, or any other quantitative summarization of vehicle operation has been created. The reviewer noted only a list of summary metrics for each vehicle was presented, which is inadequate for drawing any conclusions or comparisons to conventional vehicle use in the same application.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said the collaboration on the UPS EVs seems to be working, although the truck OEM does not seem to be incentivized to keep the EVs operational. Perhaps consider that as a financial milestone if you were to do a similar project in the future.

The reviewer suggested that not having a fleet partner on the hydrogen truck seems to be a large detriment. Perhaps taking a step back and understanding what part of the project is unfavorable to fleets and adjusting the scope makes sense. While it is clear that this is an unknown fuel, there are hydrogen producers in the area so educating fleet owners is a hurdle that could be overcome. Consider the incentives and how business decisions are made at the Fleet Partner level and adjust the project to align better with that.

Reviewer 2:

The reviewer noted that U.S. Hybrid is a partner in both this project and the ZECT project in California. It is good to leverage the work in these California projects that are further along and help speed this one to completion. The drayage project has an interesting mix of vehicle up fitters, researchers, and a non-governmental organization. Overall the partner list is reasonable and the team is working on a new local fleet which will be important. The delivery project has both a vehicle OEM and a major fleet partner. These are important components for success in a project like this.

Reviewer 3:

The reviewer reported for both projects, partners for hardware (OEMs) and analysis seemed appropriate. For the Zero Emission Delivery project, the fleet partner selected is a very solid partner, who has participated in a number of demonstration and deployment projects, and who is also anticipated to be an ultimate user of the technology (UPS). The project is still seeking additional fleets. However, for the Fuel Cell project, the original fleet partner was apparently not as solid, and no process appeared to be identified in the original plans to address the departure of the fleet partner. It is simply tough to obtain a fleet for this application in a geographic area where fuel cells are not being promoted. There will need to be a balance between getting a fleet partner soon and getting a good partner, or else perhaps resources should be moved from the Fuel Cell side to the Zero Emission Delivery side of the project.

Reviewer 4:

The reviewer reported that again two projects are being reviewed.

The reviewer said the hydrogen project only has a partner to deliver on trucks, Gas Technology Institute (GTI) and a university. The reviewer noted this would be great experience for students, but at what cost. The reviewer commented it is surprising that GTI cannot help with hydrogen infrastructure.

The reviewer stated Zero Emissions Delivery Vehicles have strong partners, as noted earlier but are still missing a critical partner with EV fleet knowledge that can keep things up and running.

Reviewer 5:

The reviewer said that the Houston-Galveston Area Council has been subjected to poor collaboration and commitment with its partners. The hydrogen portion appears worse than the electrification project.

Reviewer 6:
The reviewer stated collaboration in the Hydrogen Fuel-Cell Electric Hybrid Truck Project is completely unsatisfactory. The project has failed to secure a demonstration partner, which is the focus of the entire project.

The reviewer commented the approach to the Zero Emission Delivery Vehicle Deployment is satisfactory.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented the future plans to complete the drayage truck construction and delivery truck demonstration are reasonable and straightforward. The project team is addressing the previous issues with finding more fleets and getting more demonstration miles on these vehicles. The reviewer noted the team is focusing correctly on getting the vehicles in service and collecting as much operational data as possible.

Reviewer 2:
The reviewer observed the data collection process is good. It would be better if they could make all 18 vehicles available more often so the utilization increases. It was not clear if all the utilization drop was based on technical problems or whether there were also driver preferences that play into that utilization number. Perhaps start collecting data on the reasons the EV is not available so one can see what percentage of the time it is due to chargers versus battery energy management system versus something else.

It is not clear that a fleet partner will ever be found under current project structure for the hydrogen vehicles. The reviewer suggested to consider redirection of efforts.

Reviewer 3:
The reviewer remarked the most critical activity will be to find a fleet partner, or else move the resources from the Fuel Cell effort to the Zero Emission Delivery activity. If a fleet partner can be obtained for the Fuel Cell project, there will clearly need to be an extension to allow for data collection and analysis. The reviewer note that seems to be a long-shot at this point.

Reviewer 4:
The reviewer warned that time has expired on this project, there is little guarantee for future success with a time extension.

Reviewer 5:
The reviewer warned the plan for no cost extension of the Fuel Cell effort should be reviewed with great scrutiny. The plan is not sufficient to enable good ROI for continued investment. The reviewer questions if trucks are placed into service will they really have any relevancy. The reviewer asked if they operate as true examples, what burn-in time will be required to determine that the recently completed trucks will have a shot at producing useful data. The reviewer suggested the project should not be continued without significant re-scoping of the project again.

The reviewer stated the Zero Emissions Delivery Vehicles has a chance to produce useable data, still prior to providing extension. Current data needs to be reviewed along similar data to see if continuation is a value add for the program. The reviewer asked what new will be learned here if there is an extension. Since UPS has tested other EV fleets, the reviewer wonders if the architecture is correctly sized for mission and is there weather or other unique characteristics to this program which make the continuation beneficial.

Reviewer 6:
The reviewer observed a number of actions were proposed, but recommended that the Hydrogen Fuel-Cell Electric Hybrid Truck Project be cancelled immediately due to failure to perform.

The reviewer noted the proposed future actions for the Zero Emission Delivery Vehicle Deployment are fair, but again, a plan for data analysis to make meaningful conclusions from the project must be made. Otherwise, the demonstration will not produce any meaningful results.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer said the project is relevant as it addresses a long-term research opportunity for electric drayage trucks and delivery vans to reduce petroleum consumption. The demonstration aspect of the project addresses the issue of acceptance since if fleets do not accept technology the petroleum displacement cannot occur.

Reviewer 2:
The reviewer indicated yes, deployment of alternative fuel vehicles lowers petroleum use during the project and hopefully educates stakeholders so that the displacement continues after the project end date.

Reviewer 3:
The reviewer commented the project is focused on reducing barriers to introduction of high efficiency and low emissions technologies for particularly high fuel-use emissions applications.

Reviewer 4:
The reviewer observed petroleum reduction would occur if it were successful. This project was developed and executed with best intension to demonstrate and quantify the benefits of alternative energy storage.

Reviewer 5:
The reviewer remarked electrification of medium-duty delivery trucks and heavy-duty (HD) drayage trucks has the potential to significantly displace U.S. petroleum consumption. There are a number of barriers to electrification of these vehicles. This project has the goal of addressing some of those barriers.

Reviewer 6:
This reviewer expressed dislike for this question and opined that it should not be a yes or no question. The reviewer stated there would have been a petroleum displacement impact if this project had been a success; there is minimal impact given the limited progress or differentiators from other EV delivery projects.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed resources appear to be sufficient to achieve the stated goals and deploy the stated number of trucks.

Reviewer 2:
The reviewer commented funds appear sufficient, at least for now, but it is certainly unclear going forward. If no fleet partner is found soon for the Fuel Cell project, it may make sense to redirect resources toward the Zero Emission Delivery effort.

Reviewer 3:
The reviewer remarked though it is apparent that this project has faltered, it is not due to resources provided by DOE.

Reviewer 4:
The reviewer stated based on original milestones, funding was appropriate, to maybe insufficient. The reviewer noted given re-scope, and value of information obtained, project was overfunded.

Reviewer 5:
The reviewer commented resources are judged to be sufficient for completion of the projects. However, the reviewer suggested the Hydrogen Fuel-Cell Electric Hybrid Truck Project be discontinued and remaining funding be redirected.

Reviewer 6:
Given that the hydrogen trucks are not deployed and that there are only a portion of the 30 EVs originally envisioned, the reviewer suggested this is more funding that is needed for the scope currently underway. The reviewer noted that the PI's organization is missing a network connection / industry knowledge to address the missing fleet partner for the hydrogen vehicles in its project.

Presentation Number: gi157
Presentation Title: UTEMPRA—Unitary Thermal Energy Management for Propulsion Range Augmentation
Principal Investigator: Sourav Chowdhury (Mahle Behr USA, Inc.)

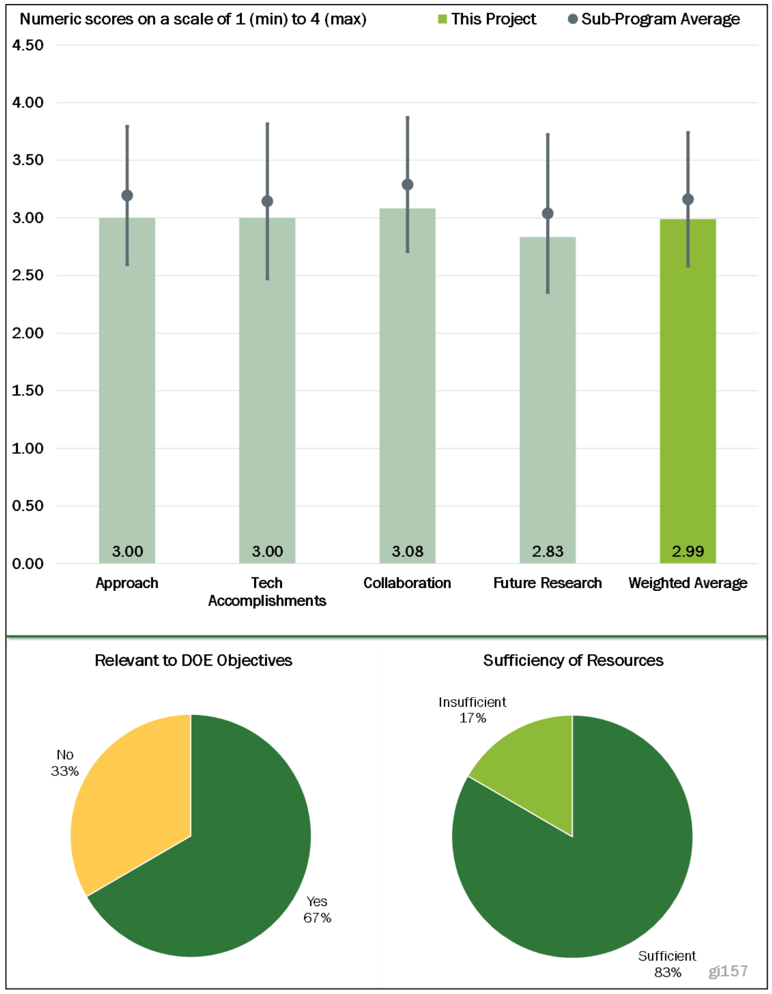

Figure 6-8 - Presentation Number: gi157 Presentation Title: UTEMPRA—Unitary Thermal Energy Management for Propulsion Range Augmentation Principal Investigator: Sourav Chowdhury (Mahle Behr USA, Inc.)

Presenter

Sourav Chowdhury, Mahle Behr USA, Inc.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported this project follows a well-established approach of identifying vehicle and technology requirements, advancing technology through identification of component and system specifications and subsequent development, conducting system integration and testing, and ultimately vehicle demonstration.

The reviewer said the focus is to develop a coolant-based heat pump system (which provides heating and cooling) to reduce the energy impact of climate control on EVs especially at low temperatures, thereby increasing range. The reviewer noted heat scavenging from the battery and power electronics is employed.

The reviewer observed the principal technical challenges are development of the multi-mode fluid controller (MMFC) with minimal leakage, flux free brazing, and as always cost effectiveness. The valve system is the heart of the project, with hardware and control being key issues driving cost and commercialization potential. These areas are being focused upon. The reviewer noted there is no direct mention of the project's specific integration with other efforts.

Reviewer 2:

The reviewer noted the project has comprehensive approach with a production oriented design that has shown solid performance.

Reviewer 3:

The reviewer said this is a well-focused project

Reviewer 4:

The reviewer noted HVAC draw in extreme temperatures is a large concern for EVs, and this project seeks to address the low extreme with a new system design. The system development and vehicle build and development phases appear to be sound and well designed. A successful project could significantly in reducing the impact of extreme temperatures on EV range.

The reviewer noted the vehicle baseline testing is lacking in drive cycle selection and temperature. The presenter indicated that more drive cycles will be used in the future, and these should include those from the 5-cycle methodology. The temperature testing occurred only at -6^{o} C, and had to be extrapolated. Testing to the full limit should be conducted. The presenter indicated that -10 ^{o} C covers 98% of the continental U.S., but this reviewer is skeptical of this number. A reference should be provided to corroborate the rationale for not establishing a lower goal temperature for the unitary thermal energy management for propulsion range augmentation (UTEMPRA) system.

Reviewer 5:

The reviewer stated this is a rather expensive DOE project. It seems as if scope or budget was inadequate with a budget overrun which was picked up by supplier partner.

Reviewer 6:

The reviewer said it is tough to justify business case to proceed to a conclusion.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted the project has achieved a number of technical accomplishments including the following. Testing has confirmed that the second generation MMFC has fully addressed leakage issues through design improvements and new materials at a modest cost penalty. Successful flux free brazing with excellent control has been demonstrated and validated in components including chillers which have surpassed burst requirements. The reviewer noted that Mahle believes the flux-free technology will be independently applicable to components in any vehicle.

Numerous components have been successfully designed and built including chillers, compressors, pumps, and heat exchangers. Bench testing has confirmed successful valve operation and the absence of leakage. Through simulation, a baseline range improvement of 15.5% at -10^{0} C has been projected through reductions in energy requirements for cabin warm-up and driving cycle steady state operation. However, it is not clear what the projected quantified range improvement is over the entire driving cycle under more typical operating temperatures. Although, the presentation does indicate that energy reductions and subsequent range improvements will be had throughout the span of cold weather operation, with a modest penalty incurring at warm temperatures.

Reviewer 2:

The reviewer commented accomplishments and progress seem satisfactory but it is tough to justify business case to proceed to a conclusion.

Reviewer 3:

The reviewer said good results based on hardware iteration.

Reviewer 4:

The reviewer remarked that when this project was presented, it was a bit confusing as to whether the flux free product would be put in production, or whether the plastic part would move to production. The reviewer noted that there was little data provided to address questions about through put or quality of the manufacturing process. The reviewer questioned if this was well thought out because data does not exist.

Reviewer 5:
The reviewer remarked coolant distribution network is the novel part of project. The reviewer noted a heat pump with low level of working fluid it intelligently channels fluids to individual elements.

The reviewer stated the project had leakage of fluids between loops. This problem was solved and the reviewer suggested it is patentable. The reviewer suggested a need to develop flux free brazing method. The project has demonstrated significant energy use reduction.

Reviewer 6:
The reviewer noted the project is behind schedule for reasons that were not fully explained by the presenter. The reviewer suggested mitigation plans for how to re-establish a feasible schedule should be developed. This plan should include additional baseline testing as mentioned in the approach review section.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed this project has a strong and well-balanced team including Mahle, Norgren, Fiat Chrysler Automobiles (FCA), and NREL. All the principal areas are represented including system developer and integrator, valve manufacturer, OEM, and independent testing and verification entity. This reviewer reported that the PI conducts regular communications and coordination with project partners through bi-weekly WebEx meetings and frequent site visits. The reviewer said Mahle indicated it has been in discussions with other OEMs with regards to this technology, but it would be good to incorporate additional OEMs more formally if viable at this stage of the project.

Reviewer 2:
The reviewer said there was collaboration with Mahle, Norgren, FCA and NREL.

Reviewer 3:
The reviewer reported there is good collaborations in line with a production oriented product development. An OEM will test the system now that it is designed.

Reviewer 4:
The reviewer commented there is a good balanced collaborative team. Hopefully this will result in an implementation with FCA

Reviewer 5:
The reviewer reported the collaborations are good, but a battery OEM would be a useful partner in developing a system that will impact EV range. A battery OEM partner should be sought for insight and advice into thermal management of batteries.

Reviewer 6:
The reviewer cannot recall substantive partner institutions.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer reported this effort has for the most part stayed on schedule and proposes a straight-forward approach for future research and completion of the project. Key remaining elements are targeted in budget period three including completion of the commercially viable, plastic MMFC; development of vehicle controls; durability validation of components; manufacturing plan and cost estimates; and vehicle testing, build, and final analysis and delivery to DOE.

The reviewer observed that Mahle mentions that in budget period three, there is going to be focus on project cost and timing. This is good, but an additional suggestion as part of this effort is to not only focus on the directly quantifiable cost elements of bringing the technology to commercialization, but also approaches to overcome the associated intangibles. For example, this may include the reluctance of an OEM HVAC or other engineers to adopt the new technology given inherent risk aversion and the constraints of the vehicle design and technology integration cycles, or possibly consumer acceptance.

The reviewer remarked there is a lack of complete clarity on the ultimate energy savings of this proposed technology over realistic drive cycles across typical ambient temperatures. It is shown there is a range penalty at warm temperatures. The reviewer noted that a question arises as to the strategy to sell a UTEMPRA equipped EV in warm climates. The reviewer questions how this would be handled from an OEM marketing standpoint and wonders if the UTEMPRA system would be offered as an option only in relatively cold climates. In addition, the reviewer questions if this is viable from an OEM manufacturing and integration standpoint.

Reviewer 2:

The reviewer suggested there is still much to accomplish for this project. A plan to accelerate progress that does not depend necessarily on the no-cost extension by the DOE should be developed.

Reviewer 3:

The reviewer noted this was a rather lengthy project with a large amount of DOE money. Financial overruns on the project were handled by Mahle. The reviewer has a concern as to why DOE was paying for a process improvement process in moving to flux free, which seems like it would be more of a benefit to Mahle besides cooling for electronic components. However, not much was presented on how this was progressing, how the manufacturing was progressing, or if there was improved quality and lower cost. There also was not a comparison of flux free, versus plastic, versus machined aluminum.

Reviewer 4:

The reviewer remarked it was the project's intention is to complete the design, pre-validate through OEM testing, and continue with a low-cost production design scheme.

Reviewer 5:

The reviewer commented that it is recommended that the vehicle test be performed by an independent party.

Reviewer 6:

The reviewer said improvement versus status quo future is not great.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

The reviewer stated electric vehicles have the potential to significantly reduce the transportation sector's reliance upon petroleum. However, they currently face challenges including range limitations due to battery capacity and the high energy use for climate control especially at low operating temperatures. The development of a commercially viable, high efficiency heat pump system to reduce energy requirements for climate control will help mitigate the range penalty for EVs and increase commercial viability. Additionally, some of the technologies developed under this project, such as flux free brazing, are potentially applicable to a broad range of other vehicles and components both electric drive and conventional.

Reviewer 1:
The reviewer observed lower energy use in EVs allows for longer range and potential increased adoption of petroleum displacing EVs.

Reviewer 2:
The reviewer remarked, this addresses the significant auxiliary power usages of climate control which impacts range and thus consumer acceptance.

Reviewer 3:
The reviewer said EV range is negatively and significantly impacted by extreme temperatures. A novel thermal management system (TMS) certainly aligns with DOE goals of extending the range of EVs with the goal of reducing petroleum consumption.

Reviewer 4:
The reviewer commented that the project somewhat supports the overall DOE objectives

Reviewer 5:
The reviewer noted petroleum displacement prospects seemed minimal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed as indicated by Mahle within the presentation, financial resources to successfully complete this project are sufficient. Despite exhaustion of resources for budget periods one and two, no significant resource issues have been highlighted. Current projections indicate that financial resources required to finish budget period three will be underspent by about five per cent, therefore, funding is sufficient. The reviewer said sufficient human resources for engineering are available with Mahle having brought on board a control engineer and FCA assigning a test engineer.

The team has the full span of equipment and facilities necessary to successfully complete the project.

Reviewer 2:
The reviewer noted the resources appear to be sufficient for this project.

Reviewer 3:
The reviewer said resources seem good.

Reviewer 4:
The reviewer said the project is staffed in accordance with a production oriented development program.

Reviewer 5:
The reviewer opined that funding seemed to exceed value proposition and that achieving milestones in a timely basis was secondary.

Reviewer 6:
The reviewer commented obviously, resources are insufficient. There was a cost overrun.

Presentation Number: gi158
Presentation Title: Zero Emission Cargo Transport II: San Pedro Bay Ports Hybrid and Fuel Cell Electric Vehicle Project
Principal Investigator: Joseph Impullitti (SCAQMD)

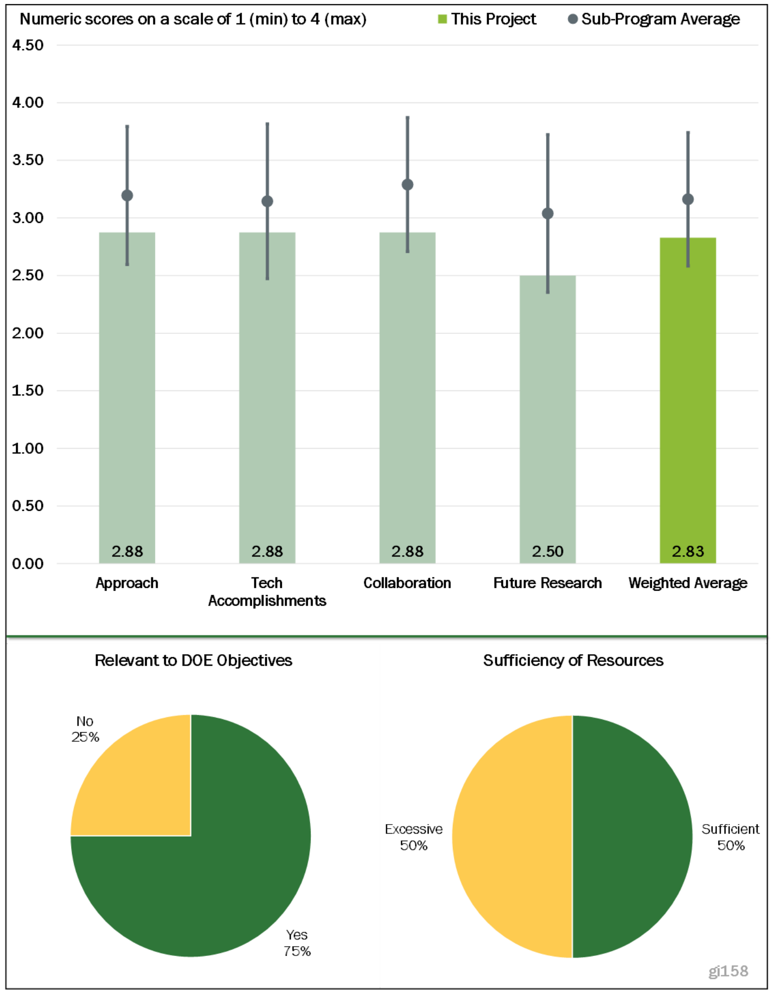

Figure 6-9 - Presentation Number: gi158 Presentation Title: Zero Emission Cargo Transport II: San Pedro Bay Ports Hybrid and Fuel Cell Electric Vehicle Project Principal Investigator: Joseph Impullitti (SCAQMD)

Presenter

Joseph Impullitti, SCAQMD

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported this project involves the demonstration of a wide variety of advanced vehicle powertrains in several types of applications. These types of deployment projects align well with DOE goals of petroleum displacement because of the real-world data on usage and performance. This project is well designed and involves industry consortia with that require relevant expertise.

The reviewer suggested the project could include an analysis of the potential for fuel cell technology in these applications, including a cost analysis and H_2 production and infrastructure analysis. The project could also include an investigation of other H_2 storage technologies besides compressed H_2.

The reviewer also suggested a battery OEM partner would be a useful addition to the project group.

The reviewer commented RDE testing with PEMS units would be useful with the hybrid vehicles in order to be able to quantify the emissions advantages of the fuel cell-based vehicles.

Reviewer 2:

The reviewer stated the approach being used of all existing fuel cell companies is good, but should be more clearly identified as part of the objective. There are not many opportunities for these kinds of comparisons between companies in this high technology space.

Reviewer 3:

The reviewer questions how DOE’s goals are severed with OEM’s and contractors deploying already existing technology. In addition, the reviewer questions if this advances research.

Reviewer 4:
The reviewer observed this project has big bucks, but the approach seems to be to just try this and that and one of those, because it will probably work. There does not seem to be any background plan of what types of features might be most useful for different vocations, with an attempt to design vehicle characteristics to match needs. The reviewer remarked each design is well thought through and technically sound, but the project team should figure out which make sense and focus on those. The reviewer suggested the different types of trucks need to be compared to each other and to conventional alternatives.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted all the pieces are being addressed in a timely manner.

Reviewer 2:
The reviewer stated technical progress seems alright on vehicles (although difficult to gauge with so many combinations and approaches). There is little mention of progress on fueling infrastructure, which is identified as a significant barrier on this project.

Reviewer 3:
The reviewer said the vehicle build and deployment appear to be on schedule. The establishment of the temporary H_2 refueling should provide sufficient capability for the deployment. The project was able to successfully replace industry partners, which is a testament to the mitigation plan and/or abilities of the PI to manage unforeseen circumstances.

Reviewer 4:
The reviewer remarked the progress seems slow considering that the project is in its fourth year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer affirmed collaborations with industry are the strength of this project. The various industry partners are highly representative of the significant and active participants in the advanced powertrain HD industry. The reviewer suggested a battery OEM partner would be a welcome addition in these projects instead of simply integrating cells and modules by the overall integrator. Additionally, an academic collaborator would help deepen the analysis, including both the performance against other powertrain technologies but also on the commercialization side.

Reviewer 2:
The reviewer observed there are lots of industry partners, all working away, but did not see anybody doing any analysis of performance or potential benefits, not to mention costs.

Reviewer 3:
The reviewer remarked there are lots of partners on this project, which is a benefit. However, actual collaboration seems lacking between the different contractors and some of the historical Drayage vehicle projects from the past.

Reviewer 4:
The reviewer mentioned although there was no specific slide on collaborators it seems like there are a number of contractors involved.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer acknowledged the proposed work to complete the deployment and testing appears to be feasible and on schedule. Development of the test plan for the vehicles is not explicitly shown, and considerable thought should be put into how these vehicles will be monitored and what will constitute a success in the deployment phase.

Reviewer 2:
The reviewer noted the proposed future research is a continuation of what the project team has been doing, which is lots of different trucks being developed and tried. The reviewer suggested some project integration and analysis and comparison of technologies.

Reviewer 3:
The reviewer commented fuel cells is future enough. There was little said in the presentation about future work, but fuel cell applications are likely to be in the future for some time.

Reviewer 4:
Although, FY 2019 is referenced as the end of project, this reviewer pointed out that no future work was mentioned.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed this project supports the overall DOE objective of petroleum displacement by advancing the art in advanced powertrains in HD vehicles. HD vehicles have significant potential for fuel economy improvements, and this deployment project provides considerable learning opportunities for government, industry, and the general public.

Reviewer 2:
The reviewer said any one of the technologies under development would use less diesel than conventional trucks.

Reviewer 3:
The reviewer noted fuel cells provide 100% reduction in petroleum use.

Reviewer 4:
The reviewer commented that no mentioned of actual petroleum savings was made.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked the cost share of 50% means that industry is providing a significant amount of funding, which is advantageous leveraging of industry resources. The overall funding amount is large, but deployment projects that involve significant design work require this funding level.

Reviewer 2:
The reviewer commented the project has big bucks, but it is developing and demonstrating a whole set of different technologies. The reviewer noted f everybody’s budgets are slashed, one could consider funding only those shown to be most practical, but then somebody would need to do analysis to see which.

Reviewer 3:
The reviewer commented that $20 million seems a lot of resource for demonstration of four different vehicles that do the same thing. The funding also does not address one of the primary barriers to adoption which is infrastructure. The reviewer suggested there seems like there would be a better way to spend this much money to promote hydrogen fuel for this application and considers it to be a good application for the technology.

Reviewer 4:
The reviewer noted the funding level seem high compared to the accomplishments.

Presentation Number: gi161
Presentation Title: Multi-Speed Transmission for Commercial Delivery Medium-Duty Plug-In Electric Drive Vehicles
Principal Investigator: Bulent Chavdar (Eaton)

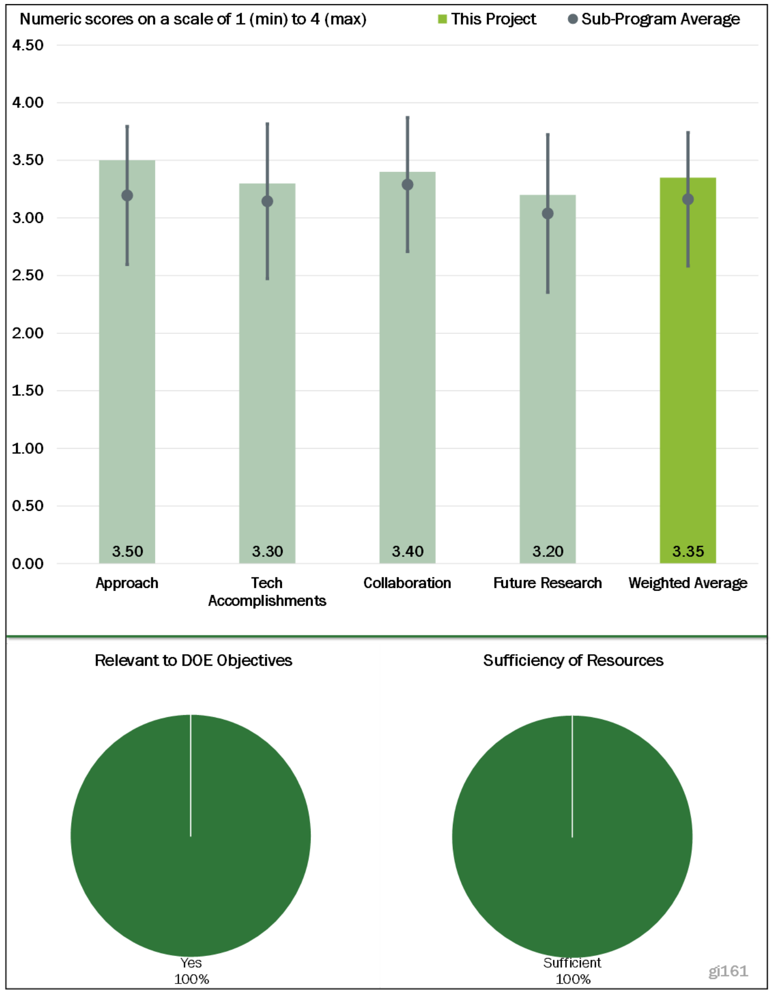

Figure 6-10 - Presentation Number: gi161 Presentation Title: Multi-Speed Transmission for Commercial Delivery Medium-Duty Plug-In Electric Drive Vehicles Principal Investigator: Bulent Chavdar (Eaton)

Presenter
Bulent Chavdar, Eaton

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented the approach seems fine, but hardware in-the-loop (HIL) in-vehicle testing timeline is not well-presented. Vehicle demonstration is due to be complete in October, which seems fast, but this is the part of the project where ORNL and Proterra start doing their testing. The reviewer remarked that it seems like scheduling and coordination will more difficult and/or complicated than presented here.

Reviewer 2:
The reviewer stated this was a good idea, and it looks like technical details have been addressed carefully.

Reviewer 3:
The reviewer observed the weight reduction is a significant achievement in addition to the other performance achievements. The details of how this was achieved should be explained in more detail as this would add more value to the overall project.

Reviewer 4:
The reviewer noted the class of vehicle range for this transmission is not feasible. There are many technical barriers between class seven bus duty cycles and a class three van duty cycle. The reviewer suggested this should be focused on class one or two vehicles.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
Regarding the improvements on Slide 3 showing Urban Dynamometer Driving Schedule efficiency and acceleration, the reviewer questioned what the contribution ratio for the improvement consists of between weight reduction, design/control improvements or something else.

Reviewer 2:
The reviewer observed the modeling results look good and are to be validated against in-vehicle performance.

Reviewer 3:
The reviewer noted the project appears to be on target and the results look very promising.

Reviewer 4:
The reviewer reported performance goals for class seven appears to be feasible.

Reviewer 5:
The reviewer said there is a solid team assembled on this project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed a good team with DOE and other industry partners and stated that the upcoming four months is the part where the collaborators get to play their role. The reviewer commented that the project has a very compact schedule and that coordination is required to realize value from the collaborations.

Reviewer 2:
The reviewer said a small solid team promotes this.

Reviewer 3:
The reviewer suggested the project team should have some end user participation to obtain some real-world usage by class.

Reviewer 4:
The reviewer suggested actually getting a vehicle partner to enable much improved project integration and coherence.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer, as previously indicated, was unsure that the future work planning is presented with enough detail and was not convinced that HIL/in-vehicle testing can be done in the timeline presented.

Reviewer 2:
The reviewer remarked again, the project team needs end user participation.

Reviewer 3:
The reviewer noted how the equipped buses actually perform will be the interesting part. It would also be interesting to install the system in other vehicles. The reviewer indicated one question not addressed is how much improved performance will enable the more rapid penetration of electric vehicles.

Reviewer 4:
The reviewer indicated there is not much research left to do.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer indicated the project supports the DOE objectives through the development and vehicle integration of an efficient and low weight transmission.

Reviewer 2:
The reviewer stated yes, the work supports the DOE objectives.

Reviewer 3:
The reviewer state yes, performance on class seven buses show improvement.

Reviewer 4:
The reviewer said having EVs that actually perform well is a prerequisite for actual market penetration. If the bus takes a week to get up the hill, you cannot use it in San Francisco.

Reviewer 5:
The reviewer indicated not being convinced this is the best way to reduce petroleum usage compared to other projects but it has value.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted the resources seem fine.

Reviewer 2:
The reviewer suggested the project team could use an end user in this project.

Reviewer 3:
The reviewer noted the project team did lots of work.

Presentation Number: gi165
Presentation Title: Design and Implementation of a Thermal Load Reduction System in a Hyundai PHEV
Principal Investigator: Cory Kreutzer (National Renewable Energy Laboratory)

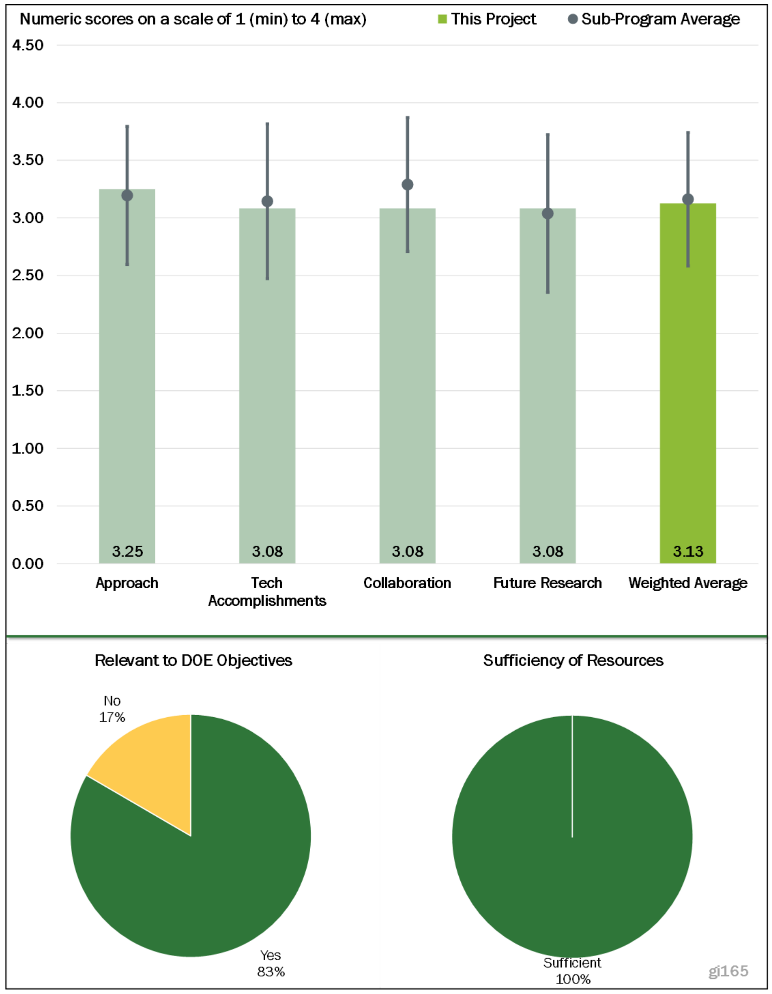

Figure 6-11 - Presentation Number: gi165 Presentation Title: Design and Implementation of a Thermal Load Reduction System in a Hyundai PHEV Principal Investigator: Cory Kreutzer (National Renewable Energy Laboratory)

Presenter

Cory Kreutzer, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated the approach is to segment the individual parasitic load elements and to address each of them with individual technology improvements. In addition, it increases range with a low climate system energy load using solar control glass and reflective paint as well as a pre-loaded heating system. The reviewer said this is an excellent approach.

Reviewer 2:

The reviewer described this as an excellent approach to overall project with good consideration of resources required and solid partnerships established for effort. Additionally, this reviewer observed good recognition of areas that would impact comfort of passengers and understanding of need for various performance measures including windshield clearing. The reviewer noted it is difficult to solve cost barrier without better partner supplied data, to understand ROI. The grid connected vehicles can provide much of transient power without impact to all electric range (AER).

Reviewer 3:

The reviewer remarked this project incorporates a two-phase process. First the design and development including evaluation and analysis, and second integration and validation including full system impact on range, national impacts, and occupant comfort.

The reviewer stated the project is fundamentally well-designed and feasible from a technical standpoint, with a goal to increase grid-connected electric drive vehicle (EDV) range by 20% during operation of the climate control system over a standard baseline.

The energy savings potential during transient and steady state operation of five technology areas are addressed for climate control including: solar control glass/heated windshields, solar reflective paint, heated surfaces, climate control seating, and door glass defrost/defogger.

The reviewer commented it is not clear how well the project is integrated with other efforts.

Understanding the proprietary challenges, there is little discussion or analysis with regards to technology costs and the potential impact upon commercialization.

Reviewer 4:

The reviewer reported that it is clear the testing that was done relative to occupant comfort is one of the most subjective aspects of the project. The researchers should provide more detailed information on the approach used to conduct these tests to that the validity of the results can be better supported.

The reviewer noted Slide 12 presents numbers on the efficacy of solar reflective paint to a very high degree of precision. Given the part-to-part variability perhaps the results should be rounded off to fewer significant digits, to prevent creating a false impression of accuracy.

Reviewer 5:

The reviewer acknowledged that this was not a favorite paper to evaluate. The reviewer remarked that this looked like suppliers looking for reasons to incorporate their technology onto vehicles. There was not an overall system approach to a vehicle, which would also incorporate electrical loads on the vehicle, wiring, and costs.

Reviewer 6:

The reviewer noted the business case is better than others reviewed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that many areas for energy use reduction were evaluated. Some were experimental level with base data fed to analysis of cabin thermal loads and how they affect EV range; numerous glass technologies were evaluated at 23%-43% reduction of load. The reviewer also reported the following: solar reflective paint was different; used ventilated and cooled seats; used heated surfaces like arm rests coupled with improved heated seats are more important in steady state; no transient improvement and heated windshield and door defogger. This broad range of items establishes excellent technical progress.

Reviewer 2:

The reviewer stated the project has made good progress to timeline and milestones. The reviewer commented that highlighting the large transient loads needed to establish comfort prior to stabilization is important for many projects, and allowed good use of prior work regarding simulation tools. The reviewer noted the project seems on track to complete on time, though still question whether or not impact to AER will calm OEM apprehension about investing in new technology or change perceptions for potential vehicle buyers.

Reviewer 3:

The reviewer observed the project completed Phase one, candidate technology evaluation, and downselection for Phase two, system level integration and evaluation. The project has demonstrated a number of technical accomplishments with regards to quantifying the energy savings potential of the downselected technologies in five technology areas under summer cooling and winter heating scenarios.

Summer cooling conditions accomplishments include glass package: 42.5% transient and 12.8% steady state energy savings, solar reflective paint: 5.3% transient and 16.1% steady state savings, ventilation / cooled seat: 25%-45% transient and 10%-17% steady state savings and heated surfaces: 1%-2% transient and 29%-59% steady state savings. Under winter heating conditions 19.5% reduction in time to clear windshield and 24.5%-67.8% reduction in power demand and the project has developed a national level analysis process for range estimates under varying U.S. environmental conditions.

Reviewer 4:
The reviewer noted accomplishments and progress were in line with goals.

Reviewer 5:
The reviewer observed progress is being made toward the goal, but in the end, the proof is in the pudding. Once the national level analysis has been completed, it will give a better idea of the petroleum displacement potential. The national level analysis will presumably consider several different scenarios and evaluate a range of possible outcomes.

Reviewer 6:
The reviewer noted accomplishments are good, not great. The reviewer did not want to rate the project lower than good. The reviewer indicated some of this technology is old news in the industry. Costs are especially important on this, not just engineering data. The reviewer suggested what has to be looked at are various OEM standards for heating and cooling of occupants.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented there is a very comprehensive group of collaborators representing the individual technology expertise for each energy saving areas listed.

Reviewer 2:
The reviewer noted there is a good set of collaborators, though seems a little bit like a hard sell from suppliers to leverage government funds for R&D.

Reviewer 3:
The reviewer remarked the NREL project team incorporates all the requisite partners including technology developers in each technology area and a major automotive OEM supplier for overall integration and assessment.

The reviewer said there is little mention of discussions with other automotive OEM suppliers or OEMs to potentially broaden out the market base for the respective technology options.

Reviewer 4:
The reviewer stated collaboration with others was demonstrated and good.

Reviewer 5:
The reviewer noted several industry partners are included, but it does not seem to be including other national laboratories. Given the funding atmosphere, perhaps more involvement of other laboratories should be sought.

Reviewer 6:
The reviewer suggested this project really needs someone to look at the costs, system integration and manufacturing complexity of these ideas. This is not done here.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said future research prospects look good.

Reviewer 2:
The reviewer is looking forward to results of the national level analysis.

Reviewer 3:
The reviewer reported the project is completed in FY 2017 when the validation testing at Death Valley and in the cold chamber at Hyundai American Technical Center, Inc. This will establish a path to commercialization and will complete a research project that evaluates elements of new technology that when grouped together will meet the 20% reduction goal.

Reviewer 4:
The reviewer suggested there is a need to continue to report out on possible solution set to the items that reduce range for EVs.

The reviewer remarked future work may need to include some sort of human factors standard set of comfort but not to develop it, just to do research to see what exists with industry experts. This would eliminate some of the perceived variability in participant response to tests with same parameters.

Also, the project may look to EV use in colder climates to see what percentage of operators complain about windshield clearing performance, or if they even understand the range impact.

Reviewer 5:
The reviewer reported future proposed research as part of Phase two includes cold and warm temperature evaluation in an environmental chamber and hot weather field evaluation for baseline and thermal load reduction system vehicles plus refinement and validation of models and performance of national level energy savings analyses.

The reviewer suggested to the extent feasible, future proposed research would benefit from a greater emphasis upon cost analysis and development of technology packaging approaches to best present the technologies' energy savings potentials to automotive suppliers and OEMs. For example, as proposed, all downselected Phase two technologies will be integrated into a vehicle for cold and hot weather performance evaluation. But, the reviewer questions if this approach will provide the disaggregated data necessary to encourage one or a suite of these technologies to be adopted by the OEMs. The reviewer asked if there is a clear understanding of the optimal pathway and thereby the appropriate Phase two testing, analysis, and information dissemination strategy to encourage adoption of these technologies singly or as a group.

Reviewer 6:
The reviewer suggested to not continue this path.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer indicated this project will create a path to commercialize energy efficiencies in EVs and hybrid electric vehicles making them more desirable to consumers. The reviewer noted more EVs means more petroleum displacement.

Reviewer 2:
The reviewer noted obviously, increased market penetration for EVs would aid the DOE objective of petroleum displacement. Performance of HVAC and passenger comfort for EV has great potential to reduce customer apprehension, and counteract reduced range fears. Still, there is a great need to understand the cost of these solutions.

Reviewer 3:
The reviewer commented this project is relevant as the range of EVs is severely limited in extreme weather conditions, especially cold temperatures. The goal of this project is to extend grid connected EDV range by 20% through thermal load reductions which will significantly improve mainstream commercial viability leading to greater petroleum displacement.

Reviewer 4:
The reviewer stated energy reduction met objectives.

Reviewer 5:
The reviewer said it is weak.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed based on task progression, being 80% complete, and projected remaining work, funding resources appear to be adequate. The equipment and personnel are available to conduct the remaining elements of the project.

Reviewer 2:
The reviewer noted a very wide range of expertise in individual technologies as well as a good integration partner in Hyundai. Resources are sufficient because the project is on a path to achieve its objectives in the timeframe originally proposed the reviewer reported.

Reviewer 3:
The reviewer stated resources are alright.

Reviewer 4:
The reviewer said the project should finalize in a timely fashion.

Reviewer 5:
The reviewer remarked it appears that a good part of the work remaining is the responsibility of the other industry partners.

Reviewer 6:
The reviewer commented that while resources are bordering on excessive, in terms of reduced petroleum per dollar of R&D, this project helps to validate a number of tools and concepts which should be able to be projected thru use of tools in the future.

As stated previously, transitional thermal loads for Grid connected vehicles should be moved to vehicle preconditioning. The steady state load understanding is a greater area of importance in my view, and critical to understand the impact of AER and cost to adopt these technologies. In truth, some of cooling techniques are applicable to standard ICE vehicles, which could reduce their air-conditioning use, thus bringing technology costs down thru economies of scale. The project just has to get someone to identify that this is a critical customer demand.

Presentation Number: gi187
Presentation Title: Comprehensive Assessment of On- and Off-Board Vehicle-to-Grid Technology Performance and Impacts on Battery and the Grid
Principal Investigator: Sunil Chhaya (EPRI)

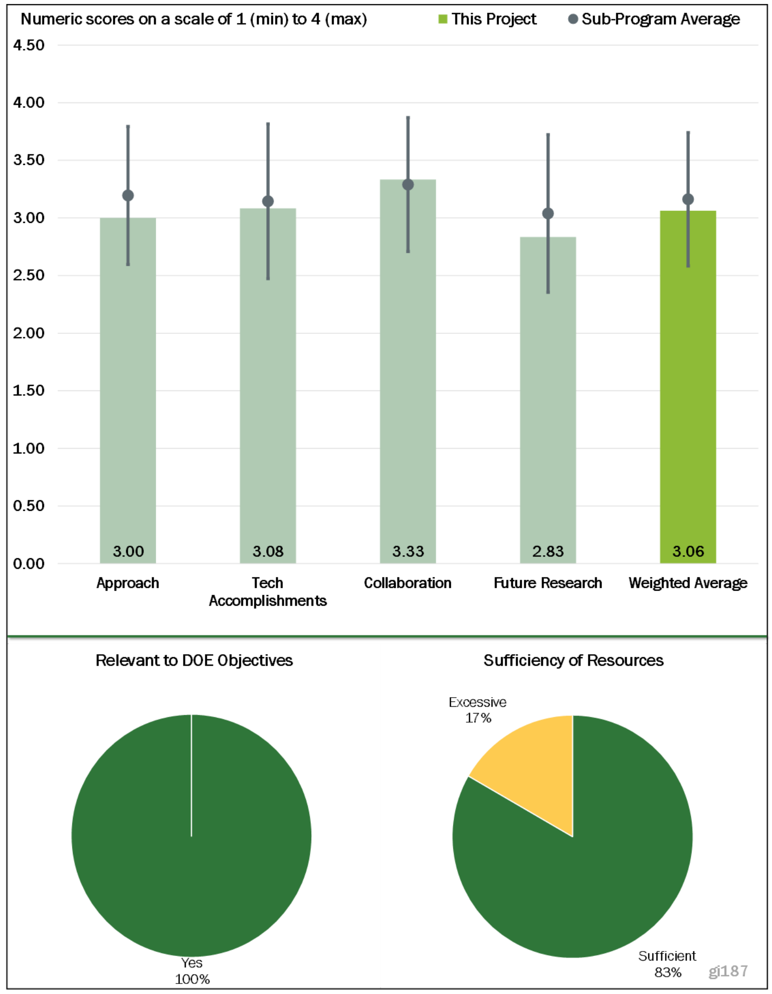

Figure 6-12 – Presentation Number: gi187 Presentation Title: Comprehensive Assessment of On- and Off-Board Vehicle-to-Grid Technology Performance and Impacts on Battery and the Grid Principal Investigator: Sunil Chhaya (EPRI)

Presenter
Sunil Chhaya, EPRI

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said all the technical pieces are going to be addressed in this new project, and does not see any insurmountable technical barriers. The only minor misgivings the reviewer has to do with the human factors and the actual benefits to be accrued. The reviewer inquired about the potential and whether any car-owner wants to have a car on the grid while at work. The reviewer noticed that the battery life study will show that battery life will be reduced, so it may be a commercial non-starter.

Reviewer 2:
The reviewer remarked the project seems to include a very ambitious set of activities, covering a broad range of efforts with a large number of milestones scheduled over a relatively short period of time. Some activities are clearly parallel paths, but some are inter-related. The hope is that all will occur as planned, or else there may be concerns on multiple activities backing up.

The reviewer observed the overall structure appears to be trying to answer a lot of questions with this one project and these are important questions to answer. Time will tell exactly how well the approach has been structured since the project only began in November 2016.

Reviewer 3:
The reviewer likes the approach to the work.

Reviewer 4:
The reviewer reported this project is very diffuse. This reviewer opined that it is a bit difficult to get a grip on all of the pieces because there are really two separate systems being developed: one is for the DOE, off-vehicle; and one is for the California Energy Commission (CEC), on-vehicle. The reviewer observed this project seeks to develop a suite of controls and power electronic systems that can enable V2G, but there are many aspects that are not clear.

Reviewer 5:
The reviewer commented that the technological approach is pre-mature. Just like all information technology enterprise systems, the business requirements must be worked out and articulated with each business owner associated with a requirement before taking a technological approach. The reviewer noted here the business requirements were never worked out or articulated. It is not even clear that there is a business case for this study. Neither a test cycle nor a business model has been worked out yet.

Reviewer 6:
The reviewer remarked V2G is a promising technological application, but the business case still needs to be made. If it can be implemented, it supports the DOE petroleum displacement goals. However, while V2G demonstrations are useful, the satisfaction of the various stakeholders in V2G deployment (e.g., the vehicle OEMs, ESS OEMs, utilities, vehicle owners, and building owners) must be ensured. The reviewer suggested a comprehensive analysis of the V2G business case is thus warranted.

The reviewer said the still-developing standards for V2G make this project challenging in that it is less than ideal to be testing communications protocols that may be changed in the future. Every effort should be made to support the standards development and acceptance by the V2G community and industry to ensure the relevance of this project.

The reviewer acknowledged the on- and off-vehicle parallel paths are useful in showing which path has the most promise for V2G applications.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said the progress on both paths appears to be on schedule from a technology standpoint, albeit with protocols that have not yet been finalized within a standards framework. The use cases must be addressed in a comprehensive manner. This complements the business case mentioned in the Approach section.

Reviewer 2:
The reviewer remarked the project began only last November, so it is early. The reviewer noted the milestones for early 2017 have been accomplished, though not that much of the funding has yet been spent (5% according to the presentation, at least at the time the presentation was prepared). No other milestones are scheduled until October 2017. The reviewer said accomplishments are in line with the project's plan, however, at this time it is hard to tell if the planned schedule will be sufficient to complete planned activities on time.

Reviewer 3:
The reviewer noted this is a new project.

Reviewer 4:
The reviewer stated it is so early in the project that this question regarding accomplishments is actually somewhat meaningless. The researchers are focused on the technical details, which is both the strength and the weakness of the project.

Reviewer 5:
The reviewer noted the progress to DOE goals needs to be more explicitly stated in a front slide. However, it is understood that V2G is important, along with standards to meet this goal. The project is just getting started.

Reviewer 6:
The reviewer indicated the goals are not well-defined instead, they just seem to be fuzzy, motherhood, apple-pie concepts. The goals do not seem to be quantifiable at this point in time.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said the project is coordinating among the utility industry (through Electric Power Research Institute (EPRI), the Principal Investigator organization), hardware manufacturers, a vehicle manufacturer, and several national laboratories. These appear to be the critical participants necessary. The reviewer noted the project is also focused on particular requirements for California, coordinated through the CEC.

Reviewer 2:
The reviewer reported it seems like a good team with utilities, DOE and other industry partners.

Reviewer 3:
The reviewer praised the collaboration with Government and Industry, and that the project team used multiple vehicles.

Reviewer 4:
The reviewer commented the team looks good, and the division of tasks seems appropriate.

Reviewer 5:
The reviewer remarked an electric power utility supplier or distributor was not included in this project unless it has been made clear that EPRI considers itself as taking on that role.

Reviewer 6:
The reviewer suggested more engagement with industry partners (specifically, more vehicle and ESS OEMs) as well as academic partners might improve the project results. The collaborations that already exist appear to be working well with strong coordination.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed many of the upcoming activities are identified, although the PI acknowledges a few will develop over time which is likely the appropriate approach. The planned future activities appear to answer many of the remaining questions for this project, but, due to the broad scope of this project, it is a bit early to tell if these are exactly the correct activities needed. The PI stated that they are still looking for participants for future efforts. The PI did indicate that EPRI has already been awarded a follow-on project by the CEC.

Reviewer 2:
The reviewer stated since this project is quite new, most of the work remains in the future. The proposed future research work appears to be part of a feasible and logical schedule and implementation plan.

Reviewer 3:

The reviewer commented the project plans to address all of the technical aspects thoroughly and would like to see some analysis of the detailed logistics and the human factors. The reviewer question if a car is plugged in at work, will there be enough charge left to get the person home. Also, the reviewer wonders if the user will need to charge more often, will they be compensated and what would happen if the user needs to leave for an emergency will they be able to get there.

Reviewer 4:

The reviewer noted as this project is just in start-up mode, there is not much mentioned about future work. However, the reviewer would like to see a more phased approach on the work, assuming that the project team is successful in this approach.

Reviewer 5:

The reviewer commented regarding the “off-vehicle” system, this project proposes the equivalent of a smart inverter. These smart inverters are commercial products and, (in general) the EVSE is mostly an alternating current cord and ground fault circuit interrupter, so it is unclear what is particularly novel about this SPIN inverter. The reviewer questions why this is a single box, as opposed to a distributed system and wonders if it should be able to use off-the-shelf EVSE and be able to communicate with the TMC.

The reviewer has many questions about the business case that will be developed. The speaker said that they were aiming to do more than just frequency regulation, but some of the information on the slides suggests that frequency regulation is under consideration. For example, Slide 7, Slide 12 suggests A/S and International Standards Organization integration. The reviewer suggested that maybe it is just that this business case development process needs to be clarified. The reviewer questions what the metrics of economic viability would be for this technology.

For the battery testing task, the reviewer is a bit concerned that this project will only be able to do a couple of designed experiments to look at battery degradation due to V2G cycles. The planning for these experiments should be based on the economically viable V2G use cases.

Reviewer 6:

The reviewer noted the business requirements have not been worked out yet. In addition, there is no duty cycle defined and no business model postulated. All that exists are concepts.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer observed the project is highly relevant in obtaining critical answers necessary for plug-in electric vehicles to succeed. As such, this clearly supports DOE objectives and petroleum displacement.

Reviewer 2:

The reviewer noted V2G may become a major component of demand response activities. This may not support petroleum displacement directly in that petroleum is not used in a large percentage of U.S. electricity production; however, V2G may improve the cost of EV ownership, and this certainly helps displace petroleum. Thus, this V2G project does support DOE goals.

Reviewer 3:

The reviewer noted V2G is an incentive to electrify transportation.

Reviewer 4:

The reviewer stated yes, the project supports the DOE objectives but, would like the PI to please state it more explicitly. We all understand that electric vehicles are important for petroleum displacement.

Reviewer 5:
The reviewer stated that clearly making the grid more robust enables more EVs. The reviewer suggested providing some quantitative benefits estimate in terms of reduced costs to utility from unneeded peakers or unpurchased storage.

Reviewer 6:
The reviewer remarked the principal investigator should have elucidated (instead of assuming that the reader knew) that this project would help with peak loading or peak shaving by balancing peak electric power demands with surplus electric power stored in electric vehicles and allowing electric vehicles to be re-charged during non-peak periods. No study was cited or referenced to show that this is feasible.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked the resources appear to be sufficient for this project that includes a large technology development and deployment portion.

Reviewer 2:
The reviewer indicated if funded as proposed, funding appears sufficient. In addition, EPRI has received a follow-on project from California.

Reviewer 3:
The reviewer said resources seems fine.

Reviewer 4:
The reviewer remarked since there are lots of technical details to be addressed, and that is expensive, there is not too much money. The reviewer still wonders whether the whole concept makes sense. It is certainly possible, but asks if is worth it. The reviewer questions if the concept could it actually fly commercially and what its potential mat be.

Reviewer 5:
The reviewer noted that funding for this project is excessive when it is primarily a paper study.

Reviewer 6:
The reviewer commented the project has just begun and will have more information available to be reviewed in a year’s time.

Presentation Number: gi188
Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-Grid Connectivity
Principal Investigator: Mike Ippoliti (CALSTART)

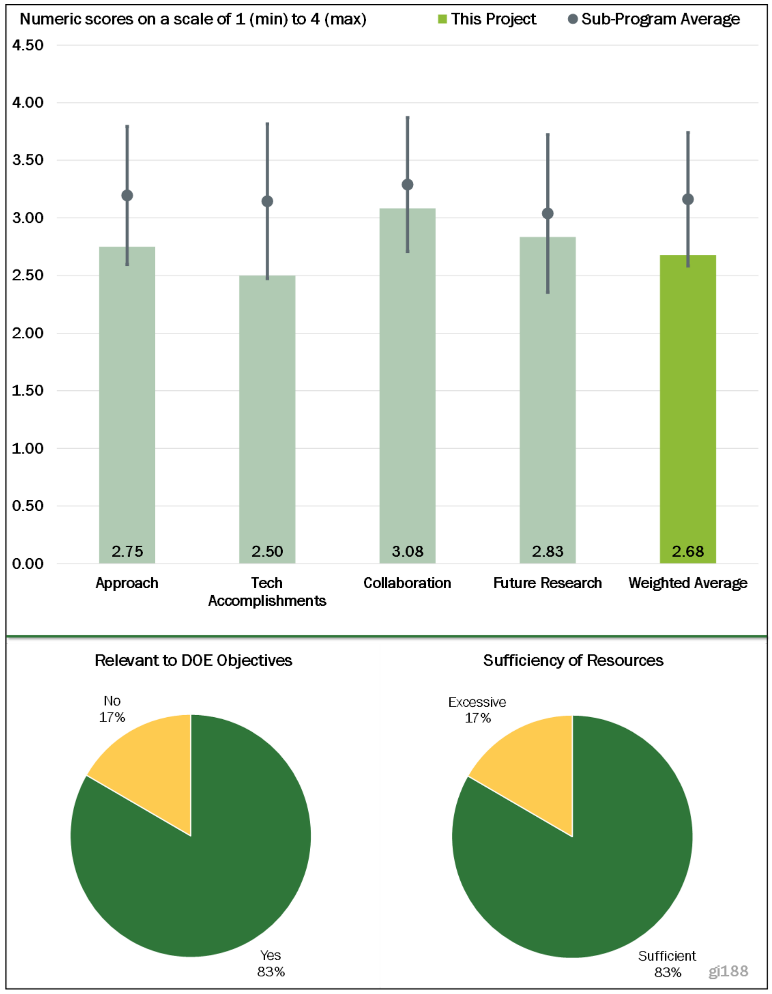

Figure 6-13 - Presentation Number: gi188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-Grid Connectivity Principal Investigator: Mike Ippoliti (CALSTART)

Presenter
Mike Ippoliti, CALSTART

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer observed the risk aversion and cost barriers are well addressed since ORNL has previously demonstrated a 20 kW WPT mono directional system integrated into a Toyota Prius. The constantly changing technology barrier is also addressed by the head start that ORNL has using a previously demonstrated design. The computational model barrier is also likely well addressed since ORNL can leverage its existing models to include the secondary to primary power flow model.

Reviewer 2:
The reviewer stated the approach seems logical but it is still early in the project.

Reviewer 3:
The reviewer understands the difficulty of identifying the best partners for application and demonstration projects, as such the reviewer is reluctant to see the perfect fit in this case study. As UPS has been an excellent partner in many demonstrations, the limitations of their vehicles and lack of optimization of the wireless technology makes a fit seem impractical. The reviewer clarifies as follows. The UPS vehicles have fairly set routes and therefore the battery is sized to optimize for their application. They do not carry excess capacity so when the project expects to exercise “reverse flow” to grid, the fleet operator will be reluctant to allow reduction of the range of their vehicle. In addition, the 11-inch air gap to coils is not insignificant with magnetic resonance charging technology but acceptance appears to have made it into the project.

Reviewer 4:
The presenter implied that there is not much to review with the audience, but the reviewer disagrees and finds the beginning of a project to be the most appropriate time to discuss technical challenges and barriers that will be encountered. It is difficult to understand technical barriers that were not well-communicated, performance

metrics that the project will measure success of the developed power transfer system, and performance targets that the team will be trying to achieve.

Reviewer 5:
The reviewer noted this project is so new that it is difficult at this stage to rate the approach. The preliminary approach does seem logical and feasible. The business case for V2G in medium-duty vehicles (MDVs) should be made that clarifies how each of the stakeholders (i.e., vehicle OEMs, ESS OEMs, utilities, vehicle owners, and building owners) stand to benefit from this technology paradigm. The reviewer remarked the presenter did not mention which standard is to be followed. It is crucial that this project align with a wireless charging standard such as SAE J2954 to maintain the relevance of the developed technology.

Reviewer 6:
The reviewer stated the feasibility is subject to question.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed the project team has made good progress in the short time that the project has been running. The project team has established coordination meetings with the partners and ORNL has begun design activities as outlined by the project plan.

Reviewer 2:
The reviewer noted the project is still young, but acceptance of limitations such as the wireless air gaps are not being challenged.

Reviewer 3:
The reviewer indicated it is difficult to determine the degree by which the group has prepared themselves for this project since there is little justification presented for the technical designs and strategies used. The impression was given that the project's performance and system requirements was primarily motivated by UPS's needs in a bidirectional WPT system. It would be helpful if the PI and team included more information about what analysis was performed to determine the architecture for the system they will be developing and demonstrating. The reviewer noted the collaboration with UPS to be very important, the design of the charging system demonstrated should be informed by a comprehensive benchmarking of the industry's charging technologies, as well as analysis to identify what power levels, gap distances, and power electronics architecture would be most relevant to current charger development within the industry.

Reviewer 4:
The reviewer suggested this project is too new to assess the technical accomplishments.

Reviewer 5:
The reviewer stated the project was only recently started.

Reviewer 6:
The reviewer commented that it seems like this project is so new that it should not have been reviewed this year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer is impressed to see the level of enthusiasm and collaboration developed among the involved partners and contributors.

Reviewer 2:
The reviewer indicated it looks like a good list of collaborators.

Reviewer 3:
The reviewer acknowledged UPS and Workhorse are good and competent partners, but as prior note, perhaps not the best choice.

Reviewer 4:
The project plan concentrates most of the early activities at ORNL and has assigned the other project partners well defined roles with appropriate workloads. The degree of collaboration and coordination will not drain all the project resources.

Reviewer 5:
The reviewer noted the collaboration could be improved by including academic institutions as partners to broaden and deepen the analysis.

Reviewer 6:
The reviewer suggested collaboration and coordination with end customers (users) needs to be developed.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed the future work outlined by the presentation is a logical progression of next steps for the project to pursue. The future work outlined allows for the possibility of significant design modifications to mitigate any unexpected issues.

Reviewer 2:
The reviewer remarked the proposed future research, which is essentially the entire project, appears to be sound and feasible. The project results could be quite useful in advanced the art of V2G for MDVs.

Reviewer 3:
The reviewer indicated the future work is described in the project work plan, as it should be for a young program. The project would score better with expressing for site beyond the tasks of the present program.

Reviewer 4:
The reviewer commented considering the early stages of the project the future work could have been more detailed.

Reviewer 5:
The reviewer said future research results seem dubious but satisfactory to date.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The project supports the objective of petroleum displacement by developing a WPT system for a MD electric vehicle. This type of WPT technology will increase the convenience of charging the MD EV and will add some vehicle to microgrid features that has potential to make the EV more marketable. MDVs have lower fuel efficiency than LDs and therefore the electrification of MD vehicles will displace significant amounts of petroleum from the U.S. transportation sector.

Reviewer 2:
The reviewer observed all projects which develop and assess EV technology (as this project does) also support the primary objective of the DOE by reducing dependence on petroleum fuel.

Reviewer 3:
The reviewer stated wireless power flow is a relevant topic in DOE's framework.

Reviewer 4:
The reviewer observed V2G does not necessarily produce petroleum displacement since petroleum is not used in a significant amount of electricity production. However, if V2G improves the total cost of ownership (TCO) of EVs and induces more EV adoption, V2G could become an important factor in petroleum displacement and therefore align with DOE objectives.

Reviewer 5:
The reviewer noted petroleum displacement value needs to be proven.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said the project describes reasonable funding levels for the program described.

Reviewer 2:
The reviewer reported the budget seems in line for the project scope.

Reviewer 3:
The reviewer indicated the resources appear to be adequate for this project.

Reviewer 4:
The reviewer affirmed the resources are likely sufficient to meet the basic milestones of the project. One area that may require additional resources may be the evaluation of battery degradation due to V2G operations. To be statistically significant this evaluation may require a lot of test cycles and possibly multiple battery packs.

Reviewer 5:
The reviewer stated resources are not the question the results are!

Reviewer 6:
The reviewer suggested that given the benefit and vested interest that UPS is receiving from this collaboration and cost-sharing, they should increase their contribution amount.

Presentation Number: gi189
Presentation Title: Electric Truck with Range-Extending Engine (ETREE)
Principal Investigator: John Kresse (Cummins)

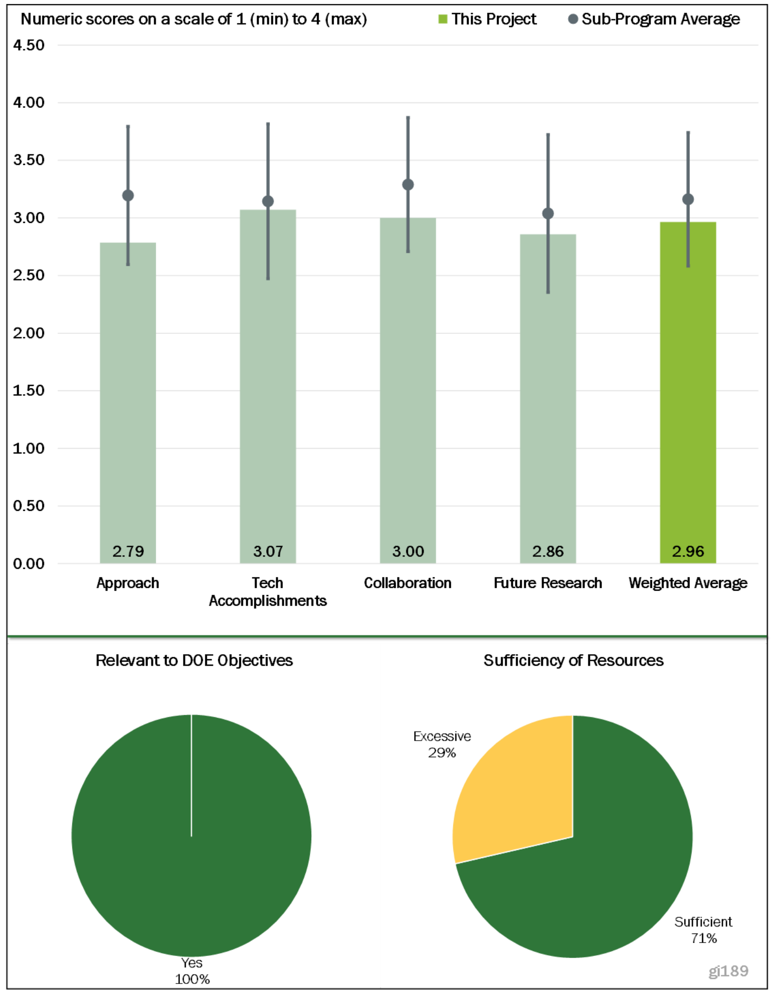

Figure 6-14 – Presentation Number: gi189 Presentation Title: Electric Truck with Range-Extending Engine (ETREE) Principal Investigator: John Kresse (Cummins)

Presenter

John Kresse, Cummins

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer reported the approach of this project is logical and sound, with appropriate go/no-go milestones. Medium -duty vehicles have large potential for fuel economy improvement, and the range extender approach could be commercially viable while also aligning with DOE petroleum displacement goals.

The reviewer noted there are three “competing” simulation efforts, but there is no mechanism or process in place to evaluate and compare and contrast the results. There should be extensive effort in developing such a process.

The reviewer remarked the ESS TMS is passive air cooling. However, this was not justified explicitly by the presenter. The reviewer asked if the use cases corroborate this design decision In addition, the reviewer asked if a liquid-cooled TMS considered and if so a justification is required.

The reviewer indicated it was not explicitly mentioned whether DC fast charging was or is being considered. This could further enhance the lower operating costs of these vehicles while also increasing utility.

Reviewer 2:

The reviewer said the approach is logical and well presented.

Reviewer 3:

The reviewer observed the PI indicated that the project is a little less than one year into a total three-year level of effort. Planned system development activities in the first year include establishing the powertrain requirements, selecting components, designing the control and mechanical systems, and performing evaluations through simulation and component testing. After clearing the 12-month go/no-go decision gate (based on demonstrating 50% fuel consumption reduction of the prototype powertrain system operating in a test cell), a few of the system development activities will continue, but overall efforts in year two will shift largely to vehicle integration. The 24-month go/no-go decision gate involves successful SAE J1321 Type II demonstration of the first test vehicle, which is to be followed in the final year by targeted testing of the second demonstration vehicle and field demonstration of both vehicles in a participating partner fleet.

The reviewer commented overall, the approach seems fairly sound, though the PI referred to a potentially excessive grade-ability requirement that may drive some components to larger and more costly levels than would otherwise be the case. It may be worth discussing this trade-off with the fleet that set the grade requirement to see how firm it actually is. It looks as though the requirement is at least relaxed in the vehicle's charge sustaining mode, so that could be a good test case during the demonstration phase to determine whether or not reduced grade-ability ever becomes an issue once the battery depletes, and/or to forecast if it ever would have been an issue prior to the battery having depleted were the components to have been sized differently. The reviewer suggested that another potential approach improvement would be to incorporate best-available battery life modeling capabilities into the design and analysis stage, though it is understood that life data specific to the batteries being considered is difficult to come by. It is possible that these two issues related to potential battery over-sizing on the one hand and potential underappreciation of life/degradation in the intended application on the other hand may offset to some degree. The final critical comment on the approach is that the plan is unclear as to the relative roles and overall benefit from the "competitive/cooperative" simulations being conducted by three different members of the project team.

Reviewer 4:

The reviewer reported the goal of this project is to meet at least a 50% energy efficiency improvement over a wide range of driving cycles for Class 6 Package and Delivery Trucks. This vehicle will have to work over a variety of missions and environmental conditions and be manufacture red, serviced, certified, and delivered using standard commercial processes. The vehicle will be a prototype and is to deliver comparable performance and range as a conventional Class 6 truck.

The reviewer noted the focus is to solve barriers to electrification of Class 6 trucks including cost and range while minimizing fleet operator risk.

The reviewer observed the approach is to utilize a PHEV with a low-cost range extender in the near- to mid-term. Based upon the Kenworth K270/Peterbilt 220 platforms, the project follows a well-founded and structured approach including system development (simulation, component selection and design, control design, and testing); vehicle integration (thermal systems, mechanical design, and accessory selection); and vehicle demonstration.

The reviewer warned the one notable weakness in the project approach is the under emphasis upon cost analysis early in the project. An extensive cost analysis should be conducted (in concert with fleet partners) early to determine and frame the commercial viability of the overall concept from the customers' standpoint.

The reviewer indicated milestones are well identified and structured with the exception that it would have been preferable that consideration be given that the first go/no-go milestone be based on a detailed cost and market feasibility study.

In addition, there is no mention of project integration with other efforts.

Reviewer 5:

The reviewer stated the design cycle is alright as an overview. However, technical barriers were not identified or addressed. It is feasible, but does not appear to leave any room for troubleshooting/ addressing issues. The project is not directly tied to other efforts. The technical approach appears to be to design, test, then define the goals or eventually ask for relief as stated in the reviewer slides. The reviewer noted this is not well designed, as the goals should be defined up front, then try and achieve them.

Reviewer 6:
The reviewer reported the specifics on the approach could be more clearly stated in the presentation of the project.

Reviewer 7:
The reviewer indicated the approach is very disjointed. The reviewer pointed out that adding 3,000 pounds of weight, using an oversized diesel engine with an after-treatment system and designing it for a 200 plus mile range while testing for an 80-mile route does not make sense.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer remarked this project is on schedule and has achieved numerous technical successes in its first year.

These technical successes include identification and amalgam of appropriate representative duty cycles upon which to base testing and analysis (NREL 80 and NREL 100 composite cycles) and establishing predicted fuel consumption for the target NREL 80 cycle exceeding 60% fuel efficiency improvement.

In addition, simulation-focused component selection including simulation-driven architecture identification downselecting to a hybrid architecture with 112 kWh energy storage was achieved.

In the first year, the project also identified predicted performance on level ground at minimum state of charge (SOC) is still marginally acceptable due to generator size (130kW), and progress was achieved in optimizing SOC trajectory. Finally, advancements in vehicle design and integration, J1772 level two EVSE support, electronic braking system, electrified accessories, TMS, and passively cooled battery were made.

Reviewer 2:
The reviewer reported the project appears to be on schedule and is meeting its targets. The simulations appear to validate the design decisions and warrant physical prototype development and testing. The NREL drive cycle development is a useful contribution on its own and is a laudable technical achievement. This could be further developed and validated to make it a true contribution.

Reviewer 3:
The reviewer said the DOE objectives for fuel economy improvement is clearly identified and progress toward this is apparent from information presented.

Reviewer 4:
The reviewer noted good progress has been shown all the way up to hard implementation.

Reviewer 5:
The reviewer commented the technical progress on the project has included analysis of relevant duty cycles for the targeted application and creation of a representative cycle for testing (and against which to evaluate whether or not the project achieves the targeted 50% reduction in fuel consumption). However, one of the slides indicates that the NREL 80 cycle is both 80 miles long and “represents 80th percentile of required energy of representative drive cycles.” It would be helpful to clarify whether the 80th percentile criteria were applied to cycle energy intensity, driving distance, or both, and whether or not it is simply a coincidence that 80 miles aligns with the 80th percentile daily driving distance if that is indeed the case. Due to the PHEV approach, it is particularly relevant to select a daily driving distance that accurately represents typical in-use driving distances.

The reviewer indicated reported technical progress included selecting the powertrain architecture and component sizes based on the established requirements, and demonstrating through simulation that the selected design should achieve the 50% fuel savings goal. Progress was also reported on establishing SOC trajectory optimization (though the team should be sure to err on the side of using up the stored battery energy early as opposed to leaving some energy un-used by the time the vehicle ends up recharging), design of a system to blend regenerative and mechanical braking when drivers attempt to brake. It is good that the project team is simultaneously considering driver acceptance while trying to maximize efficiency benefits from the electrified components and setting up the powertrain in the test cell. This is a prudent step ahead of vehicle integration. Lastly, the project plan indicated that the fleet to be used for system demonstration in the third year would be selected by the end of the first year, but progress toward that fleet selection objective was not mentioned in the presentation.

Reviewer 6:

The reviewer indicated the project presented a graph showing in simulations the design would exceed a 50% fuel reduction target. The project did not address if it would meet the 50% utilization of grid power goal. It did estimate a 40 mile all electric range, and the drive cycle being used is an 80-mile drive cycle, so it is possible the project is close to or meets the goal. The reviewer suggested this should be directly addressed in the future. The goal of having a commercially viable vehicle was not addressed and should be. The reviewer observed the project is on track with the project plan and currently laboratory testing components.

The reviewer remarked that in the reviewer backup slides, the project implied there were requirements that would not be met when talking about commercial viability. These should be called out up front.

Reviewer 7:

Although the reviewer does not believe this is a solid project it has fairly well accomplished its goals.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said there is a good partner team.

Reviewer 2:

The reviewer reported this project has a lot of large partners and seems to have coordinated fairly well.

Reviewer 3:

The reviewer stated the Cummins team is strong and diverse with heavy weights in a position to address all of the technical challenges of the project. The reviewer identified a notable omission is the lack of fleet partners as part of the formal team. While dialogue is undoubtedly underway and will intensify in the future, it would have been greatly preferable to have several fleet partners on the team from the outset. This would have been especially beneficial to early on best identify and refine approaches to potential cost and operational challenges from the fleet perspective.

Reviewer 4:

The reviewer acknowledged the current collaborations appear useful and constructive. An ESS OEM is a missing collaboration that could really assist in this project. The TMS being air cooling is a concern and the input of an ESS OEM could increase the performance and commercialization potential for this design.

Reviewer 5:

The reviewer said collaboration with federally funded research and development centers is clearly identified, and their key collaborative role was presented as an important part of the project's progress.

Reviewer 6:
The reviewer observed contributions from a team of relevant experts seem to be benefitting the project, including system development, integration support, drive cycle analysis, fleet monitoring, simulation and controls. However, the relative value and integration of the three "cooperative/competitive" modeling efforts is unclear.

Reviewer 7:
The reviewer noted the project has an OEM and research laboratories. It would be a little stronger with a vehicle manufacturer as a direct team member.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed the proposed future research is fundamentally sound and logically presents an orderly course of action until project completion.

This includes vehicle integration and build including implementation of TMS in the prototype and cell testing. Reasonable future milestones (including go/no-go) are established.

The reviewer suggested the project should emphasize cost analyses and commercial viability moving forward.

Reviewer 2:
The reviewer commented the proposed future work appears to include everything needed to achieve the project objectives. One addition could be dynamometer testing that includes the NREL drive cycle to validate the simulation efforts.

Reviewer 3:
The reviewer articulated future work efforts are to complete the test cell testing, vehicle integration and build tasks (including implementing vehicle TMS), perform track and targeted environmental testing, and ultimately testing in a deployed fleet in the third year of the project. The reviewer agrees these are very appropriate areas of focus for future work. The reviewer suggested in the second and third years of the project the team should also increasingly focus on making sure the incremental system cost relative to a conventional vehicle can reasonably be offset by the expected fuel and operating cost savings.

Reviewer 4:
The reviewer remarked the future plans are logical, but the schedule seems a bit compressed. There should be a few more decision and design review points to make sure the different engineering disciplines are aligned and that the vehicle integration design is checked against test results. The reviewer noted the thermal management of the system (especially the air-cooled battery) when operating at heavy-duty cycle points (heavy acceleration/deceleration). The reviewer indicated the project did not list risks of barriers or have risk mitigation identified. It appears the project is assuming everything will work the first time, which puts it at risk for schedule slip especially since there are not any risks identified.

Reviewer 5:
The reviewer said future research identified, but activities not significantly into the future. The reviewer commented it might be a bit early in the project to identify need for future work and that next year's presentation should include more on this.

Reviewer 6:
The reviewer stated the vehicle results will be very interesting to see.

Reviewer 7:
The reviewer offered the current design of this project has little to no chance of being a viable solution for Class 6 trucks. There are too many other innovative ways to optimize powertrains today.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer observed the project aims to solve barriers to electrification of Class 6 package and delivery trucks including cost and range while minimizing fleet operator risk. In the near- to mid-term, the proposal is to use a PHEV with a low-cost range extender. The reviewer concluded if technically and commercially successful, this technology could replace many conventionally powered package and delivery trucks thereby leading to significantly greater energy efficiency and accompanying petroleum displacement benefits.

Reviewer 2:
The reviewer articulated that MDVs represent a significant opportunity for petroleum displacement through electrification and higher fuel economy. This project could result in a commercially viable design that will align with the DOE's objectives.

Reviewer 3:
The reviewer remarked reduced consumption of fuel is clearly a displacement of petroleum use and a 50% reduction in use is a significant achievement toward this objective.

Reviewer 4:
The reviewer stated the design of an electrified delivery vehicle with the goal of reducing diesel consumption by 50% in the intended application is certainly relevant to DOE's objectives.

Reviewer 5:
The reviewer commented the intent of the project is to demonstrate a prototype commercially viable vehicle that utilizes 50% or more energy from the grid. Having a vehicle that uses grid energy instead of petroleum, and is commercially viable so it can be adopted, directly supports the DOE objective.

Reviewer 6:
The reviewer indicated the medium-duty world can really benefit from this technology.

Reviewer 7:
The reviewer warned this project can displace petroleum but there are much better ways to spend resources for displacing petroleum than the outdated concepts within this project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer reported that minimal information was provided as to the expenditure of project funds to date and the project appears to be right on schedule. As such, it is assumed that funding resources are sufficient.

In addition, the reviewer noted the technical depth and diversity of the project team partners indicates there should be no challenges with regards to availability of equipment or facilities to conduct the required activities to successfully bring the project to fruition.

Reviewer 2:
The reviewer observed there was no shortfall noted in presentation, and project on schedule. Therefore, by deduction, the resources are sufficient.

Reviewer 3:
The reviewer stated the resources for the project appear to be sufficient.

Reviewer 4:
The reviewer said the project appears to have sufficient resources.

Reviewer 5:
The reviewer commented there is a good match between funding and project.

Reviewer 6:
The reviewer noted the DOE share of the overall project cost, which is nearly 67% is too high and more industry resources should have been leveraged for this project.

Presentation Number: gi190
Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP)
Principal Investigator: Alexander Freitag (Bosch)

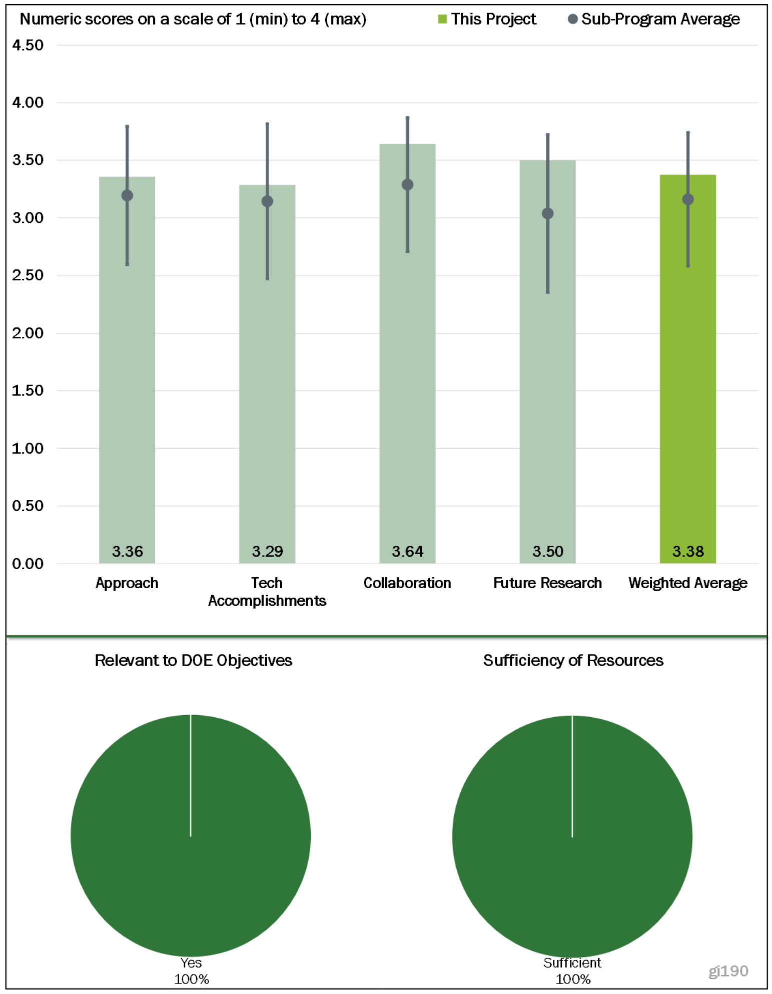

Figure 6-15 - Presentation Number: gi190 Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP) Principal Investigator: Alexander Freitag (Bosch)

Presenter

Matt Thorington, Bosch

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed the approach is clearly defined in project plan and schedule, which showed multiple parallel paths toward objectives.

Reviewer 2:

The reviewer said the approach had well defined goals and performance objectives as well as understanding of the target market. In addition, there is good use of available tools for architecture selection. The reviewer stated there is a solid partner and collaboration group, with experience and commitment to complete the milestones.

The reviewer warned the cost target would seem to be the only concern area, though the selection of the commercial off the shelf motor and inverter/converter help. The reviewer indicated it would be great to see data prompting the 35-mile AER.

Reviewer 3:

The reviewer noted the approach is feasible and the three year payback make the project more attractive.

Reviewer 4:

The reviewer commented the cost target barrier is overlooked with the selection process of the transmission.

Reviewer 5:

The reviewer is interested in more information on how to downselect the powertrains. This seems like the primary output of the current phase of the project, but it is not clearly documented. The reviewer asked if cost, control-ability, performance, packaging, or grade-ability were considered.

The reviewer noted when one uses dynamic programming (DP), one has to think pretty hard about how the controls are influencing the FE outcomes. There is much opportunity for the development of difficult-to-implement controls. Generally, the reviewer commented, DP give FE benefits that are higher for systems that have greater complexity and have more degrees of freedom. Because this project is optimizing both powertrain architecture and controls, it may be particularly in danger of this problem.

Reviewer 6:
The reviewer remarked the base MPG is very low for a Class four delivery truck. It should be closer to 13 MPG.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed as a new project, the technical accomplishments are in laying out approach and modelling. This project is clearly making progress toward its technical objectives.

Reviewer 2:
The reviewer said though early in the program, the detailed plan seems adequate and milestones are being met. Additionally, this reviewer noted integration of early commercial EV driveline components, ESS, and controls software will determine if the project is able to meet next milestones. The reviewer further remarked that integration of the dual planetary gear transmission will require additional controls tuning time in the second phase of project, after the first go/no-go milestone.

Reviewer 3:
The reviewer said the project is making progress against objectives.

Reviewer 4:
The reviewer noted there is missing selected system cost information to support presenting on the cost barrier (less than a three-year payback period).

Reviewer 5:
Progress is very aggressive for all the design work involved to meet the goals. Baseline MPG should be much higher.

Reviewer 6:
The reviewer remarked the baseline MPG does not seem appropriate for Class four trucks.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated this project partners involved are excellent and will all provide good value to the entire team.

Reviewer 2:
The reviewer commented the project has as great team.

Reviewer 3:
The reviewer stated the project has assembled a great team.

Reviewer 4:
The reviewer indicated collaboration was clearly identified in the project presentation. Roles for each collaborator were also identified, as well as overall Bosch objectives for the project.

Reviewer 5:
The reviewer observed a there is a good grouping of support for this project. Team members are reliable and capable. Full use of the team's areas of expertise should be exercised. The reviewer suggested more simulation by University of Michigan may show areas for future consideration of 2PG transmission, and additional data mining by NREL of Fleet DNA could result on other market information for comparison and field deployment selection.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that a good group should cover all of these bases.

Reviewer 2:
The reviewer suggested that the go/no-go decision on fuel efficiency simulation should use a rules-based controller even if its DP is derived.

Reviewer 3:
The reviewer noted it is early in the project, so ability to identify future research needs is difficult at this time. What was identified are clearly needed, but are part of this project already. The reviewer looks forward to the evaluation of this project next year.

Reviewer 4:
The reviewer stated since the project hinges on the 2PG, it will be interesting to watch that development. Other portions of the projection are challenging, but fully within the teams' capability.

The reviewer suggested as this project progresses some more outreach opportunities should be scheduled to show the capability of the 2PG technology.

In addition, fuel displacement projections could be done by University 0f Michigan or NREL to help show the potential of this technology

Reviewer 5:
The reviewer stated this project will need to evolve with current technology advancements before its end date. The reviewer did not see a viable future using a diesel-powered range extender requiring after treatment.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked this project does support DOE objective by proposing to improve fuel consumption

Reviewer 2:
The reviewer said yes, the project supports the DOE objective of petroleum displacement.

Reviewer 3:
The reviewer commented yes, this project is very relevant to class four vehicle operations.

Reviewer 4:
The reviewer stated fuel economy improvement displaces petroleum needs. The objective of 50% reduction of fuel used is a significant effort to support this objective.

Reviewer 5:
The reviewer suggested there needs to be a quantitative number assigned to a successful deployment of this technology, but the potential is clear. As the delivery industry is headed for growth in the U.S. market, and will be a primary consumer of liquid fuels, this type of program blends technology development with deployment supported by the DOE to showcase technology benefits to first line consumers (Fleet owners). This project is very relevant to the DOE mission.

Reviewer 6:
The reviewer indicated this project has potential to do better at reducing petroleum usage and thinks the baseline MPG goal should be revisited.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked resources seems fine.

Reviewer 2:
The reviewer commented this is good team.

Reviewer 3:
The reviewer noted it is early in the project and on schedule. The budget does not appear to be insufficient for the scope, but detail is insufficient to conclude that resources are excessive.

Reviewer 4:
The reviewer commented the only question about funding would be the number of trucks or transmissions that are planned.

The reviewer suggested for this large of an amount of DOE spending, the second transmission should be placed into service or have additional testing run with alternative engine sources for possible model calibration and verification.

Presentation Number: gi191
Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration
Principal Investigator: Wiley McCoy (McLaren)

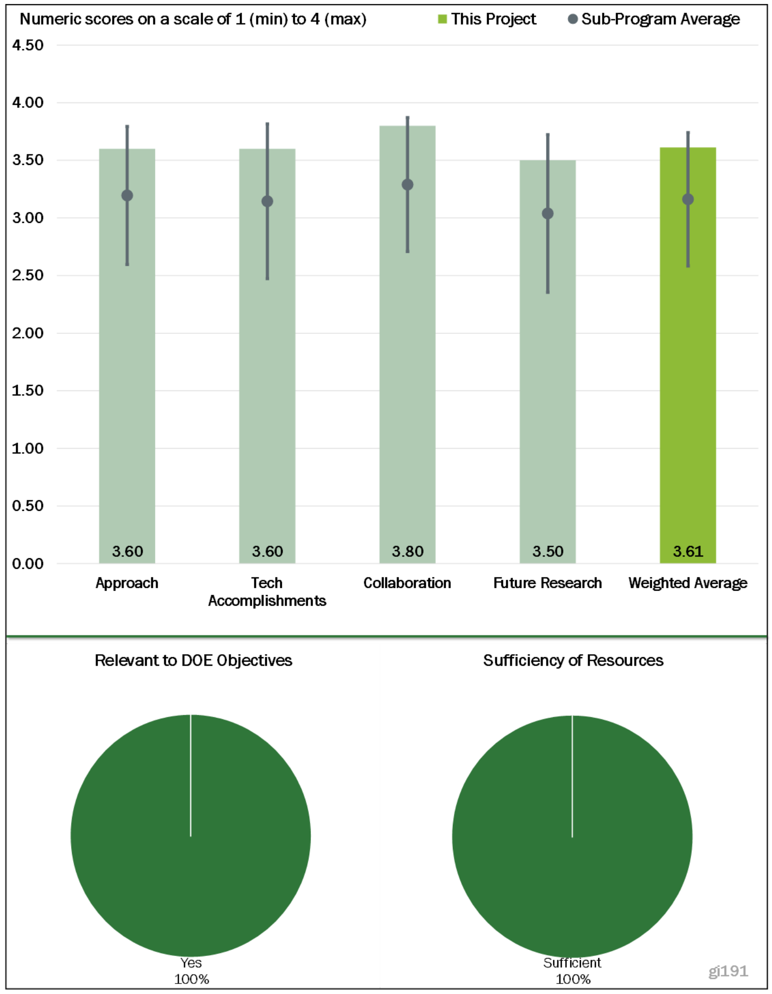

Figure 6-16 - Presentation Number: gi191 Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration Principal Investigator: Wiley McCoy (McLaren)

Presenter
Wiley McCoy, McLaren

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer noted the approach is outstanding with respect to the engineering design process and also in the practicality of the system goals and proposed design solution features. The practical nature of the goals and design solutions increase the likelihood of being able to deliver progress on the TCO barrier to adoption of MD EVs.

Reviewer 2:
The reviewer remarked the approach seems highly appropriate, aimed at ensuring success. A key element of this approach was clearly assembling the correct team, including a very solid demonstration partner. The reviewer observed that to bring costs down, the approach focused on using automotive products, and therefore included partners who provide those products. The approach also included working with UPS to develop the testing processes.

Reviewer 3:
The reviewer indicated the approach for the project includes designing and developing a PHEV powertrain, building four demonstration vehicles, and running a demonstration of cost and reliability for a full year. These efforts, and particularly the emphasis on commercialization potential at the end of the project, are appropriate areas of emphasis. It is also good that the project engages directly with a potential customer fleet to obtain input on requirements, included real-world operation expectations. The reviewer suggested it would be helpful to articulate a clearer path to overcoming the total cost of ownership barrier for successfully commercializing such a plug-in hybrid technology.

Reviewer 4:
The reviewer commends the PI for using a contemporary Define-Design-Verify approach to product development in this project. The use of real-world duty cycle data to define design requirements in excellent. The use of sophisticated simulation tools for powertrain sizing and driveline design is also admirable. The

reviewer recommends that cost targets be identified (or communicated, if already identified) early in the project to ensure that the project achieves its goal of producing a product with acceptable TCO for commercialization.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that based on the limited information provided the technical progress appears to be outstanding. The design process has spent significant effort in defining the requirements and modeling the proposed design features. The team has performed a significant amount of engineering to meet the overall project milestone delivery schedule.

Reviewer 2:

The reviewer reported the project appears to be accomplishing activities in accordance with an aggressive schedule. It has already accomplished a lot in less than a year, including many of the inputs necessary for making decisions concerning design choices. A particular highlight was the decision to instrument UPS in-use vehicles to establish a useful baseline. This data has impacted decisions already. The reviewer noted that so far, it appears all technical performance requirements are being met, at least when looking at predicted performance.

Reviewer 3:

The reviewer observed the project accomplishments included obtaining and integrating requirements from UPS, completing the initial conceptual design, and demonstrating through simulation that 100% fuel economy improvement is possible. Specific analysis accomplishments included modeling both the conventional baseline vehicle and the PHEV design in AVL Cruise. To do so the team used generic component maps available from the AVL Cruise library. The reviewer indicated it would have been nice at least for the baseline vehicle to have shown some validation of the model against the current UPS vehicle data.

The team did well to draw upon actual UPS vehicle operating data for evaluating the design, though the extent of the data used remained unclear. For instance, the reviewer asked how many vehicle-days of data went into the analysis, and what efforts were undertaken to ensure that the data captures both the breadth of likely operating conditions and in aggregate accurately represents average/typical operation that these vehicles would see in service.

The reviewer stated the simulated fuel economy table presented on Slide 14 indicates application of a “0.8 reduction factor” to simulate conventional and HEV operation “in order to be conservative.” However, it is confusing that this factor is called out only on the lower set of tables and not on the higher set of tables, and use of the label “Hybrid” is also confusing. Typically, “hybrid” refers to a non-plug in vehicle that uses an energy storage system to capture regenerative braking and load-level the engine, but it appears as though the term here refers to both the charge-depleting and the charge-sustaining operation of the PHEV being designed for this project. This should be clarified. The reviewer also recommends showing the relative energy consumption comparisons without this 0.8 factor (in principle the real-world profiles should give an accurate comparison without this adjustment; if adjustments really are needed, such as for external environmental factors, it is quite likely that these factors would impact each powertrain differently—bringing into question the appropriateness of applying a fixed 0.8 factor to both powertrains). Finally, the reviewer takes issue with the use of “mpg equivalent” in the table. It would be better to stick with more physically meaningful measures, such as the total diesel, electricity and LPG use over a typical month or year for both the conventional and the PHEV (and the associated total operating costs and greenhouse gas emissions for each case).

Reviewer 4:

The reviewer noted the project is on schedule. Powertrain simulation results appear promising. The PI reported that additional analysis was done with partner Dana to ensure the addition of unsprung mass in the rear axle will not adversely impact driving dynamics. That analysis is important and should be included in future reports and presentations. Likewise, the rationale to use a series hybrid design (and pay the efficiency penalty over a parallel design with direct drive at high speeds) should be documented. The reviewer indicated the simulation results use an appropriately conservative derating factor. Simulation predicts that the target fuel efficiency will be achieved and other vehicle performance requirements will be met or exceeded. However, the proposed design must be evaluated for cost and design iterations should be performed, as necessary, to ensure the end result meets cost requirements for commercialization.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated the project has what appear to be exactly the correct types of partners, including an excellent fleet partner in UPS. In addition, the project has clearly shown that it knows how to work with these partners, taking advantage of the opportunities they present.

Reviewer 2:

The reviewer affirmed the collaboration in this project is stellar. The project team includes highly reputable companies including leaders in their respective fields with expertise in product development, manufacturing, and deployment. The reviewer remarked the PI is wise to include a partner that specializes in truck retrofitting, because retrofitting existing trucks is the commercialization goal of this project.

Reviewer 3:

The reviewer observed there appears to be effective collaboration and coordination amongst appropriate stakeholders for designing and building the desired vehicles. Again, it would be nice to have a better idea of the extent of the drive cycles provided by UPS that went into the analysis and how this compares with the total typical daily or monthly miles driven by all vehicles using the targeted depot.

Reviewer 4:

The reviewer stated the project team spans the range of expertise needed to address the project’s issues. Having UPS as a demonstration partner is especially useful to validating the system requirements and providing a useful real-world test environment.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer indicated the remaining steps appear to make sense, and are fully appropriate for this type of project. The project is now shifting toward a manufacturing process. The reviewer reported Phase three will not start until January 2018 due to small delays, and UPS does not want to interfere with the holiday delivery season. That stage will involve vehicle build, test, and demonstration. This will be followed by a commercialization plan.

Reviewer 2:

The reviewer noted the plan for future work is robust, adequately sophisticated, yet not overly ambitious.

Reviewer 3:

The reviewer said the future path of completing vehicle builds and testing and demonstrating the vehicles in service is appropriate, as is the stated emphasis in commercialization potential. The PI indicated that “costs are still in development but preliminary results suggest the product can be successful." The reviewer suggested that at the next review it would be good to hear more specifics and more definitive language about what is needed for the vehicle to result in a competitive total cost of ownership for the fleet purchaser relative to conventional vehicle options.

Reviewer 4:

The reviewer observed this presentation does not contain much information on mitigation strategies but it does outline several significant technical challenges. The project team's near-term future work is appropriately focused on addressing the challenges outlined.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer mentioned the project is aimed at increasing electrification in a sector that tends to use a lot of fuel per vehicle. This also results in significant emissions reductions, largely in urban areas. The reviewer stated this project is fully in line with DOE's objectives in this area.

Reviewer 2:

The reviewer asserted the project seeks to commercialize a vehicle technology that can displace use of diesel fuel with a combination of electricity and LPG so is certainly relevant.

Reviewer 3:

The reviewer commented the project is relevant to petroleum production since MD vehicles typically have half the fuel efficiency of LD vehicles. The introduction of a cost-effective MD hybrid retrofit for delivery fleets that doubles the fuel efficiency over the conventional baseline vehicle would be a huge step in reducing the petroleum consumption of this portion of the U.S. transportation sector.

Reviewer 4:

The reviewer remarked electrification of medium-duty trucks has the potential to significantly reduce U.S. transportation petroleum consumption. This project addresses a significant barrier to electrification which is how to cost-effectively electrify existing trucks on the road.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed the resources provided for the project should be sufficient to achieve the stated goal assuming that the team can address the outlined technical challenges within the project budget and schedule. The project team's reputation's and experience base give credibility to the expectation that they can perform within the budget and schedule constraints.

Reviewer 2:

The reviewer noted that so far, funding appears sufficient if it remains as originally proposed.

Reviewer 3:

The reviewer commented resources appear to be sufficient for the project.

Reviewer 4:

The reviewer indicated on first glance, $3.65 million seems excessive to produce a four-vehicle test fleet. However, the focus of this project in on product development, not deployment. Given the sophisticated approach being taken to product development and the significant challenge of cost-effectively electrifying

MDVs, the reviewer judges the financial resources of the project to be sufficient, but perhaps only just sufficient.

Presentation Number: gi192
Presentation Title: Hybridization of Class 8 Line Haul and Regional Refrigeration Trucks CRADA
Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

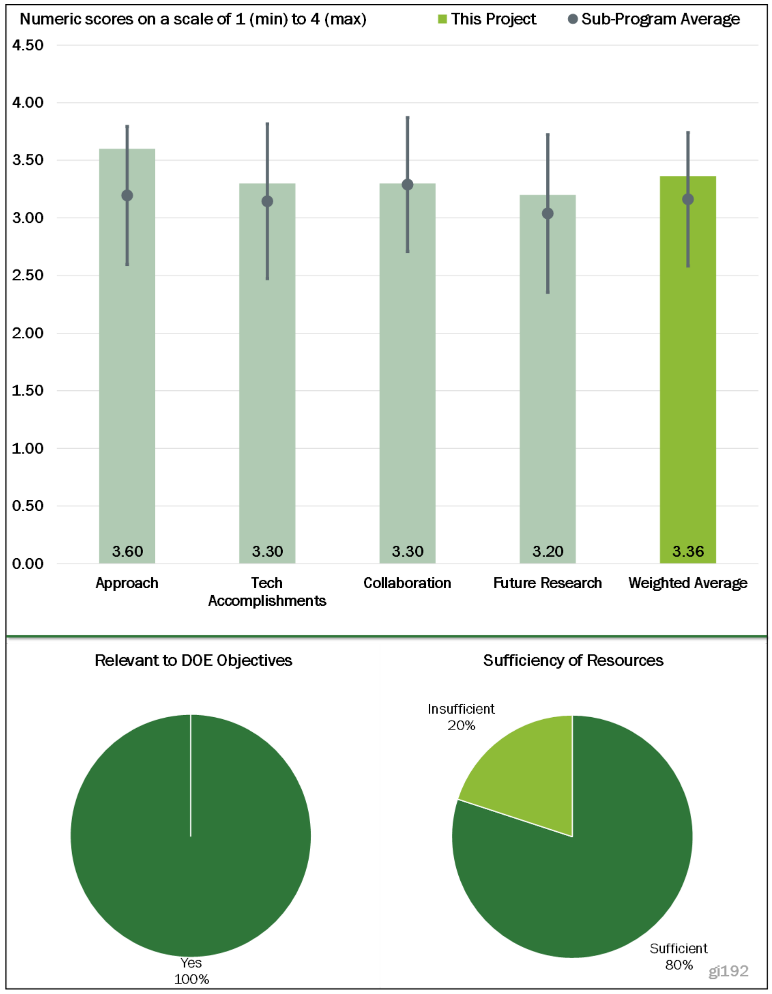

Figure 6-17 - Presentation Number: gi192 Presentation Title: Hybridization of Class 8 Line Haul and Regional Refrigeration Trucks CRADA Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Presenter

Dean Deter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer observed the approach is based upon a three-phase structure including modeling and simulation, hardware in the loop and then vehicle testing and validation. These are the steps that appear correct for this type of project. The project is focused upon eliminating a relatively low-efficiency engine that runs constantly.

The reviewer remarked that early in project, ORNL determined that an appropriate fleet partner was needed. They used a rational approach to select a partner, focused upon commonality of equipment throughout the fleet. Selecting this partner also allowed project to focus on the ultimate user’s operational needs.

The project also worked with a refrigeration unit provider, Carrier, to help in determining technical needs.

Reviewer 2:

The reviewer commented this type of hybridization of the refrigeration container is an excellent example of “second/next level” hybridization of ancillary systems for energy savings.

Reviewer 3:

The reviewer remarked the approach appears to best address the risk aversion barrier since it will provide some HIL test data for the proposed system. The approach does not appear to address the cost barrier since there is no evidence of a cost analysis for the proposed system. It is difficult to forecast a long-term benefit from this activity without the cost analysis being included in the project scope.

Reviewer 4:
The reviewer said it is good to know that the developed system control strategies will be supported by experimental validation and verification of functionality and petroleum consumption reduction as a result of the proposed technologies

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted the technical progress is excellent considering the paltry budget for the project.

Reviewer 2:
The reviewer reported solid analytical methods are being or have been deployed to bind the engineering parameters of the problem. The development process appears to be well on track for successful demonstration.

Reviewer 3:
The reviewer commented the project finished data collection and validation of conventional models as baseline.

Reviewer 4:
The reviewer said the PI believes the project will stay on schedule, but there have been some smaller portions of the project that have had a few issues. The baseline system had been modeled, and then the new system identified and modeled. Initial simulation results were developed. Overall savings appear to range from 2 to 8.6% for the system.

The reviewer observed some of the delays were due to hardware development, which is not completely surprising, but the PI feels testing will still take place pretty much on time.

Reviewer 5:
Given actual drive profile can be obtained through the CTI telematics link, the reviewer suggested simulation and testing with actual drive profile rather than generic CMI cycle

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed initially, the project team was only Cummins and ORNL (after issues with keeping Carrier on team). The project added a fleet partner along the way (CTI), and obtained technical data from a refrigeration system manufacturer (Carrier). It also added TM4 for engineering support. The reviewer remarked the team is more robust now. The PI indicated that ORNL had access to trailers for the project, so that a trailer OEM was not needed. In addition, Cummins will serve as the route to deployment, potentially selling the product to truck OEMs.

Reviewer 2:
The reviewer affirmed ORNL, Cummins, and Carrier are excellent partners in this endeavor with TM4 as engineering support. It is recognized that a demonstration partner (CTI) will be difficult to work with due to the risk of failure is a high dollar value of cargo.

Reviewer 3:
The reviewer noted the project team is collaborating with OEMs and other industrial partners.

Reviewer 4:

It is difficult for the reviewer to assess the degree of collaboration with other organizations since there is no funding or resource breakdown for the team partners.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated the future of the project plan appears to be well described for successful completion through demonstration. The reviewer asked if there any possible follow-on efforts being explored in similar areas.

Reviewer 2:

The reviewer observed the future work planned will likely contribute to the technical knowledge base for using a hybrid system to power the trailer refrigeration unit. The presentation acknowledges the incompleteness of this effort to fully address the project challenges.

Reviewer 3:

The reviewer indicated the remaining efforts appear to be the correct ones and are laid out in a rational manner. If completed as planned, the project should result in finding the answers needed.

Reviewer 4:

The reviewer noted on road testing and fleet testing are included.

Reviewer 5:

The reviewer noted future challenges in hardware development is described generically. Specific future work in hardware development is not stated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer indicated the project can result in the elimination of the on-truck diesel engine used to power refrigeration units, which will result in significant petroleum reductions.

Reviewer 2:

The reviewer stated energy savings in this ancillary application is generally in alignment with DOE objectives to displace petroleum energy in transportation of goods.

Reviewer 3:

The reviewer noted hybridization of refrigeration trailers can provide significant reductions in fuel consumption, criteria pollutants, and greenhouse gas emissions.

Reviewer 4:

The reviewer commented the project provides a hybrid solution for trailer conditioning that is more fuel efficient in situations where electrical infrastructure does not exist to support pure electric conditioning

Reviewer 5:

The reviewer observed trailer refrigeration units are used throughout the United States and consume petroleum while awaiting pickup and in route to delivery of the load. This project has predicted that it would save between 1.8% and 8.0% of the petroleum consumed. The analysis does not include the petroleum consumed idling while awaiting the pickup of the load so the petroleum savings from a hybrid technology is likely higher than the project estimates.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted the resources are sufficient.

Reviewer 2:
The reviewer said no indication was made that funding as proposed is not sufficient.

Reviewer 3:
The reviewer remarked the funding for this project is generally in line with associated engineering costs.

Reviewer 4:
The reviewer stated the funding for this project appears to be insufficient for the stated project objectives.

Acronyms and Abbreviations

AER	All-electric range
ANL	Argonne National Laboratory
APRF	Advanced Powertrain Research Facility
BET	Battery electric truck
BMS	Battery management system
CAV	Connected and automated vehicle
CEC	California Energy Commission
DC	Direct current
DOE	U.S. Department of Energy
DP	Dynamic Programming
EDV	Electric drive vehicle
EPRI	Electric Power Research Institute
ESS	Energy storage system
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FCA	Fiat Chrysler Automobiles
FE	Fuel economy
FOA	Funding opportunity announcement
FY	Fiscal Year
GTI	Gas Technology Institute
HATCI	Hyundai American Technical Center, Inc.
HD	Heavy-duty
HET	Hybrid electric truck
HEV	Hybrid electric vehicle
HIL	Hardware-in-the-loop
HVAC	Heating, ventilating, and air conditioning
ICE	Internal combustion engine

INL	Idaho National Laboratory
kW	Kilo-Watt
LD	Light-duty
MDV	Medium-duty vehicle
MMFC	Multi-mode fluid controller
MPG	Miles per gallon
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PEMS	Portable emissions monitoring system
PHET	Plug-in hybrid electric truck
PI	Principal investigator
R&D	Research and development
RDE	Real-world driving emissions
ROI	Return on investment
SAE	Society of Automotive Engineers
SOC	State of charge
TCO	Total cost of ownership
TMS	Thermal management system
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy
UPS	United Parcel Service
UTEMPRA	Unitary thermal energy management for propulsion range augmentation
V2G	Vehicle to grid
VTO	Vehicle Technologies Office
WPT	Wireless power transfer
ZECT	Zero emission cargo truck

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7. Lightweight Materials

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Lightweight Materials (LM) R&D area supports research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber (CF) composites, and multi-material systems to enable lighter automotive structures with performance and manufacturability that equal or exceed today's technologies. This focus area supports projects to address materials and manufacturing challenges spanning from extraction to assembly with an emphasis on dissimilar material joining, assembly technologies, and corrosion prevention that enable the use of various lightweight materials as best suited for particular applications. LM supports national laboratory research and joint work with industry through the Lightweight Materials (LightMAT) Consortium established under the Energy Materials Network (EMN).

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: lm000 Presentation Title: Material Technologies – Overview
Principal Investigator: Felix Wu (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer stated that the current program area for Materials Technology was covered very thoroughly including background, overarching strategy, focus areas and program goals. The current approach to address strategic future challenges and significant opportunities is somewhat dated; however, the presentation indicated that revisions are underway. The presentation addressed materials research that is ongoing to reach VTO goals by 2030 including the types of materials and where they will be used in commercial vehicles. The presentation also described the trend for increasing fuel efficiency using weight reduction and materials research in the area of internal combustion engines.

Reviewer 2:
The reviewer said that the strategy was well-stated.

Reviewer 3:
The reviewer commented that the program area was adequately covered for internal combustion engines. However, the scope needs to be broader to identify material challenges for electrified vehicles.

Reviewer 4:
The reviewer noted that the Materials Technology program contains two portfolios (lightweight and powertrain). The issues related to the two portfolios are presented and the outcomes from the past were discussed. The future direction of the portfolios including budget were presented. Even though the future budget is yet to be confirmed, planning for the program had been presented. Inputs were sought from participants during a separate discussion in the evening.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer said that the balance between near-term and mid-term R&D is well balanced to address the challenges in materials research as defined in the VTO Multi-Year Program Plan (MYPP). The long-term R&D requirements are currently being restructured and should be based on the revision of the Materials Technology roadmap that will address any new challenges and R&D opportunities over the next 5 to 10 years.

Reviewer 2:
The reviewer observed that the objective is well balanced between near-, mid- and long-term activities.

Reviewer 3:
The reviewer suggested that the presenter provide a roadmap that shows the near-mid-long term research clearly with timeline.

Reviewer 4:
The reviewer stated that because the lightweighting portfolio is relevant even when complete electrification of vehicle propulsion occurs, it is necessary to look into the long-term future. While the work on Al alloys caters to the near- and mid-term focus, the research on Mg and carbon fiber-reinforced polymer (CFRP) caters to the long-term future. In case of powertrain materials, the reviewer remarked that the development of materials for high temperature stability is the only area of focus which will benefit in near- and mid-term goals. The program is not planning to work on long-term research.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer stated that the issues and challenges for the current program were adequately addressed and that the major accomplishments supported how the program has addressed these issues. Future issues and challenges are currently under review in order to properly structure the program to address new issues and challenges.

Reviewer 2:
The reviewer said that the benefit and importance of this program is well stated.

Reviewer 3:
The reviewer remarked that issues and challenges were addressed to some extent. The reviewer would like to see gaps and/or challenges identified and presented for existing projects moving forward.

Reviewer 4:
The reviewer noted that the fuel efficiency improvement is the major challenge; this is the focus of the two portfolios. The powertrain materials research focuses also on emissions.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer remarked that plans were identified for addressing issues and challenges. The presenter addressed the current plan to update and revise the matrix for future opportunities, critical challenges, and impacts of a variety of materials and issues that may arise for incorporating materials into vehicle lightweighting projects. The presenter also stated that a meeting of representatives from industry, academia and government was being held during the Annual Merit Review (AMR) to start changes to the matrix. These inputs will assist in updating the matrix so that it can be used for development of a revised Materials Technology roadmap to aid in funding future research projects.

Reviewer 2:
The reviewer said that the future program identifies the possible areas of research for both portfolios (lightweighting and powertrain).

Reviewer 3:
The reviewer stated that no plan was presented for addressing issues and challenges.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer noted that there were five areas addressed that benchmarked progress in terms of accomplishments that has occurred over the last year. In each case, the innovations and impacts of the accomplishments were detailed.

Reviewer 2:
The reviewer stated that the major achievements in five different projects were presented highlighting the past achievements. No roadmap was presented explaining the current developments against the older ones.

Reviewer 3:
The reviewer remarked that accomplishments were presented but not in an incremental manner relative to last year.

Reviewer 4:

The reviewer was not able to connect fiscal year (FY) 2017 results to FY 2016. The presenter focused too much on the innovation aspect which is "ok" but difficult to compare the progress from last year.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer said that the projects in the Materials Technology area are addressing broad problems and barriers in the VTO such as reducing the weight of an internal combustion engine vehicle by 10% to improve fuel economy by between 6% and 8%, and achieving a 13% improvement in freight efficiency from a 6% reduction in vehicle structural weight. Also, research in catalysts will help to improve combustion efficiencies for highly efficient gasoline engines. Progress is being accomplished through projects for lightweight metals, composites and multiple-material joining methods for these materials as well as new high temperature alloys and catalysts for more efficient combustion.

Reviewer 2:

The reviewer stated that both problems of fuel efficiency and emissions are addressed by the portfolios.

Reviewer 3:

The reviewer would like to see electrified vehicles to broaden the scope.

Reviewer 4:

The reviewer did not feel that the projects were addressing the broad problems and barriers. The propulsion material projects do not include lightweight driveline.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer commented that the Materials Technology program is focused on addressing the need to provide lightweight material and propulsion systems solutions to the automotive industry that will achieve fuel savings in future vehicle designs. The Integrated Computational Materials Engineering (ICME) efforts demonstrated excellent collaboration between academia, the national laboratories and industry (original equipment manufacturers (OEMs) and suppliers). Considering the small budget for the number of projects, the program appears to be well managed and is very effective in achieving the goals in the current VTO MYPP.

Reviewer 2:

The reviewer agrees that the program appears to be focused, well-managed, and effective.

Reviewer 3:

The reviewer stated that the focus for both portfolios is on Integrated Computational Materials Research and computer aided decision making. The work on CFRP may be over extended with many projects during the review process.

Reviewer 4:

The reviewer remarked that the group headcount of two persons was insufficient to achieve a focused, well-managed portfolio.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer noted that the key strength of projects in this program is the focusing on the correct material solutions for addressing lightweighting of vehicle structures and combustion engines. An additional strength is the highly effective collaboration between academia, national laboratories and industry that is resulting in good transition of lightweight materials technologies and ICME products to the automotive industry. The weaknesses of projects in this program are the lack of defined transitions in certain areas of propulsion materials and the slow execution of specific projects; e.g., a 2013 FOA project that has only reached 50% of its goal after 4 years of research. Projects are normally not funded for more than 5 years.

Reviewer 2:

The reviewer identified the key strength as reducing cost and weight using a multiple-prong approach. The primary weakness identified was not including electric vehicles (EVs) to reduce the weight (e.g., cables or motor).

Reviewer 3:

The reviewer identified the key strengths as the work on development of ICME tools for metals, and low-cost CF. The reviewer identified the key weakness as the joining of CFRP with other metals using mechanical joining. The destruction of CF reduces the effectiveness of joining. This has been understood for a long time but still there are a few projects or tasks studying this effect.

Reviewer 4:

The reviewer noted the key strengths as an understanding that progress is made with a vertical supply chain project team. The primary weakness identified by the reviewer was that the funding awards include large consortium projects which include many universities, several DOE national laboratories, several OEMs and several suppliers. Felix even stated “the Friction Stir Welding project is a great demonstration of a well-balanced project team, which delivers results.”

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer noted that in some cases the approach is very novel. For example, joining methods for dissimilar metals using high temperature fusing technology and tailored welds, ICME design and crash validation of structural components made of lightweight metals and composites, and next generation three-way catalysts to improve combustion efficiency at lower temperatures.

Reviewer 2:

The reviewer stated that the approach taken for the projects is quite unique and would forward to seeing future progress in the next meeting.

Reviewer 3:

The reviewer commented that some projects are quite innovative in the use of current testing and computational expertise. The examples include the hydrogen intake in Mg and ICME of steel alloy development.

Reviewer 4:

The reviewer said that these projects represent novel and/or innovated ways. The reviewer further noted that ICME and science-based projects have achieved incremental progress.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer remarked that, for the projects presented, there was outstanding collaboration between academia, the national laboratories, manufacturers, automotive partnerships, and first-tier suppliers. The slides that showed the organizations' logos and described the program partnerships is an excellent example of collaboration. The description of the Lightweight Materials Automotive Consortium is another good example of how to connect industry with a network of 10 national laboratories.

Reviewer 2:
The reviewer stated that the program has engaged appropriate partners.

Reviewer 3:
The reviewer said that overall, the number of partners involved in the projects is healthy. However, in some projects the partners do not contribute significantly to technical expertise of other resources. The partners seem to get involved only for in-kind cost contribution.

Reviewer 4:
The reviewer said that the program has engaged appropriate partners, just too many on the same project.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer stated that, based on the technology transitions described, the program appears to be collaborating very effectively in the majority of the projects. This appears to be occurring with hardware as well as software developers and suppliers.

Reviewer 2:
The reviewer considered it difficult to comment due to limited information.

Reviewer 3:
The reviewer did not feel the program collaborated with partners effectively. The lack of staff (two total) does not enable sufficient time to collaborate.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer noted that the only possible gap would be the current lack of definition and prioritization of research efforts in the Materials Technology Program for the next 5 to 10 years. With the potential for reduced budgets, it is important that the proper areas of research be defined to allow funding to be applied in those areas. Hopefully this will be resolved with the revision to the significant opportunities and critical challenges matrix.

Reviewer 2:
The reviewer would prefer to see the scope extended beyond internal combustion engines.

Reviewer 3:
The reviewer said that a major review of the current state-of-the-art may be needed. The last review was done a few years ago.

Reviewer 4:
The reviewer identified driveline and technology projects to overcome commercialization barriers as the key gaps.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer noted that the overview presentation did not allow time for a description of the full Materials Technology portfolio. In general, all areas of materials research (metals, CF and composites, methods of multiple-material joining, integrated computational materials engineering, high temperature materials, and materials to improve propulsion systems) adequately address the needs to meet VTO goals.

Reviewer 2:
The reviewer identified life cycle analysis (LCA) as a topic not adequately addressed. Cradle to grave analysis needs to be part of every project. This methodology identifies CO_2 associated with production, use and recycling. Every recipient must be forced not to ignore LCA.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer noted that the program is described as addressing problems with well-known materials (Al, Mg, high-strength steels, and CFs) where automotive manufacturers and first-tier suppliers have the most interest. Future materials will use nanotechnology to provide better properties and characteristics that will be applicable to the automotive industry. The reviewer suggested that some investment should be made in those areas to further meet or exceed VTO programmatic goals.

Reviewer 2:
The reviewer recommends considering EVs.

Reviewer 3:
The reviewer noted that the research on propulsion materials to reduce emissions will be useful.

Reviewer 4:
The reviewer identified the area of lightweighting relative to driveline and transmission systems. Demonstrating efficiency related to mass reduction versus general engine downsizing should be considered, which results in 6% for every 10%.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer stated that the current approach is very good for addressing near-term and mid-term barriers and challenges. New challenges will prevail for the long-term over the next decade and the program should be prepared to address them. Research organizations that are developing cutting-edge technologies should be solicited for input as to what will be the future generation of materials and how they may apply to VTO future goals. Until there is an update to the VTO MYPP, this may be a difficult task.

Reviewer 2:
The reviewer commented that the course being taken by the current team is good; international collaboration and funding to support could improve the pace of research.

Reviewer 3:
The reviewer would like to see a broader view of the material technologies in terms of the roadmap along with describing the challenges associated with each area. The reviewer said that less focus should be placed on describing innovations.

Reviewer 4:

The reviewer recommended LCA as a new way to approach the barriers, using metrics such as total manufactured cost at volume of 100,000 or 250,000 units per year.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer remarked that, overall, the Materials Technology program is very effective. A few of the projects have poor execution and should be re-directed to better meet the goals and milestones of the research. Some projects do not have transition partners identified in the early stages of the projects and the principal investigators should be encouraged to identify partners in the first year of their projects.

Reviewer 2:

The reviewer recommended increasing the size of the group in order to better manage and engage with projects instead of simply monitoring them. The program MUST stop funding of several programs which have not met go/no-go objectives.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 7-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
lm080	Integrated Computational Materials Engineering Approach to Development of Lightweight 3GAHSS Vehicle Assembly	Lou Hector (USAMP)	7-14	3.83	3.33	3.83	3.50	**3.54**
lm084	Validation of Material Models for Crash Simulation of Automotive Carbon Fiber Composite Structures (VMM)	Anthony Coppola (Ford Motor Co.)	7-17	2.63	2.75	3.13	2.25	**2.70**
lm087	Active, Tailorable Adhesives for Dissimilar Material Bonding, Repair, and Assembly	Mahmood Haq (Michigan State U.)	7-20	3.38	3.38	2.75	N/A	**3.29**
lm089	High-Strength Electroformed Nanostructured Aluminum for Lightweight Automotive Applications	Robert Hilty (Xtalic Corporation)	7-23	3.00	2.70	2.70	2.90	**2.80**
lm098	Brazing Dissimilar Metals with a Novel Composite Foil	Tim Weihs (Johns Hopkins U.)	7-27	2.60	2.40	2.10	2.25	**2.39**
lm099	High-Strength, Dissimilar Alloy Aluminum Tailor-Welded Blanks	Piyush Upadhyay (PNNL)	7-31	3.60	3.60	3.70	3.10	**3.55**
lm101	Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles	Xuming Su (Ford Motor Co.)	7-34	3.33	3.33	3.50	3.33	**3.35**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
lm103	E. coli Derived Spider Silk MaSp1 and MaSp2 Proteins as Carbon Fiber Precursors	Randy Lewis (Utah State U.)	7-38	2.88	2.88	2.75	2.50	**2.81**
lm104	Solid-State Body-in-White Spot Joining of Aluminum to AHSS at Prototype Scale	Zhili Feng (ORNL)	7-40	3.67	3.33	3.50	3.17	**3.42**
lm105	Friction Stir Scribe Joining of Aluminum to Steel	Piyush Upadhyay (PNNL)	7-43	3.30	3.40	3.70	3.20	**3.39**
lm106	Enhanced Sheared Edge Stretchability of AHSS/UHSS	Kyoo Choi Sil (PNNL)	7-47	3.40	3.40	3.40	3.00	**3.35**
lm107	Optimizing Heat Treatment Parameters for Third Generation AHSS Using an Integrated Experimental-Computational Framework	Xin Sun (PNNL)	7-51	3.13	2.88	3.13	3.00	**2.98**
lm108	Development of Low-Cost, High-Strength Automotive Aluminum Sheet	Russell Long (Arconic)	7-54	3.50	3.38	3.25	3.00	**3.34**
lm109	High-Throughput Combinatorial Development of High-Entropy Alloys for Lightweight Structural Applications	Jeroen van Duren (Intermolecular)	7-58	2.75	2.75	3.00	2.75	**2.78**
lm110	*In-Situ* Investigation of Microstructural Evolution During Solidification and Heat Treatment in a Die-Cast Magnesium Alloy	Aashish Rohatgi (PNNL)	7-62	2.60	2.60	2.40	2.50	**2.56**
lm111	Phase Transformation Kinetics and Alloy Microsegregation in High-Pressure Die Cast Magnesium Alloys	John Allison (U. of Michigan)	7-66	3.25	3.25	2.88	3.25	**3.20**
lm112	Cost-Effective Magnesium Extrusion	Scott Whalen (PNNL)	7-70	3.38	3.38	3.00	3.25	**3.31**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
lm113	Magnesium Corrosion Characterization and Prevention	Mike Brady (ORNL)	7-73	3.50	3.50	3.38	3.38	**3.47**
lm114	Friction Stir Scribe Joining of Carbon Fiber Reinforced Polymer to Aluminum	Blair Carlson (General Motors)	7-77	2.50	2.83	3.33	2.67	**2.79**
lm115	Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites	Dave Warren (ORNL)	7-80	3.33	3.50	3.67	N/A	**3.48**
lm116	Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites	Leo Fifield (PNNL)	7-83	3.25	3.13	3.25	4.00	**3.28**
lm117	Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications	Venkat Aitharaju (General Motors)	7-86	3.38	3.38	3.38	3.38	**3.38**
lm118	Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly	Srikanth Pilla (Clemson U.)	7-90	3.50	3.33	3.33	3.17	**3.35**
lm119	Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration	Nate Gravelle (TPI)	7-93	3.00	2.67	3.00	2.67	**2.79**
lm120	Ultra-Light Door Design	Tim Skszek (Vehma International)	7-96	3.60	3.60	3.50	3.30	**3.55**
lm121	Carbon Fiber Technology Facility	Dave Warren (ORNL)	7-100	3.25	3.63	3.75	3.25	**3.50**
lm122	Close Proximity Electromagnetic Carbonization (CPEC)	Felix Paulauskas (ORNL)	7-104	3.13	3.25	2.88	2.88	**3.13**
lm123	Safety Statistical Analysis	Tom Wenzel (LBNL)	7-108	3.10	3.00	3.40	3.25	**3.11**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Overall Average				3.19	3.15	3.18	3.04	3.15

Presentation Number: lm080
Presentation Title: Integrated Computational Materials Engineering Approach to Development of Lightweight 3GAHSS Vehicle Assembly
Principal Investigator: Lou Hector (USAMP)

Presenter

Lou Hector, USAMP

Reviewer Sample Size

A total of three reviewers evaluated this project.

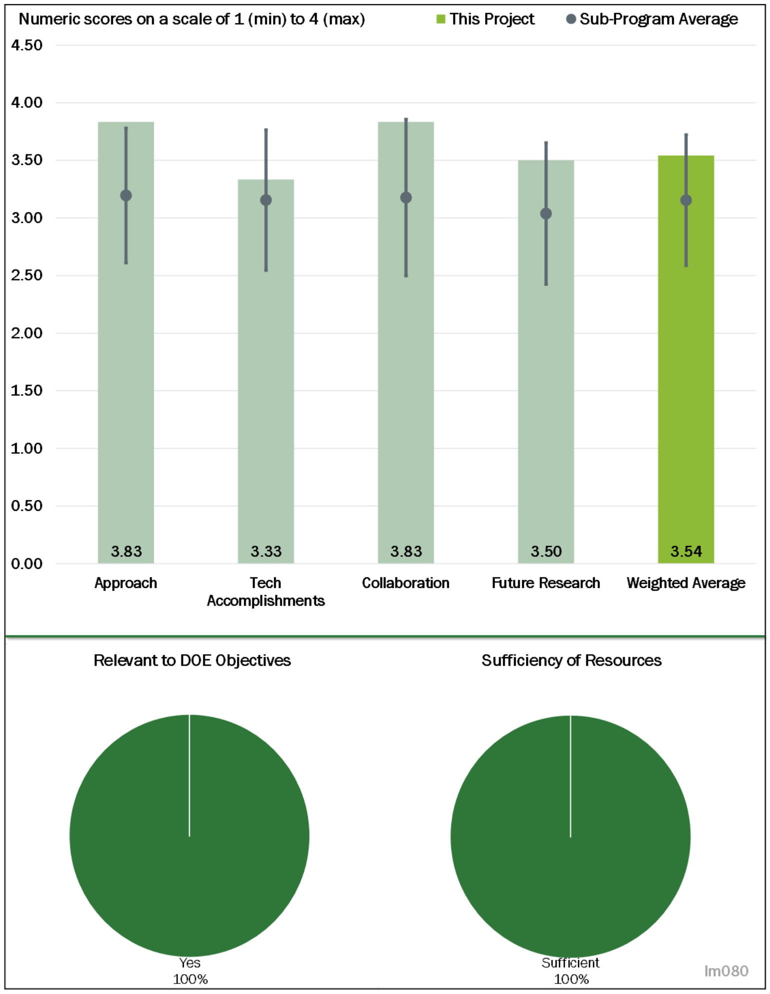

Figure 7-1 - Presentation Number: lm080 Presentation Title: Integrated Computational Materials Engineering Approach to Development of Lightweight 3GAHSS Vehicle Assembly Principal Investigator: Lou Hector (USAMP)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised this project as having an outstandingly solid approach to address technical barriers, challenges, and viability for use of third-generation advanced high-strength steels (3GAHSS) in automotive structures. The reviewer agreed that it is a highly collaborative effort with automobile manufacturers, steel companies, universities, and national laboratories that has greatly contributed to the feasibility of completing the project successfully. Additionally, the reviewer remarked that the project is fully integrated with other efforts and that the approach includes all of the elements for successful research and project management such as experimentation, modeling, fabrication, design optimization, and cost analysis.

Reviewer 2:

The reviewer affirmed that this project has a superb execution of a very complex and unexplored area of computational materials engineering as it relates to 3GAHSS.

Reviewer 3:

The reviewer remarked that the project has a good approach gaining consensus within the scientific community, and added that this is a great challenge.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
This reviewer affirmed that the project has been highly successful in meeting performance indicators (milestones) within the timeframe and funding requirements. The reviewer also attested that it has fully demonstrated the ability to meet project and DOE program goals for lightweighting performance and cost per pound saved when these materials are used for automotive parts. The reviewer observed that all 11 milestones were met with the exception of one that was redirected. In addition, the reviewer found that the project has demonstrated the ability to produce 3GAHSS materials with high ductility and strength in a production environment; and formulate two material recipes, an effective ICME model, and a technical cost model. Finally, the reviewer concluded that the project successfully met DOE goals for a 35% mass savings and a $3.18 cost per pound, in addition to meeting other project objectives.

Reviewer 2:
The reviewer praised the project's excellent use of Argonne National Laboratory and synchrotron beamline to characterize phases and teach ICME models that will have future use in advanced steel alloys by design.

Reviewer 3:
The reviewer asserted that the project was completed without disclosing cost per pound saved and added that this is totally unacceptable. The reviewer remarked that the actual result is much lower than the DOE objective, adding that this lack of compliance with DOE objectives must be noted.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised this project is an outstanding example of collaboration and coordination with five universities, one national laboratory, four steel companies, three automotive OEMs, and two engineering firms. The reviewer declared that this project is the best example of collaboration for any of the projects presented at the AMR.

Reviewer 2:
The reviewer remarked that this project has done a great job in collaboration with universities and DOE national laboratories.

Reviewer 3:
The reviewer commented that while there were almost too many collaborators to manage, nevertheless the project leader did an excellent job managing a complex and diverse group of engineers and scientists.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the project is in its final year and added that the expectation is for DOE to offer future funding opportunity announcements (FOAs) to further development in ultra-high strength steels (UHSS).

Reviewer 2:
The reviewer noted that the project ended March 31, 2017.

Reviewer 3:
The reviewer remarked that there is much work yet to do in this area and offered that the project must identify in more detail what need be done.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer offered that this project supports the overall objectives of DOE’s VTO of reducing vehicle assembly weight and costs per pound saved which will, in turn, both reduce U.S. dependence on imported petroleum and increase fuel economy. The reviewer added that a 35% weight reduction in a vehicle assembly part can result in a significant displacement in the use of petroleum.

Reviewer 2:
UHSS will drive low cost weight savings and when coupled with other DOE-funded projects, the reviewer said, increasing competitiveness of U.S. industries.

Reviewer 3:
The reviewer observed that cost-effective mass reduction capable of high-volume manufacturing is the objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that this project has ended; however, the resources in terms of funds and coordinating partnerships were adequate to meet the stated goals and objectives. The reviewer added that this four-year project with a total budget of $8.5 million including cost-share had several major accomplishments for the available resources.

Reviewer 2:
The reviewer found that this project was appropriately resourced and delivered all milestones.

Reviewer 3:
The reviewer stated that many participants were directed by DOE to address this activity.

Presentation Number: lm084
Presentation Title: Validation of Material Models for Crash Simulation of Automotive Carbon Fiber Composite Structures (VMM)
Principal Investigator: Anthony Coppola (General Motors)

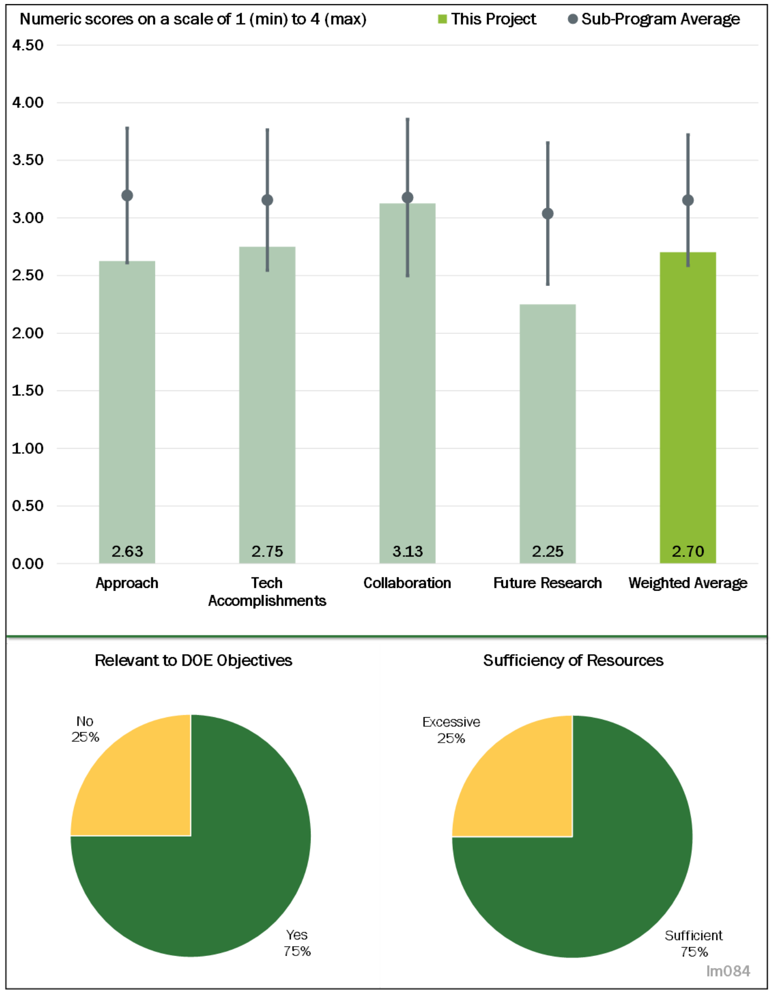

Figure 7-2 - Presentation Number: lm084 Presentation Title: Validation of Material Models for Crash Simulation of Automotive Carbon Fiber Composite Structures (VMM) Principal Investigator: Anthony Coppola (General Motors)

Presenter

Anthony Coppola, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that material model validation for crash behavior prediction of automotive CF composite structures is a critical research area because of its commercialization potential. The reviewer praised the project for its excellent combination of approach that has been considered consisting of physical tests, computer-aided engineering (CAE) activity, and validation.

Reviewer 2:

This reviewer noted that the project was established to interrogate specific CAE codes and evaluate the effectiveness based on the code, the analysis supplier, and the crash mode. The reviewer added that the single element used in the detailed analysis was well thought out. This reviewer believed that more constraints in establishing the analysis parameters (i.e., consistent material properties, boundary conditions, etc.) should have been applied so that consistency in the modelling technique was established and a more critical view of the code could be completed but concluded that otherwise, it was very well done.

Reviewer 3:

The reviewer indicated that no barriers were addressed.

Reviewer 4:

While affirming the understanding that the front bumper will be lighter, this reviewer was not convinced that its crash performance is better than the current one. The reviewer would have liked to have seen comparisons between the bumpers as a function of time (weight and performance) to have a better idea of the progress.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer observed that non-destructive evaluation (NDE) of front bumper ribs was compared against both experiment versus predictions of five commercially-available codes. The reviewer stated that the accuracy level obtained between the CAE tools and experiments varied as one would expect but that how the accuracy level varied with various crash modes and software used was highlighted.

Reviewer 2:
The reviewer agreed that the project completed its stated goals, outlined the technical gaps, and provided recommendations for improvement in CF-based structural CAE for crash analysis. However, the reviewer remarked that the project as a whole would have increased its value if more work was done to identify the specific details of the analysis output to include failure modes predicted versus those observed in high speed crash experiments. The reviewer further remarked that is well-recognized that capturing the mechanics of failure in these transient response analyses is critical to accurate results and added that hopefully more of this information is included in the final reports.

Reviewer 3:
This reviewer observed that everything of the proposal seems to have been accomplished, but questioned whether it has been.

Reviewer 4:
The reviewer stated that nothing was accomplished.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer favorably commented that this project, if nothing else, included a broad set of participants across the supply chain and academic world. The reviewer cited the use of multiple material suppliers, software firms, and respected university programs, noting there was a solid tier-one firm as well as a firm specializing in software development and NDE, adding that it was all well done.

Reviewer 2:
The reviewer praised the collaboration of this project as a model for all these lightweighting projects.

Reviewer 3:
The reviewer praised as excellent the collaboration and coordination with more than 15 institutions and as having helped in achieving a successful project completion. However, the reviewer remarked that it was not apparent what were specific contributions made by each institution to the overall project.

Reviewer 4:
This reviewer stated that this project has resulted in nothing since 2012 and has not been halted by go/no-go decision points.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that this kind of research should be continued and extended.

Reviewer 2:
The reviewer stated that the project is scheduled to be completed by the end of June 2017 and added that ICME techniques may be considered to improve accuracy by predicting material property variations resulting from manufacturing imperfections.

Reviewer 3:
The reviewer warned that we must learn from the negative experience of this project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer agreed that this project supports the overall DOE objectives of petroleum indirectly by developing tools to facilitate the acceptance of automotive CF composite structures.

Reviewer 2:
The reviewer stated that weight saving is important and added this is very relevant to DOE objectives.

Reviewer 3:
The reviewer offered that clearly, the goal of displacing the use of petroleum is dependent upon many factors, however, chief among them is vehicle weight reduction, elaborating that whether the vehicle is a conventional internal combustion engine (ICE), hybrid-ICE or plug-in battery electric vehicle (BEV), weight is critical. The reviewer explained that the use of reinforced polymer systems in vehicle design has a demonstrated ability to drive weight out of the structure of the vehicle. However, the reviewer clarified that the use of any materials system in a complex structural design demands high fidelity CAE tools that accurately capture structural response in the variety of crash situations identified for safe operation. The reviewer concluded that this project sets the industry on a path to identifying the capability of the existing state of the art.

Reviewer 4:
The reviewer declared that nothing was accomplished other than engaging 17 companies and USAMP for 5 years.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that while this was an ambitious project with many individual stake holders, it is clear the team accomplished a tremendous amount of work. Well-funded and well-conceived, the reviewer concluded that it would appear the government was well served and the intent of the work completed.

Reviewer 2:
The reviewer found that in view of the accomplishments, it appears that resources were sufficient, but added it was hard to be sure since the project has ended.

Reviewer 3:
The reviewer stated that resources for the project is insufficient only if the five-year project performance is considered and offered that a future project should consider a shorter timeframe, similar to some of the existing demonstration projects.

Reviewer 4:
The reviewer remarked that resources were extensive, involving 17 companies and three OEMs and nothing was accomplished over 5 years.

Presentation Number: lm087
Presentation Title: Active, Tailorable Adhesives for Dissimilar Material Bonding, Repair, and Assembly
Principal Investigator: Mahmood Haq (Michigan State University)

Presenter

Mahmoud Haq, Michigan State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

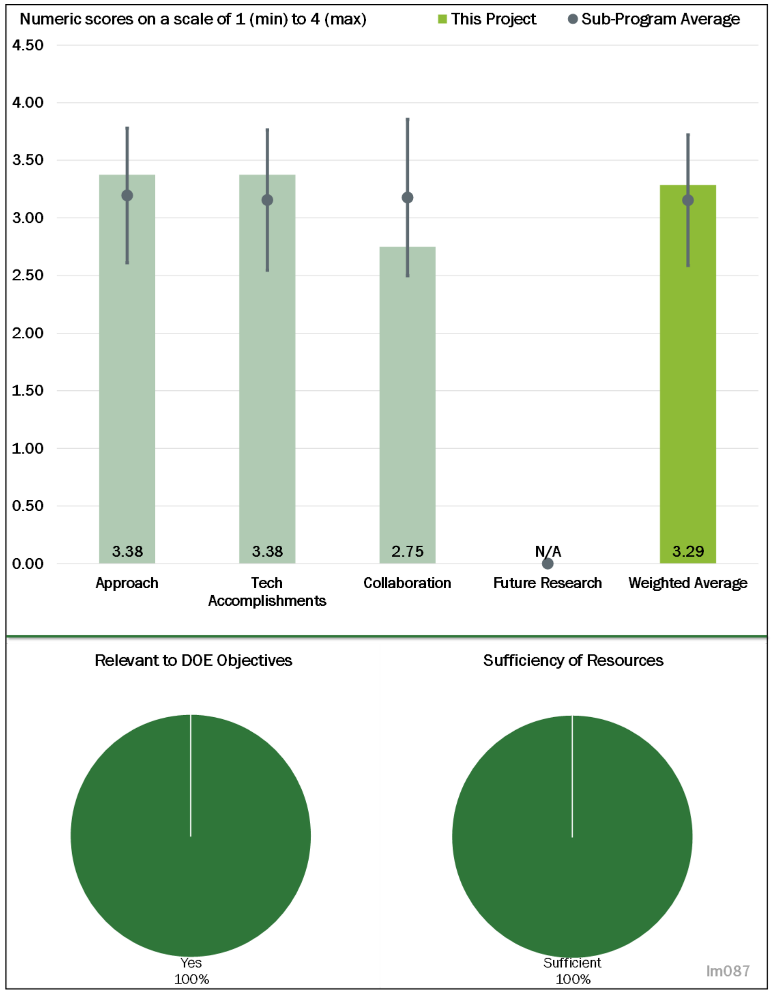

Figure 7-3 - Presentation Number: lm087 Presentation Title: Active, Tailorable Adhesives for Dissimilar Material Bonding, Repair, and Assembly Principal Investigator: Mahmood Haq (Michigan State University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

Observing that there were eight technical gaps identified for this project, the reviewer praised the approach as excellent because it included materials development and optimization, laboratory evaluation and experimental characterization, tool and database design, and data dissemination to demonstrate the feasibility of active adhesive technologies for structural joining of dissimilar materials. The reviewer found that the approach fully integrated both experimental and computational methods to investigate bonding, repair, and assembly.

Reviewer 2:

The reviewer affirmed that a great approach was taken to try and achieve the best of both worlds in mechanical and adhesive technologies but added that additional surface treatment techniques could have been evaluated to determine if one performs more efficiently than others. Stating there was not much else that came to mind to change, this reviewer suggested perhaps use of similar surface treatment for typical adhesives, etc., for comparisons.

Reviewer 3:

The reviewer remarked that the approach could focus on specific applications to prove the technology.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
Noting that the project demonstrated the joint strength of this new technology, the reviewer praised this as impressive.

Reviewer 2:
The reviewer said there were very successful results and the goal was achieved as defined in the scope. The reviewer praised the great job on the project.

Reviewer 3:
The reviewer explained that this project focused on 8 of 15 key technical gaps identified by DOE that contribute to delays in adoption of designs utilizing lightweight materials that support DOE goals for reducing U.S. dependence on petroleum and developing energy-efficient transportation technologies. Elaborating that the technical accomplishments and progress proved successful adhesive bonding, dis-bonding, and re-assembly of multiple lightweight materials, the reviewer agreed that the project successfully developed various adhesives for three methods of joining lightweight materials.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that the collaboration during this project was limited to a corporate research organization and a national laboratory with interest from the U.S. Army. However, the reviewer noted that the presenter stated that since the project has ended, they have entered into collaborations with three OEMs and an industrial supplier of adhesive materials.

Reviewer 2:
The reviewer stated that this was a single university project and other universities did not appear to be involved. While there was some industrial collaboration, the reviewer suggested targeting a real product and working closely with industry.

Reviewer 3:
The reviewer remarked that it would have been nice to have OEM participation to go after a specific joint design relevant to their applications.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated the project has ended.

Reviewer 2:
The reviewer suggested that there should be some follow up on commercialization of the technology.

Reviewer 3:
The reviewer noted that this project ended in March 2016 and expressed surprise that the principal investigator (PI) was asked to present at the 2017 AMR.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer explained that this project focused on 8 of 15 key technical gaps identified by DOE that contribute to delays in adoption of designs utilizing lightweight materials that support DOE goals for reducing U.S. dependence on petroleum and developing energy-efficient transportation technologies and agreed that it had relevant results to support these goals.

Reviewer 2:
Remarking that permanent bonding of adhesive is a huge barrier preventing their adoption into production, the reviewer stated that this project overcomes that barrier.

Reviewer 3:
The reviewer said yes, this project has relevance in enabling vehicle lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the goal was met in a timely manner.

Reviewer 2:
The reviewer agreed that $600,000 for a performance period of 2-1/2 years was sufficient for the university to conduct the needed research, adding that the remaining work is dissemination (publication) of results.

Reviewer 3:
The reviewer had no comments on this finished project.

Presentation Number: lm089
Presentation Title: High-Strength Electroformed Nanostructured Aluminum for Lightweight Automotive Applications
Principal Investigator: Robert Hilty (Xtalic Corporation)

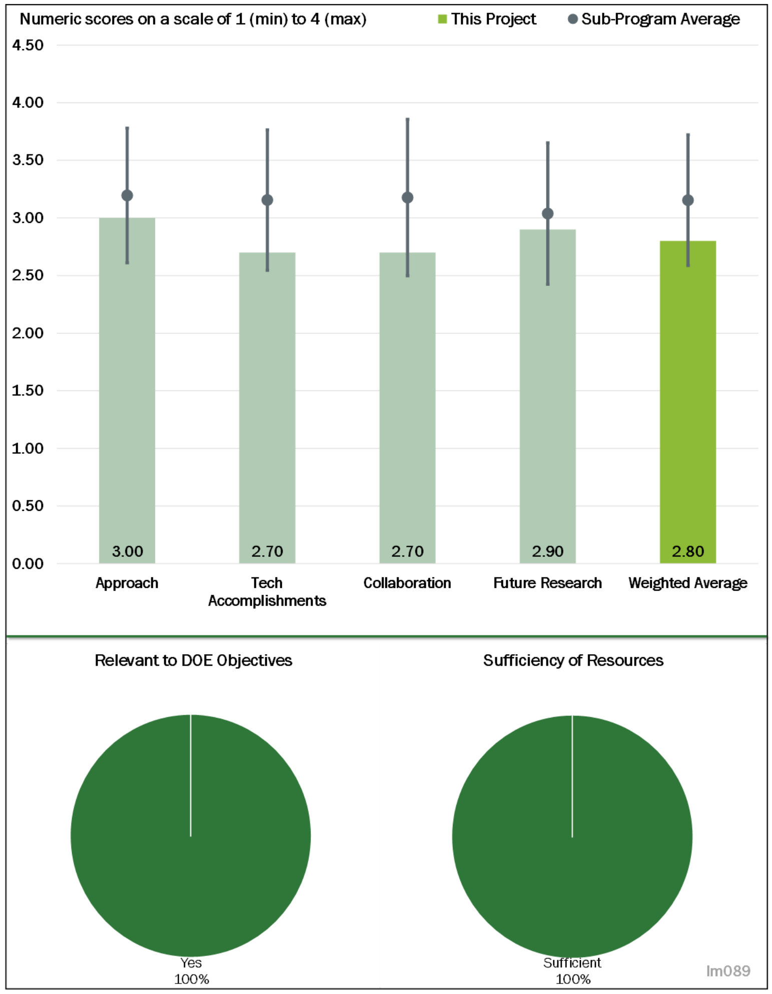

Figure 7-4 - Presentation Number: lm089 Presentation Title: High-Strength Electroformed Nanostructured Aluminum for Lightweight Automotive Applications Principal Investigator: Robert Hilty (Xtalic Corporation)

Presenter

Robert Hilty, Xtalic Corporation

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer agreed that the approach adopted contributes to achieving most if not all of the stated goals of the work.

Reviewer 2:

The reviewer remarked that the novel approach to making Al was very interesting and noted that manganese (Mn) boost is needed to increase strength. The reviewer wondered how increasing the Mn content (somewhere between 7% and 10%) will increase material and/or processing costs, and whether the Mn content will preclude joining processes such as fusion (spot) welding and thereby requiring some type of fastening process if used in vehicle components. The reviewer suggested that some thought is needed on this all-important topic.

Reviewer 3:

The reviewer noted that the project is aimed to develop Al sheet; however, the approach is to develop a coating process to deposit a nanostructured Al alloy atop an Al alloy core and added that the Issue of interface performance need to be addressed. The reviewer remarked that the use of this technology on top of Mg sheets could be a potential growth area but that it needs to be seen in the performance of the composite sheet, adding that this is not included in the current work plan.

Reviewer 4:

The approach is good and promising and this could be promising material, the reviewer stated, but warned that the plan is ill conceived. The reviewer explained that the Al core is basically an Al foil and since those come oxidized, corrosion and delamination could become real problems for this kind of material. The grading relates to the fact that this reviewer likes the initial idea of fabricating sheets with such technology.

Reviewer 5:

While the approach begins to address the technical barriers, the reviewer stated that the lack of a pilot on a continuous plating process is disappointing. Noting that the leap from 6”x6” plates to a continuous coil process is substantial, the reviewer wondered when the continuous process will be addressed. Finally, while agreeing that the plating experiments on the additives appear promising, the reviewer cautioned that both the strength and ductility are under performing at this point, meaning that the project needs to improve grain size to improve properties.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said good progress has been made and that the project appears on course to completing the work on time and achieving the state goals.

Reviewer 2:

The reviewer praised the excellent progress, noting that the project appears to be on track towards the $2.00/lb. saved target. However, the reviewer remarked that some question remains as to whether or not the requisite mechanical properties will be achieved. In addition, regarding the demonstration door beam in Slide 3, the reviewer wondered if some type of shape/geometry optimization will be conducted to determine the appropriate cross-sectional geometry that leads to the highest structural stiffness or instead will a steel beam geometry be used. The reviewer cautioned that some thought on this would be wise. The reviewer then asked a series of questions. First, the reviewer asked if some ultimate limit to the thickness of material that can be produced, for example, is 800 microns (µm) the de facto upper bound on material thickness. Secondly, the reviewer asked how often (if ever) the ionic liquid needs to be changed, and what are the cost implications. And thirdly, the reviewer noted that a forming limit diagram (FLD) will be needed, especially if a door beam is to be designed, and asked if this is planned.

Reviewer 3:

The reviewer noted the major achievement in this review period is the successful scaling up to 6”x6” panel but cautioned that the quality of the sheet and the size of it need to be improved, adding that the current thickness of 50-µm is way out of the target of 400-µm per side. The reviewer also pointed out that the technical cost modeling reveals the cost is still in technology and not much is explained to reduce the current cost which is nearly three times the target.

Reviewer 4:

Agreeing that there is steady though slow progress towards the goals, the reviewer expressed concern that the mechanical properties have degraded with this year’s larger sample size, adding that the true strength of these samples is lower than the 2016 results. The reviewer also noted that the progress on thickness and double-sided plating appears to be behind schedule, adding that it is unclear how the 6”x6” test informs the design of a full-scale reactor. The reviewer pointed out that the effects of the jets is likely to be much different at scale and wondered how the moving plate with a boundary layer will be addressed.

Reviewer 5:

While stating that overall progress is satisfactory, the reviewer expressing dissatisfaction with the answer on corrosion as “nano-Al alloys have excellent corrosion resistance due to single phase...” This reviewer expressed a desire to see thorough experiments to prove this statement, especially since there are two interfaces on an oxidized Al-6061 core. Moreover, this reviewer does not believe that there can be a “perfect bond” without treating the Al foil accordingly to remove the surface impurities. The reviewer warned that the fact that there is no mention on how to prepare the Al for the coating is a real problem, adding that the project called for an Al-6061 core but the shown tests are on brass foil.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed that parties to this work include Fiat Chrysler Automobiles (FCA) and Tri-Arrows Al, adding that these companies are listed as subcontractors, which suggests they are being funded to perform certain well-defined tasks. The reviewer said that most of the work appears to have been done by Xtalic, and concluded that they are fairly well-coordinated and the partnership seems to work well.

Reviewer 2:
The reviewer remarked that even though there are two other participants in this project, their role is limited to technical advice and material supply. The bulk of the work is still conducted by one of the partners. The reviewer stated that this is understandable due to the evolving nature of the technology and creation of intellectual property (IP), but noted more involvement in the base technology to validate the chemistry and process route chosen.

Reviewer 3:
The reviewer commented that while the cooperation appears to be effective, there is little mention about in-process collaboration. The reviewer noted that the information on Slide 19 lists responsibilities but says nothing of interactions or collaboration.

Reviewer 4:
Noting that the collaboration involves Xtalic, FCA, and Tri-Arrows Al, the reviewer wondered who is going to do the simulation for the sheet forming that is mentioned on Side 23. The reviewer added it was unclear which of the three companies will do this.

Reviewer 5:
The reviewer concluded that collaboration is not extended enough and appears to be solely for the benefit of one OEM.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed work is fairly straightforward and, if successful, should address the barriers and challenges identified. However, the reviewer commented that risk mitigation is not addressed and consequently no alternate development pathways are identified.

Reviewer 2:
The reviewer commented that there is a section on proposed future research, but it just repeats what the project plan states.

Reviewer 3:
The reviewer cautioned that it is unclear what is to be done with the sheet given the success of the project regarding forming. The reviewer asked if this is to be left to another project.

Reviewer 4:
Remarking that this appears to be a very promising material, this reviewer is surprised to find almost no relevant comments on corrosion, stability with respect to time, temperature, flexing and bending, delamination, etc., adding that generating all this information should have been planned ahead of time and will have to be obtained before such a promising material can be used in automotive applications. The reviewer also commented that the target of $2/lb. saved can only be realized if the material satisfies all the required

specifications for automotive applications and given all the needed works to be done, expressed doubt that it can be realistically achieved.

Reviewer 5:
Noting that the aim is to develop a nanostructure Al sheet having at least 1-millimeter (mm) thick, the reviewer remarked that the current plan does not identify the route to achieve this and further warned that the time available (through Dec 2018) might not be sufficient to develop the new set up to do the work.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer agreed that the project supports the overall DOE objectives of displacing petroleum by reducing the mass of automotive structures.

Reviewer 2:
The reviewer said yes, this project supports the overall DOE objectives of petroleum displacement.

Reviewer 3:
The reviewer remarked that Al sheet can be used for critical parts if the strength of it can be improved to match high-strength steels, and this project is aimed to achieve this goal. Using the low weight Al vehicles can save fuel. The reviewer commented that if the ultimate goal of coating Mg sheets with Al is achieved, then the savings could be improved further.

Reviewer 4:
The reviewer agreed, but only for specific places where the potentially additional strength is needed.

Reviewer 5:
Noting that the project addresses weight reduction and cost effectiveness in components, the reviewer remarked however that the quantification of the overall improvements in the presentation is rather limited.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said sufficient budget is allocated to address the project needs.

Reviewer 2:
The reviewer is unsure if there are suitable resources for examining formability of the Al-Mn sheets.

Reviewer 3:
The reviewer stated that while the cost to develop and scale up might be just sufficient, the timeline is too short to achieve the full potential.

Reviewer 4:
While sufficient for what has been achieved, the reviewer concluded that the resources are inadequate in view of all the additional and necessary work and testing needed to certify such material for the industry.

Reviewer 5:
The reviewer remarked that without having access to financial data and the statement of work (e.g., hours needed to accomplish tasks, charge rates, and materials cost), it is difficult to make this assessment accurately and added that there is also no matrix/presentation of data on money spent versus work done to assist.

Presentation Number: lm098
Presentation Title: Brazing Dissimilar Metals with a Novel Composite Foil
Principal Investigator: Tim Weihs (Johns Hopkins University)

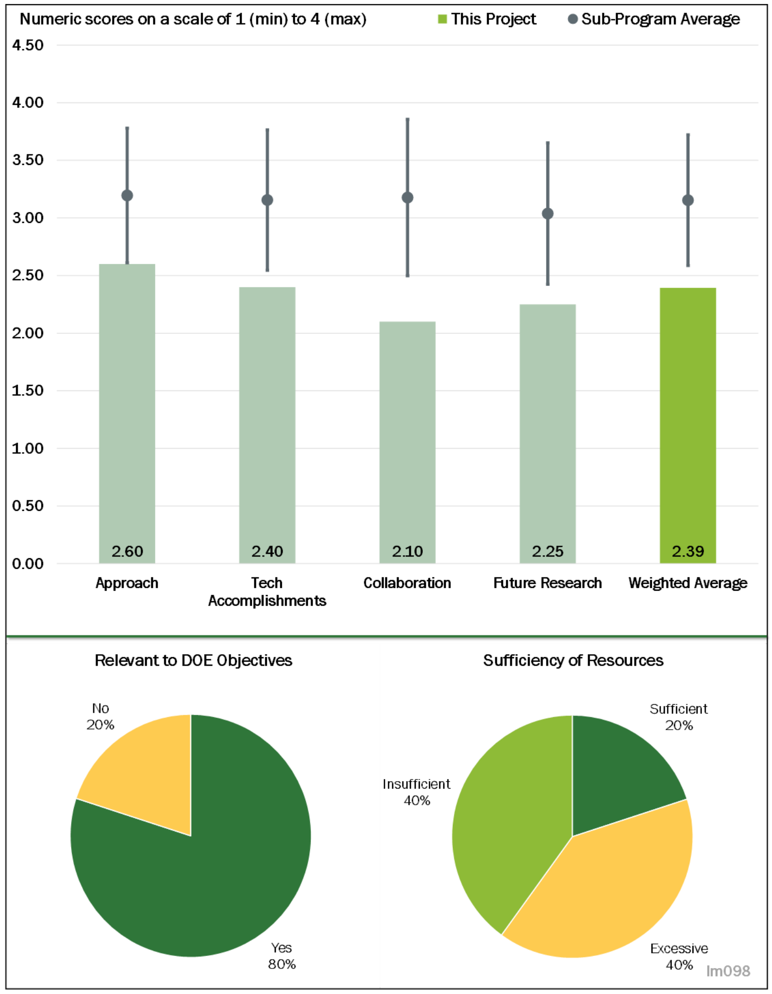

Figure 7-5 - Presentation Number: lm098 Presentation Title: Brazing Dissimilar Metals with a Novel Composite Foil Principal Investigator: Tim Weihs (Johns Hopkins University)

Presenter
Tim Weihs, Johns Hopkins University

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer affirmed that the technical barrier associated with joining of the dissimilar metals in the light weight components for auto assembly has been well addressed with a focus on the brazing technique. The reviewer added that several novel fabrication methods have been considered as well as remaining challenges and barriers have been addressed.

Reviewer 2:
The reviewer said that while the approach to overcoming technical barriers was good, the results fell short of the initial goals. The reviewer elaborated that the project was well-designed for early-stage research on novel materials for brazing dissimilar metals. Noting that this is a unique approach to joining dissimilar metals and is considered as an alternative to other technologies. The reviewer acknowledged that there is little potential for integrating with other efforts.

Reviewer 3:
While agreeing the approach is sound, the reviewer judged the tie to a high-volume solution as nebulous, adding that the additions of copper and silver, while chemically attractive, could lead to corrosion and cost trouble, respectively.

Reviewer 4:
The reviewer strongly declared that the approach was flawed.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer explained that the objective of this project was to enable new multi-material joining techniques to introduce more lightweight components for auto assembly and to develop and characterize novel reactive foils for bonding dissimilar materials. The reviewer further explained that the project identified the gaseous species during propagation of reactions; produced vapor-deposited metal composite foils with five different diluent amounts in order to identify an idealized microstructure and with impact verified by modeling; and reduced the solidification temperature on cooling by over 100°C by replacing the copper diluent with silver. The reviewer determined that research objectives were met successfully against the performance indicators and the research demonstrated some progress towards meeting DOE goals, although the technical goals for the strength of the joints was not met due to issues with joint heating and porosity of the bond. The reviewer added that values for joint strengths were lower than anticipated and there was some evidence of potential corrosion. Nevertheless, the reviewer concluded that the project still produced some good results for the initial studies on this novel composite foil joining method.

Reviewer 2:

The reviewer stated that the project addresses the DOE vehicle mass reduction goal by addressing the issue of joining dissimilar metals. The reviewer noted that several novel reactive foils for use in bonding of dissimilar metals have been examined but challenges still remain to be addressed in order for commercialization.

Reviewer 3:

The reviewer commented that technical accomplishments have steady but slow for this year with the team creatively addressing barriers as they arose. The reviewer remarked that project is progressing but it appears that more troubles are surfacing with each step forward. Nevertheless, the reviewer concluded there have been good efforts to reduce boiling by including copper into the ball milling process, adding that the promising results from Japan are encouraging.

Reviewer 4:

The reviewer stated that nothing was accomplished.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that because this is a fairly small-sized project, collaboration and coordination with other institutions have been somewhat limited.

Reviewer 2:

The reviewer commented that while collaboration has improved, there is room for further improvement to address the bond strength and corrosion issues.

Reviewer 3:

The reviewer noted that collaboration was primarily within academia with some involvement of two material suppliers and some interest from the U.S. Army. The reviewer suggested that the lack of collaboration with automobile manufacturers or parts manufacturers was possibly because the project was in the early stages of research and will end in December 2017.

Reviewer 4:

The reviewer said there was no collaboration.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the future work proposed addresses some of the challenges revealed during this phase of work and added that the current phase of work is expiring by the end of calendar year (CY) 2017.

Reviewer 2:

The reviewer observed that the project will complete in December 2017 (i.e., in 6 months) and that proposed future work is to incorporate a new material in the bonding process, optimize bonding parameters, investigate bond strengths and modes of failure, adding that analysis of bonds will have many risks and challenges to overcome in order to demonstrate that this bonding technique can meet DOE goals. However, the reviewer noted that risks and alternative development pathways, other the current approach, was not discussed during the presentation.

Reviewer 3:

The reviewer stated that the team has identified the upcoming challenges and has developed future work plans to address the challenges. However, the reviewer concluded that the efforts to address corrosion potential seem less than adequate to address the issue.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer agreed that the project addresses the overall DOE objectives of petroleum displacement by addressing one of the challenges of joining of dissimilar lightweight automotive materials.

Reviewer 2:

The reviewer replied yes and elaborated that if the project is successful and a novel method is developed for effectively joining dissimilar lightweight metals without inducing defects that enhance corrosion, then one barrier that contributes to delays in adoption of designs utilizing lightweight materials that support DOE goals for reducing U.S. dependence on petroleum will be overcome.

Reviewer 3:

The reviewer stated that this project addresses joining of dissimilar metals, a major enabler for lightweight vehicles, but cautioned that this is still very early research.

Reviewer 4:

The reviewer exclaimed there is zero joint strength, and corrosion issues.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that almost $600,000 has been invested in academic research over 4-1/2 years with results falling short of meeting DOE goals but added that this is more in line with fundamental or basic research that does not have to produce a product to transition to industry.

Reviewer 2:

The reviewer concluded that the resources allocated for this four-year project seem to be insufficient to meet the overall project objectives.

Reviewer 3:
The reviewer stated that the resources do not appear to be adequate to address the bond strength, potential corrosion, cost, and implementation issues that are anticipated.

Reviewer 4:
The reviewer urged that these projects need to be stopped at early go/no-go decision points.

Presentation Number: lm099
Presentation Title: High-Strength, Dissimilar Alloy Aluminum Tailor-Welded Blanks
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

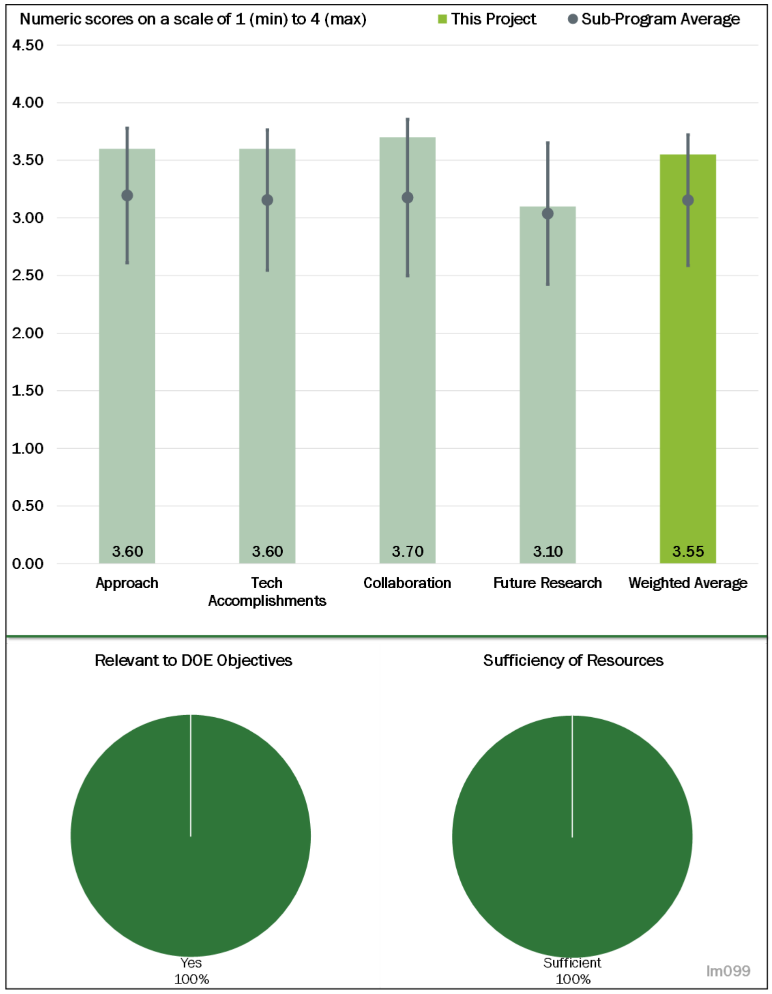

Figure 7-6 - Presentation Number: lm099 Presentation Title: High Strength, Dissimilar Alloy Aluminum Tailor-Welded Blanks Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter
Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer described this as an excellent project that is well-coordinated between Pacific Northwest National Laboratory (PNNL), industry (General Motors [GM]), and supplier (TWB Company) with a very relevant topic of next generation joining of Al sheets using friction-stir welding (FSW).

Reviewer 2:
The reviewer praised the approach as outstanding with clear steps to address the industrial needs for this technology and added that by including the FLD and the Barlat coefficients, this study is very valuable to industry.

Reviewer 3:
The reviewer affirmed the approach as good and the number of welds per combination is very impressive.

Reviewer 4:
The reviewer commented that there was a very good approach by a qualified team.

Reviewer 5:
While remarking it is a great approach to overcoming the technical barriers, the reviewer questioned the reasoning behind the 7xxx series aluinums chosen since these are not typical alloys for automotive applications and the stamping properties are not optimized. Acknowledging that the proof of concept is still being performed, the reviewer also questioned the welding parameter changes when going to, for instance, a 7055.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the technical accomplishments as exemplary and characterized the efforts on repeatability and investigation of tool life as particularly impressive, adding the team has done great work.

Reviewer 2:
The reviewer described the results-to-date as excellent with limiting dome height (LDH) forming trial looking promising. The reviewer suggested the team consider extending to make like production stamping trials on door inner panels in order to complete proof of process.

Reviewer 3:
The reviewer praised the very good accomplishment.

Reviewer 4:
The reviewer affirmed that progress is good and on track.

Reviewer 5:
While agreeing that accomplishments are right on track to meeting the goals, the reviewer expressed concern that the stamping of the 7075 and 7085 may not perform to expectations but added that this should not be an issue meeting production readiness as alloys will constantly change in the future.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer characterized a great mix of industrial lead (GM), laboratory led (PNNL), and supplier supported (TWB Co.) process development, adding that the new PI did an excellent job picking up from previous PI in a seamless transition and continuation of the project.

Reviewer 2:
The reviewer remarked that the collaboration between the welding supplier, GM, material supplier, and national laboratory leverages the strengths of each organization to produce an impressive result with strong interactions and great teamwork.

Reviewer 3:
The reviewer stated that for the tasks and goals, the team is comprised of the right folks to push this through to a production-ready scale.

Reviewer 4:
The reviewer praised it as a great example of DOE national laboratory and industry collaboration.

Reviewer 5:
The reviewer described collaboration as too restrictive, adding that there should be more than one OEM on such projects.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer affirming that the proposed future research addresses the remaining hurdles for the project.

Reviewer 2:
The reviewer stated that the project is completed.

Reviewer 3:
The reviewer suggested extending the work to include 7xxx Al alloys and FSW to 5xxx and 6xxx sheet products.

Reviewer 4:
The reviewer remarked that future research should be as planned but with more statistics included, pointing out that the plots shown have no error bars. The reviewer added that typical standard deviations should be included in plots and if the error bars are within the thickness of the graph line, then this should be specified.

Reviewer 5:
The reviewer explained that the lower rating is only due to the 7xxx series selected and the concerns with stamping, adding that the results will be interesting to see if an optimal weld for these material combinations can be met.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this provides a new and more efficient way to join these high-strength aluminums which are needed to reach VTO requirements, adding that the process will also be applicable to other areas of the vehicle for joining sheet Al that have not even been discussed.

Reviewer 2:
The reviewer remarked that the tuning of weight to meet performance needs is a critical element of vehicle lightweighting and that by having tailor-welded Al blanks in our tool box, further mass reductions are possible. The reviewer added that mass reduction directly reduces the amount of petroleum used.

Reviewer 3:
The reviewer commented that Al will drive weight savings in large trucks and sport utility vehicles (SUVs) and it meets the objectives of DOE's VTO.

Reviewer 4:
The reviewer offered that if this intended in replacing steel parts, then definitely, but probably not in replacing other Al parts. Instead, the reviewer said that cost savings are more evident.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer characterized this as a good use of DOE and industrial resources.

Reviewer 2:
The reviewer stated this had sufficient resources for the project and planned work.

Reviewer 3:
The reviewer replied the project is appropriately funded.

Reviewer 4:
The reviewer replied the resources may or may not be sufficient.

Presentation Number: lm101
Presentation Title: Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles
Principal Investigator: Xuming Su (Ford Motor Co.)

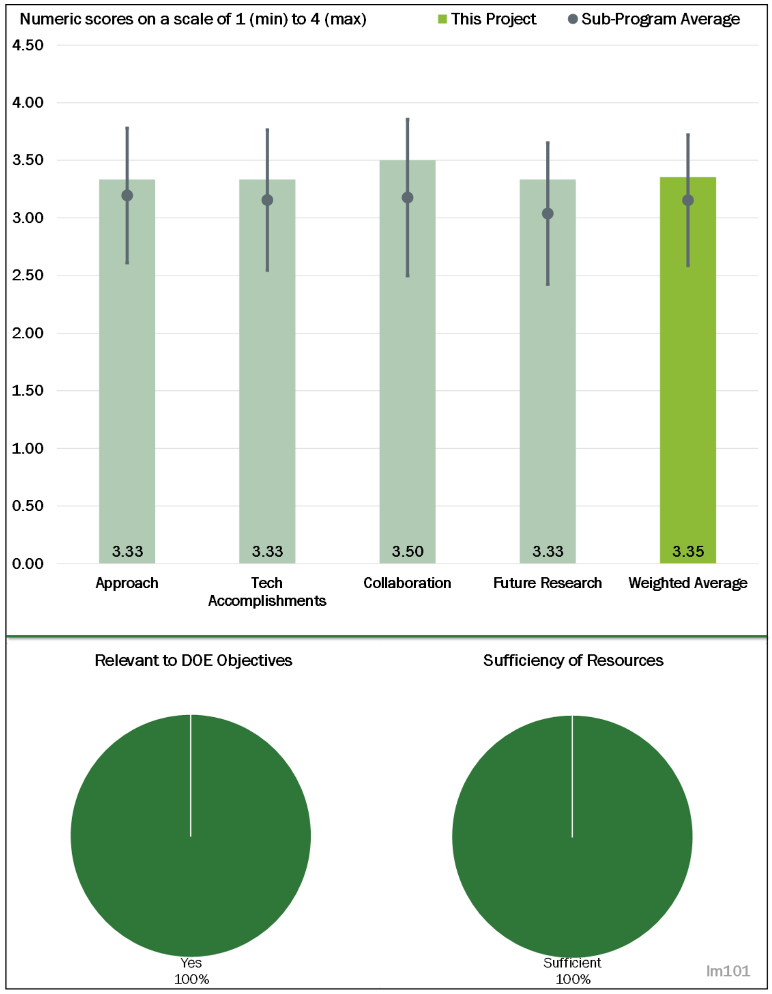

Figure 7-7 - Presentation Number: lm101 Presentation Title: Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles Principal Investigator: Xuming Su (Ford Motor Co.)

Presenter

Xuming Su, Ford Motor Company

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer began by stating this project (LM101) is a very broad and ambitious effort that addresses key technical barriers to implementation of fiber-reinforced polymers in automotive applications and praised the contractor as having demonstrated a work plan that is very well designed and technically very sound. The reviewer elaborated that if the execution continues at the level exposed to date, the effort will generate a methodology and tool set that should support achieving the stated goals. The reviewer also explained that the fundamental characterization of the micro-scale material system is critical to successful macro-scale modeling and concluded by stating it is refreshing to see how thoroughly this is addressed, in both the fundamental material form and the analysis of post-process geometry, as well as the impact on local fiber orientation/geometry.

Reviewer 2:

The reviewer praised the excellent approach in comprehending the complexity of composites using top-down and bottom-up multi-scale modeling.

Reviewer 3:

The reviewer stated that the value of molecular dynamics (MD) simulations to predict interphase strength at crash/quasi-static strain rates is not clear and wondered if a peel strength test or an analogous test could provide the same information directly. The reviewer elaborated that it seems the MD work is sensitive to the exact chemistry of the sizing and hence, perhaps, not translatable to other sizing chemistries which are typically proprietary.

The reviewer also observed that noise, vibration, and harshness is listed in the "Overall Objectives" section of the presentation file but does not seem to have been addressed in the AMR presentation. The reviewer requested an elaboration on specimen geometry optimization for fatigue testing of chopped sheet molding compound material vis-à-vis American Society for Testing and Materials (ASTM) International/International Organization for Standardization standardized geometry. The reviewer inquired whether this project can lead to a new standardized specimen geometry if no standard exists. The reviewer mused that while the project may improve upon the predictive capability of composite performance, it is not clear how the manufacturing cycle time could be reduced. To that point, the reviewer asked if the cycle time is not directly related to resin's curing time which, in turn, is a function of temperature and hence, can be reduced only to a limit (by increasing the temperature) without degrading the fiber. Alternately, the reviewer asked what desired cycle time the team is aiming for.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the excellent technical progress accomplished and said it was nice to see that the predictions are within 10% of experimental results.

Reviewer 2:

The reviewer remarked that progress on this program was demonstrated across the multi-disciplines of activity, elaborating that from microscale modeling and representative volume element work to forming technologies and prediction of outcomes from process integration studies, the PI provided significant data and successful cross-correlation of results to prediction. The reviewer concluded that the work to date suggests a successful approach to ICME is taking shape.

Reviewer 3:

The reviewer commented that it seems predicting the fiber orientation (whether chopped fiber orientation during mold filling or continuous fiber orientation during draping) is the key to achieving good predictability of overall mechanical properties. The reviewer then wondered if, alternatively, is it possible for the team to identify which aspect of this research would be most impactful in improving the overall predictability better than 15%, even though the target for error bound is 15%. The reviewer suggested that improving the predictability may avoid over-designing the product and achieve additional weight savings and cost reduction.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer praised the contractor as having demonstrated strong progress with a variety of partnerships that clearly are effective in the breadth of activities accomplished. With competent university interaction, as well as material and software support, the reviewer also praised the PI for having performed significant amounts of work to include data generation, analysis, and drawing significant conclusions for work going forward. The reviewer said it was all well done.

Reviewer 2:

The reviewer described the teams as well-balanced with excellent collaboration between them.

Reviewer 3:

With such a large team, the reviewer suggested it would be useful to remind the audience how the work was coordinated (e.g., meeting schedules, internal reviews, etc.).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer described future work as very promising to eliminate some of the barriers in predicting the performance of composite materials.

Reviewer 2:

The reviewer remarked that the PI was explicit regarding any shortcomings or failures in work to date and the gaps exposed, adding that future work has identified methods to close these gaps. The reviewer concluded that there is little reason to doubt that the contractor will be successful given the detail provided and the results to date.

Reviewer 3:

Beyond the cost of the CF, the reviewer suggested it would be useful to identify which aspect(s) of the fabrication process need to be prioritized to achieve weight savings greater than 25% with the least amount of cost increase per pound saved. Alternately, the reviewer suggested the team could plot weight savings versus cost/lb. saved to indicate the cost premium in the case that weight savings greater than 25% is desired. The reviewer commented that it is not clear how the fragmentation tests can validate MD predicted data (at strain rates 10^8 or more). Finally, the reviewer said that with a significant use of CF composites in the aerospace industry, it would be useful to clarify which aspects of modeling and fabrication in current research differ from aerospace industry and hence require additional effort beyond what is known in the industry.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer replied yes, elaborating that the technology deliverables from this project have potential to lower the weight of an automobiles. The reviewer added that lowering the weight directly increases the fuel economy and thus reduces the petroleum consumption.

Reviewer 2:

The reviewer explained that successful implementation of reinforced plastics on automotive vehicles has a demonstrated, significant impact on system weight, adding that lighter platforms drive improve vehicle emissions and reduce fuel consumption. In the case of plug-in BEVs, the reviewer noted that extending range is key to successful and economically viable consumer applications (which will further displace petroleum usage). The reviewer concluded that this project clearly lays important and necessary groundwork for successful prediction and analysis and supports manufacturing of these advanced materials.

Reviewer 3:

The reviewer suggested that perhaps lifecycle analysis is needed to answer this question effectively since both the CF and the resin are based on petroleum based precursors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer enthused that resources are perfect and right on.

Reviewer 2:

The reviewer stated that while the project is tremendously ambitious in scope, the resources available are sufficient, adding that progress is on track and future work outlined is in line with remaining funds.

Presentation Number: lm103
Presentation Title: E. coli Derived Spider Silk MaSp1 and MaSp2 Proteins as Carbon Fiber Precursors
Principal Investigator: Randy Lewis (Utah State University

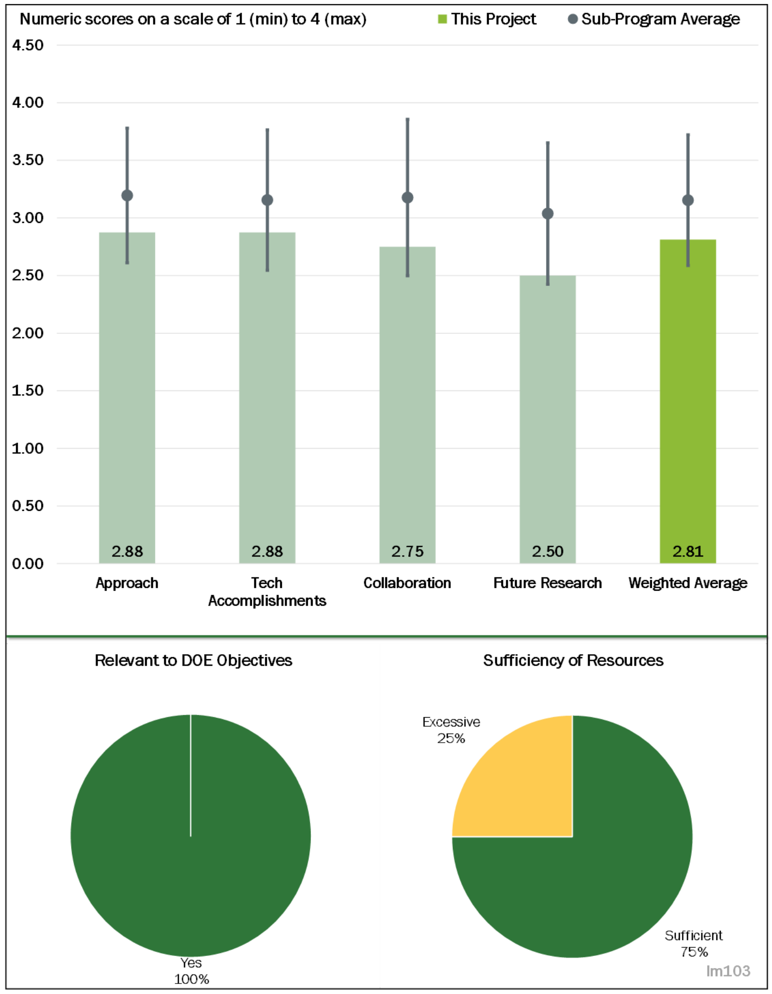

Figure 7-8 - Presentation Number: lm103 Presentation Title: E. coli Derived Spider Silk MaSp1 and MaSp2 Proteins as Carbon Fiber Precursors Principal Investigator: Randy Lewis (Utah State University)

Presenter

Randy Lewis, Utah State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer characterized the project as having an interesting subject with a good approach to develop fundamental understanding from a unique group of scientists.

Reviewer 2:

The reviewer remarked that it seems for the processing temperatures, material loss during heating and the heating duration are similar to that in conventional CF processing and, as a result, it seems these barriers still need to be overcome.

Reviewer 3:

While the overall approach was good, the reviewer commented that it would have been much better if the project team established meeting go/no-go targets in development of suitable replacement for CF, adding that the final developed properties are far less than the performance of CF from stiffness

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer agreed that the project met its milestones in a timely manner, as well as produced spider silk fibers and performed the techno-economic analysis of the process. In addition, the reviewer concluded that the project demonstrated the feasibility of using E. coli-derived spider silk proteins as precursors for CF, but cautioned how easy/difficult it is to meet the cost targets is still uncertain.

Reviewer 2:
The reviewer stated that within the time allotted, the technical accomplishments seem satisfactory but that the explanation of cost impact could have been further improved with key examples.

Reviewer 3:
The reviewer said that while there is good knowledge, the commercial application is not there.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that collaboration between identified partners appeared good but questioned whether it would have been more appropriate to have other industry partners involve in addressing the overall feasibility of using such alternative precursors in automotive applications.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project is complete.

Reviewer 2:
The reviewer stated the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the low-cost CF is a potential means of lightweighting transport vehicles.

Reviewer 2:
The reviewer suggested it would be useful for the project to identify whether any of the raw materials are derived from petroleum. The reviewer noted that the large amount of heat at high temperatures requires furnaces and wondered whether these are oil/gas-fired or electrical radiant furnaces.

Reviewer 3:
The reviewer concluded that the project by itself does not fully support the relevance of meeting DOE objectives and is of the view that additional research funding is required for flesh out the details further.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer thought that the DOE share of about $1.5 million seems excessive for the scope of work presented.

Presentation Number: lm104
Presentation Title: Solid-State Body-in-White Spot Joining of Aluminum to AHSS at Prototype Scale
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

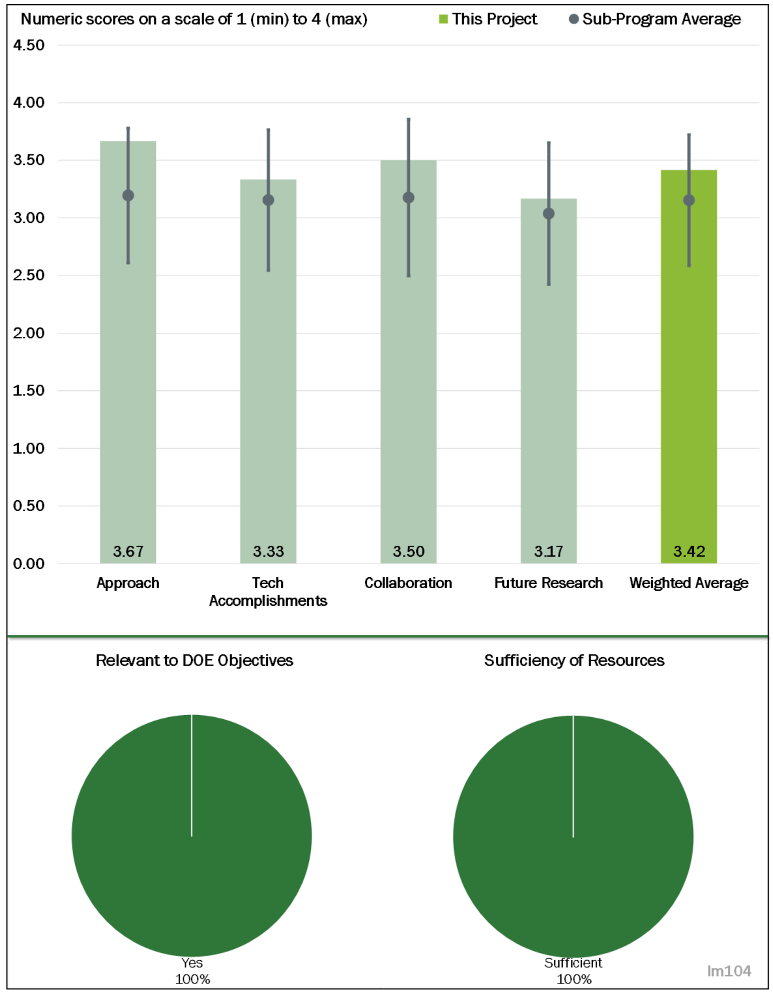

Figure 7-9 - Presentation Number: lm104 Presentation Title: Solid-State Body-in-White Spot Joining of Aluminum to AHSS at Prototype Scale Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised as excellent the inclusion of two types of joining, friction bit joining (FBJ) and friction stir spot welding (FSSW), adding that while FSSW is considered in other projects, this particular project is also evaluating the FBJ.

Reviewer 2:

The reviewer commented that corrosion performance seems to be the most challenging barrier to overcome and should be the focus of the future work.

Reviewer 3:

The reviewer praised the good approach on a very challenging problem but added that while the joining appears to be okay, corrosion stress cracking could be the real problem for this technology.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer replied there has been good progress.

Reviewer 2:

The reviewer praised the mechanical performance as excellent but added that the project needs to make progress on corrosion performance.

Reviewer 3:
The reviewer stated there is good progress on FBJ and the technical challenges on FSSW are being addressed but noted that the evaluation of a key factor in the process, corrosion, is delayed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the excellent collaboration among project partners and added that industrial collaboration is also evident.

Reviewer 2:
The reviewer said it is a very good and extended team.

Reviewer 3:
The reviewer replied that all partners have taken part in the project.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project is almost complete but it would be interesting to broaden the range of applications for these techniques (i.e., FSSW and FBJ).

Reviewer 2:
The reviewer reiterated the need to focus on corrosion in future research.

Reviewer 3:
The reviewer remarked that two technical challenges identified in the project, galvanic corrosion and thermal expansion mismatch, have not been included or detailed in future research.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer concurred that the project will enable the use of lightweight Al in vehicle construction, which lead to fuel economy in gasoline cars and contribute to the development of electric cars.

Reviewer 2:
The reviewer agreed that the ability of putting together light elements with strong ones will have a definite impact on petroleum displacement.

Reviewer 3:
The reviewer replied the project is enabling vehicle lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said there is sufficient funding.

Reviewer 2:

The reviewer observed that it seems less than 50% of the budget has been used in project that is 70% (time) completed and added that the funds will be sufficient even though scale-up happens in the final stages.

Presentation Number: lm105
Presentation Title: Friction Stir Scribe Joining of Aluminum to Steel
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

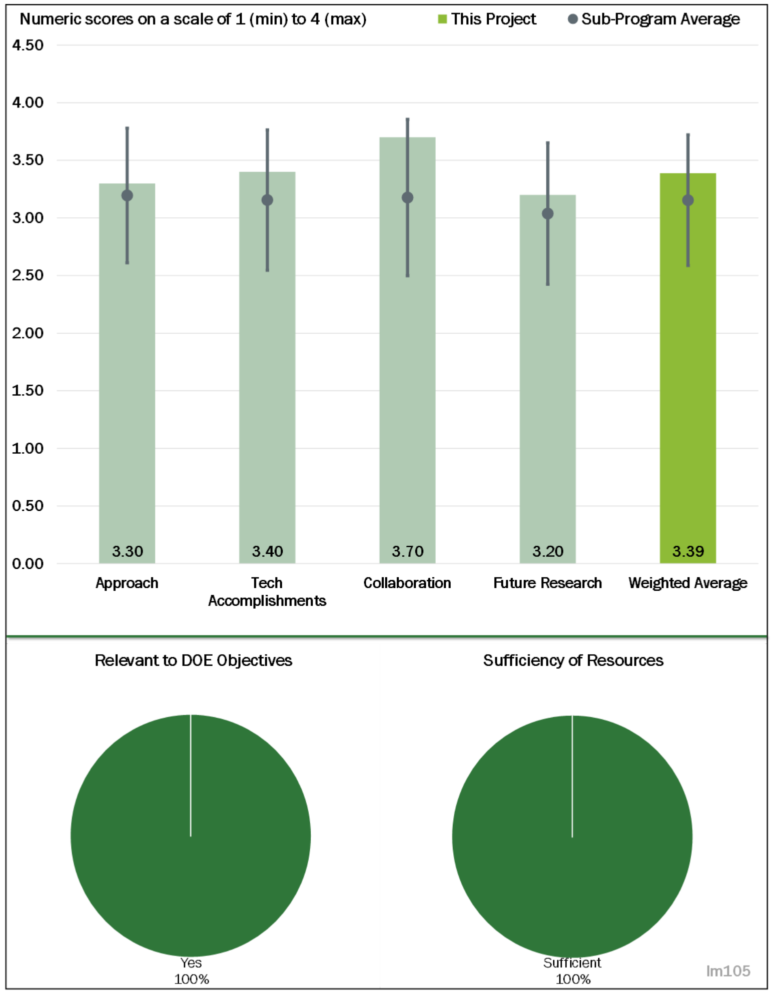

Figure 7-10 - Presentation Number: lm105 Presentation Title: Friction Stir Scribe Joining of Aluminum to Steel Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter

Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer declared this to be a great project that is enabling more multi-materials into automobiles for lightweighting.

Reviewer 2:

The reviewer agreed that technical barriers are covered very well with this effort and are resulting in successful weldments. Praising the project as very well laid out, the reviewer noted it is leveraging the work of other DOE friction stir scribe (FSS) projects and applying the lessons learned to overcome current challenges. The reviewer stated this is very nice work.

Reviewer 3:

The reviewer stated the project has a good approach on a difficult problem in which corrosion could be the proverbial Achilles' heel.

Reviewer 4:

While praising the excellent approach, the reviewer remarked that too many systems in this study will minimize the success of one mix materials system. Nevertheless, the reviewer characterized this as an excellent project looking into flash-welding mixed metal joining.

Reviewer 5:

The reviewer noted that the project is evaluating the joining of different grades of steel with different Al samples (e.g., cast, wrought) and praised this as very good. However, the reviewer observed that the evaluation of some key factors such as galvanic corrosion and coefficient of thermal expansion mismatch have not been included early on in the plan and commented that the structure-property modeling is not very solid. The reviewer concluded that the evaluation of the microstructure evolution is sadly missing since this would have been an asset in understanding the effects of different steels and Al parts.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer characterized the excellent progress, adding that three different systems from three OEMs were incorporated.

Reviewer 2:
The reviewer praised very good progress with very good results.

Reviewer 3:
The reviewer noted that the project is in its last steps for completion and transition to an OEM and explained that the technical accomplishments cover the goals set forth by DOE for dissimilar material joining. While agreeing that the OEM goals and challenges are also being met with stationary shoulder development and thermal monitoring, the reviewer commented that it would be nice to see the new material for the scribe tip and for the project to perform some welding on the higher strength steels to test if assumptions are met. The reviewer also suggested as a possible solution considering additional refractory metals.

Reviewer 4:
The reviewer remarked that the main accomplishments are on the integration of stationary shoulder in the process and the evaluation of the strength of various Al/steel joints. The reviewer also noted that a predictive structure-property model has also been initiated along with the prototype evaluation, although the latter with some delay.

Reviewer 5:
This reviewer would like to see more long-term testing of scribe life when FSW of dissimilar metals takes place when the FSW is through soft into a harder material system. Life of the scribe tool needs to be studied in more detail.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer characterized as excellent collaborations between various stakeholders.

Reviewer 2:
The reviewer praised the team as excellent with good synergy.

Reviewer 3:
The reviewer said it is nice to see multiple OEMs involved in this project to tackle a specific joint design that each is trying to achieve and added that the robotic integrator is also a nice addition as this would be one of the transition partners to get the technology implemented into production. The reviewer further commented that having this team here will really help to push this technology forward by applying to real-world applications and described as very refreshing to see such great collaboration.

Reviewer 4:
The reviewer noted the unique mix of three OEMs (GM, Honda, and FCA), each with different objectives and that PNNL is competing the tasks and milestones as expected.

Reviewer 5:

The reviewer stated that while all partners seem to be taking part, an interactive mode with the related industrial partners on materials aspects or corrosion testing is not apparent.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer agreed that the proposed future work will permit this project to its stated final goals. However, the reviewer added that even though the corrosion work is being performed outside of this effort, it would have been nice to include it from the beginning or at least report on it.

Reviewer 2:

The reviewer stated that while the project is almost complete, it should be continued to broaden the field of applications

Reviewer 3:

The reviewer urged including more studies on scribe tool life to prove longevity and durability of the FSW tool.

Reviewer 4:

The reviewer remarked that future research should include more predictive model development for understanding the physics during the FSS joining.

Reviewer 5:

The reviewer observed that no details are given for Task 3.2 (prototypical demonstration) which is the main remaining activity (other than modeling).

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that dissimilar material joining is going to be needed to meet the requirements set forth by DOE and is currently identified as the number one priority in many circles. The reviewer praised this this project as advancing the technology to the point of real world applications by looking at specific materials and joint configurations for three different OEMs. The reviewer remarked that the technology should be looked at as an enabler for lightweighting and one that can be applied to multiple material combinations and joint designs.

Reviewer 2:

The reviewer affirmed that the learning and deliverables from this project will enable usage of more Al in automobiles for lightweighting and thus reduce the consumption of petroleum.

Reviewer 3:

The reviewer agreed that the project will enable weight reduction in vehicle construction leading to fuel economy in gasoline cars and that it will also contribute to the body construction of electric and hybrid cars.

Reviewer 4:

The reviewer replied that combining light elements with strong ones will help in displacing petroleum.

Reviewer 5:
The reviewer answered that mix metal joining is a major enabler for future body in white and chassis subsystems

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer praised the project as progressing nicely and that the correct people are involved to reach completion on time.

Reviewer 2:
The reviewer agreed that project resources are sufficient to complete the project.

Reviewer 3:
The reviewer replied that this project is appropriated resourced.

Reviewer 4:
The reviewer said that no clear budget figures were presented to deduce how much of the total budget has been consumed. Noting that the project is timewise 80% completed and the FY 2016 budget is $420,000, the reviewer said it would have been good to detail the prototyping steps and the resources planned for these activities.

Presentation Number: lm106
Presentation Title: Enhanced Sheared Edge Stretchability of AHSS/UHSS
Principal Investigator: Kyoo Choi Sil (Pacific Northwest National Laboratory)

Presenter

Kyoo Sil Choi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

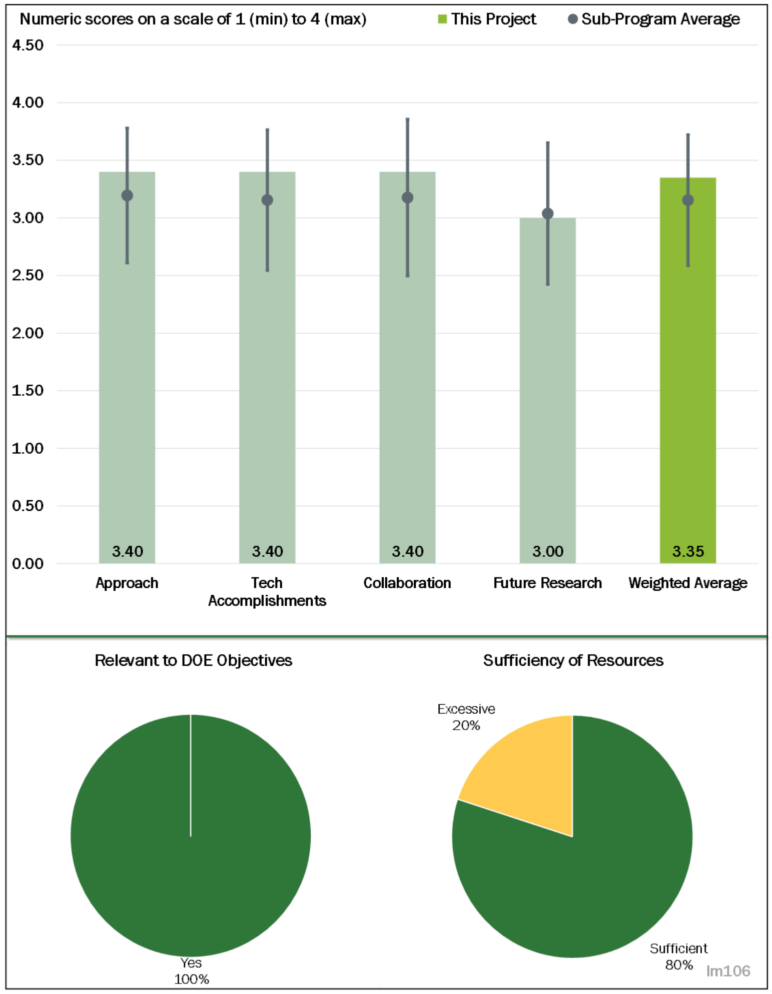

Figure 7-11 - Presentation Number: lm106 Presentation Title: Enhanced Sheared Edge Stretchability of AHSS/UHSS Principal Investigator: Kyoo Choi Sil (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised this as an excellent body of work that includes detailed microstructural characterization, fundamental modeling and forming simulation modeling of shear edge, and hole punching processes. This reviewer is very impressed with both the technical approach and level of detail in the project.

Reviewer 2:

This reviewer stated that this project has a solid, feasible approach to solving a difficult technical barrier for accepting advanced and ultra-high strength steels to be used in automotive applications. The reviewer elaborated that the project is well designed and addresses the fundamental understanding of the role of microstructure on sheared-edge stretchability, which will allow the building of predictive capabilities to quantify relationships between microstructures and trimmed-edge quality including subsequent stretchability. The reviewer added that the approach covers all aspects of initial literature reviews, material property characterization, trimming and piercing simulations and experimentation, and optimization of process parameters. The results for this project integrates well with other efforts for implementing advanced steels in automobile fabrication.

Reviewer 3:

The reviewer remarked that the project has a very good approach and the project team shows that they know what they are doing.

Reviewer 4:

The reviewer commented the approach for not including a hypothesis and being rather shotgun in nature, the result of which was that nothing was proved or disproved. The reviewer concluded that nothing more is known today than was known 4 years ago.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the technical accomplishments and progress as having been successful and significant. The reviewer remarked that the project has remained on schedule and has demonstrated progress toward meeting DOE goals by meeting all performance indicators (milestones). The reviewer affirmed that the success of this project will allow the development of next-generation steels to be accelerated and will enable a rapid and cost-effective deployment of advanced steels in vehicle structures through automobile manufacturers for substantial mass savings that meet the lightweighting goals specified in VTO's MYPP.

Reviewer 2:

The reviewer is impressed with the high-energy X-ray diffraction work coupled with the mechanical property measurements of the dual phase (DP) steels including DP1, DP2B, and DP2T 980 steels, adding that the detailed tensile data and characterization of shear edge defects is if great value to the transportation industry as it looks to use more UHSS systems.

Reviewer 3:

The reviewer stated that the progress and accomplishments are both in order with clear presentation of the results.

Reviewer 4:

The reviewer asked what was accomplished.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer enthused that the collaboration in this project is outstanding and involves a national laboratory, a university, two steel manufacturers, and an automobile manufacturer. The reviewer praised the collaborations as having resulted in shared responsibilities for experimental materials characterization at micro and macro scales, phase property and shear-affected zone characterization, predictive modeling capabilities linking microstructures to trimming conditions and edge stretchability, and optimization of microstructure and process parameters based on the ability of sheared surfaces to stretch.

Reviewer 2:

The reviewer commented there was the perfect mix of PNNL (national laboratory), steel suppliers, and industrial partners sharing in the characterization and testing of DP steels for shear edge cracking.

Reviewer 3:

The reviewer stated it was a very good team with good synergy.

Reviewer 4:

The reviewer remarked it was a good opportunity for a local university to collaborate with an OEM (Ford) and DOE national laboratory (PNNL), but emphasized that there was not too much science here.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer explained that this project is scheduled to complete at the end of FY 2017 and that the remaining efforts (future research) include completing remaining tasks to include addressing macro fracture, stretchability and hole extrusion ration predictions and experiments; development of a computational scheme for a three-dimensional model that considers the hole edge variation effects; and optimization of process parameters and microstructures for trimmed edge stretchability. The reviewer surmised that since these are part of the original project plan and developed in a logical manner to meet decision milestones, the remainder of the project is expected to be successful and added that no further future efforts were presented.

Reviewer 2:

The reviewer stated that the project is almost over but it would be desirable that the techniques of the project be extended to other areas.

Reviewer 3:

This reviewer would like to see more R&D proctored by the PI from PNNL, who is now at Oak Ridge National Laboratory (ORNL).

Reviewer 4:

The reviewer commented that the recommendations and lessons learned are non-existent.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that this project is relevant and supports VTO's MYPP goals and objectives for incorporating advanced and UHSS lightweight automobile components. By meeting lightweight materials goals, the reviewer asserted that this project will also solve problems that contribute to delays in adoption of designs utilizing lightweight advanced steels that support DOE goals for reducing U.S. dependence on petroleum and efficient transportation technologies.

Reviewer 2:

The reviewer replied yes, the application of AHSS can provide cost-effective mass reduction associated with the production of high-volume vehicles.

Reviewer 3:

The reviewer answered yes because using advanced materials will reduce part weight.

Reviewer 4:

The reviewer commented that UHSS, in particular DP steels, will continue to drive lightweight vehicle body architectures and chassis subsystems as the primary low-cost weight savings options.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer concluded that although this project is resourced at over $2 million for a 3-1/2 year performance period, the resources are sufficient for the number and types of organizations (national laboratory, academia, tier 1 material suppliers, and an automobile manufacturer) that are actively involved in different aspects of the R&D needed to solve this problem.

Reviewer 2:
The reviewer stated that from the amount of work presented, resources appear to be adequate.

Reviewer 3:
The reviewer said this project was appropriately resourced.

Reviewer 4:
The reviewer commented that valuable PNNL resources were expended but with very little to show.

Presentation Number: lm107
Presentation Title: Optimizing Heat Treatment Parameters for Third Generation AHSS Using an Integrated Experimental-Computational Framework
Principal Investigator: Xin Sun (Pacific Northwest National Laboratory)

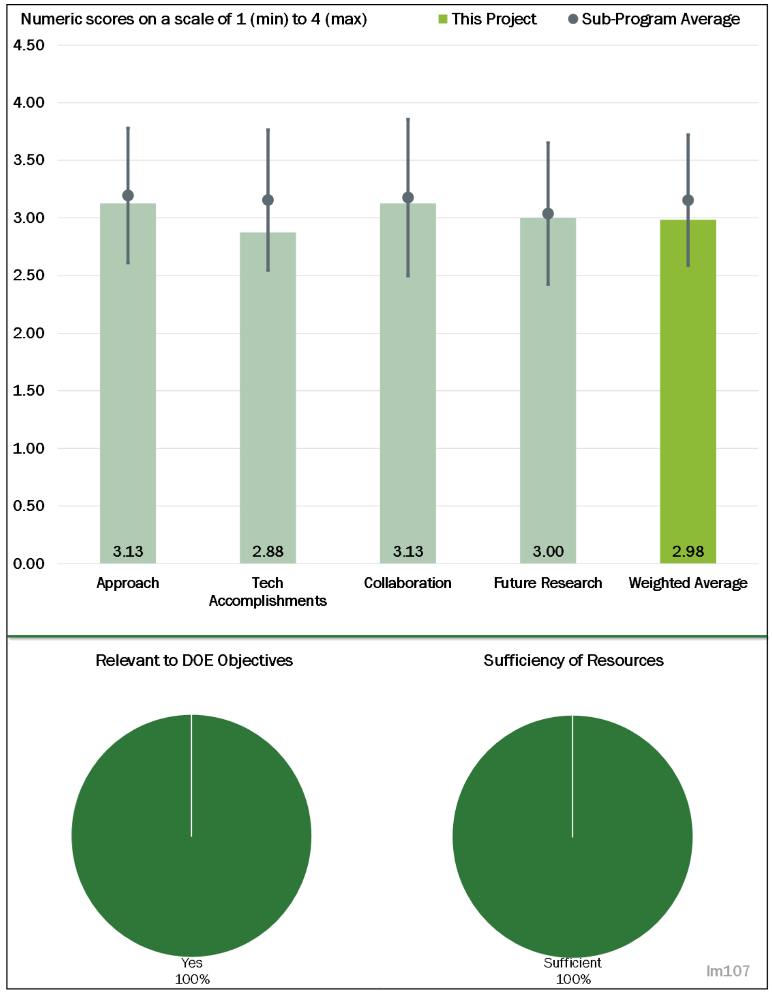

Figure 7-12 - Presentation Number: lm107 Presentation Title: Optimizing Heat Treatment Parameters for Third Generation AHSS Using an Integrated Experimental-Computational Framework Principal Investigator: Xin Sun (Pacific Northwest National Laboratory)

Presenter
Xiaohua Hu, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
This reviewer praised this as a great project to develop ICME of UHSS using state-of-the-art microstructural characterization and modeling tools to deliver alloys by design.

Reviewer 2:
The reviewer stated that the approach addresses the project goals and that the use of ICME should point to the best solutions. The reviewer also noted that the development of the ICME models for austenite volume fraction and microstructure evolution might help develop the processing recipes.

Reviewer 3:
The reviewer stated that the objective needs to be defined in a clearer definitive manner.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised this as an excellent project and one that parallels the 3GAHSS project just completed and adds to the ICME steel alloys by design toolbox.

Reviewer 2:
The reviewer affirmed that the accomplishments are on track for the project and added that the studies are progressing well. However, the reviewer cautioned that how the experimental studies and findings are tied to

the ICME modeling efforts were not well defined in the presentation. Nevertheless, this reviewer trusts that the modeling and experiments will support each other to yield verified models that give insights into the processing recipes.

Reviewer 3:
The reviewer commented that the technical accomplishments are not clearly correlated to the 3GAHSS mission.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said there is strong collaboration among the three groups to keep moving forward.

Reviewer 2:
The reviewer replied there is good collaboration with a well-defined team.

Reviewer 3:
The reviewer stated there is a good mix of national laboratories and academia, but added the project would benefit from more industrial (OEM and supplier (steel company) collaboration).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that there are great opportunities to expand this work and is recommending that DOE direct fund similar work in the future at Colorado School of Mines (CSM).

Reviewer 2:
The reviewer agreed that the proposed work addresses the remaining challenges. However, the reviewer cautioned that the ties from experiments to the ICME models that will direct processing are not clear from the presentation.

Reviewer 3:
The reviewer stated that future research is not clearly defined.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that UHSS will drive lightweight materials into vehicles cost effectively.

Reviewer 2:
The reviewer remarked that improvements in steel are critical to reducing vehicle mass and thus displacing petroleum.

Reviewer 3:
The reviewer said that heat treatment of 3GAHSS is critical to the lightweighting fuel reduction initiative

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer agreed that there are sufficient resources for this project.

Reviewer 2:
The reviewer said this project is appropriately funded.

Reviewer 3:
The reviewer concluded that the mission is not defined well enough to justify additional resources.

Presentation Number: lm108
Presentation Title: Development of Low-Cost, High-Strength Automotive Aluminum Sheet
Principal Investigator: Russell Long (Arconic)

Presenter
Russell Long, Arconic

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer affirmed there is a well-fined, calculated approach towards the development of a cost effective high-strength Al alloy.

Reviewer 2:
The reviewer agreed that the approach is well considered and appropriate for this project and that the efforts address the critical project areas, adding that the continuous casting for the prototype alloy demonstrates the potential for this improved technology.

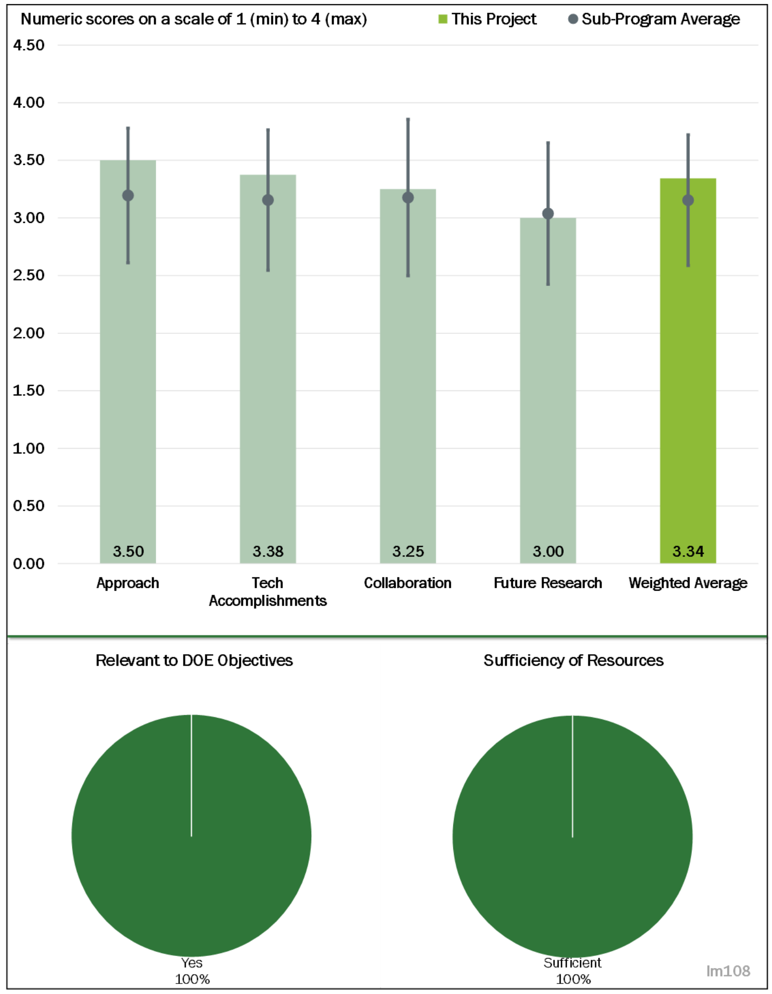

Figure 7-13 - Presentation Number: lm108 Presentation Title: Development of Low-Cost, High-Strength Automotive Aluminum Sheet Principal Investigator: Russell Long (Arconic)

Reviewer 3:
The reviewer stated that the approach detailed in the presentation is adequate to achieve the goals of demonstrating viable warm forming of a car part with a high-strength Al alloy while achieving cost reductions of $2/lb.

Reviewer 4:
The reviewer cautioned that FSW is going to be an expensive approach to joining and asked if the team has completely given up on fusion welding, e.g. spot welding, and if so, why. The reviewer wondered if the material can be engineered to improve spot weldability without loss of properties. The reviewer also noted that there is no information that would provide reassurance that the initial 2.5-mm gauge is suitable for the load cases to which the door ring must be evaluated. The reviewer asked what if the team has to upgauge to 3.0-mm to meet side impact requirements. The reviewer also observed that Slide 12 contains no label(s) on color contour keys and asked what is being shown in the corresponding contour plots. The reviewer also noted that the figure at the lower right needs a length scale and that the flow curves in Slide 12 suggest a loss of properties in the FSW. The reviewer asked why is this so and, how will this be incorporated into a model of the part when in the vehicle side-body structure.

The reviewer also remarked that the heat-affected zone (HAZ) seems too narrow for extraction of a miniature tensile specimen and asked how the flow curve corresponded to the HAZ in the flow curve plot in Slide 12 generated. The reviewer next noted that on Slide 24 to please include the baseline steel currently in use for the door ring in the strength-ductility ("banana") chart wondered if the baseline steel is a press hardening steel (PHS). Finally, the reviewer commented that for Slide 9, when are the data available, it would be helpful to show how corrosion changes with heat treatment and corresponding mechanical properties.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised as impressive the progress on testing and evaluations of the alloys, adding that the project is close to done and last year's efforts indicate success. The reviewer elaborated that forming trials show the formability of this 7xxx Al at the 225 Celsius (°C) and that the interactions of the forming temperature and the final strength show the sensitivity of the strength on the process interactions. The reviewer remarked that the 520 to 580 Mega-Pascals are below target but are still a substantial improvement over 5xxx and 6xxx alloys.

Reviewer 2:
The reviewer noted that there have been results in two major areas (tailored-welded blanks [TWB] development and forming trials) and added that the workers seem to be on course to achieve their goals.

Reviewer 3:
The reviewer stated that progress appears to be following the schedule of the project.

Reviewer 4:
The reviewer said there has been excellent progress and accomplishment relative to weight goal. However, the reviewer added there was no mention as to $2/lb. saved cost goal or cost model, but that this must be enforced as a go/no-go milestone to continue to budget period two. The reviewer also commented that there is no mention of stress corrosion cracking (SCC) and highly recommended a SCC test be conducted and reported.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer agreed that there is clear evidence of close cooperation between Arconic (formerly Alcoa), Magna Cosma, Honda, and ORNL and added that the project seems to be very nicely integrated with a good sharing of the workload all aimed at meeting the project deliverables.

Reviewer 2:
The reviewer affirmed there is strong collaboration on the alloys and processing and that the last stage will address the final testing. The reviewer also added that working with ORNL and TWB Co. as the TWB supplier are strong additions.

Reviewer 3:
The reviewer stated there is a strong team that includes Honda, Magna and ORNL, and that work appears to be well coordinated and the contributions by each partner fairly balanced.

Reviewer 4:
The reviewer stated there is a great project team comprised of material supplier, OEM, tier 1 (supplier), and a DOE national laboratory.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer agreed that the proposed future research is very good to result in a TWB bodyside type component and noted that the plan includes "evaluation" of part. However, the reviewer would like the recipient to define actual tests associated with "evaluation" and $2/lb. saved cost model.

Reviewer 2:

The reviewer stated that the proposed future work is consistent with the goals that need to be achieved but that there are some areas that need to be addressed that are not specifically mentioned in the future work to include running rate simulations, paying particular attention to temperature and throughput. The reviewer inquired about whether a high enough production rate can be sustained to make it economically viable, given all the warm press process sensitivities. The reviewer also commented that strain maps for the pressed parts would be prudent to help optimize the process, adding that this goes to address balancing strength, elongation, and degradation resistance whether by corrosion or other type of cracking.

Reviewer 3:

While the future work address most of the remaining barriers and challenges, this reviewer wanted to see something explicit about characterizing how the processing parameters influenced spring-back.

Reviewer 4:

The reviewer stated that the work needs to include the development of at least one FLD at the preferred warm stamping temperature, probably with something like the Nakajima technique appropriately corrected. The reviewer also stated that the cost-impact of cleaning warm stamped parts with wax-based lubricant needs some attention and asked what role (if any) do stamping speeds (strain rates) impact formability and asked if the warm stamping speed can be increased. The reviewer pointed out that Slide 17 suggests no future work involves the development of material constitutive models for finite element simulations of both the warm stamping process and formed component performance in a vehicle. The reviewer remarked that this is something that Honda should be able to help with and recommended that Arconic consult with Honda and perhaps Magna on these issues (especially as Slide 15 indicates Magna is to help). The reviewer also explained that the literature on low-dynamic testing of 7XXX alloys within nominal strain rate range of 10 -500/s is controversial and asked how is the project going to evaluate the high strain rate performance of the warm-stamped 7055 to provide reassurance that strain rate dependence of the flow properties is not of concern. The reviewer noted that a 2.5-mm initial gauge has been chosen and wondered if the project team needs to upgauge, where is the crossover point at which 7055 Al becomes impractical and the team is right back to PHS for the door ring part. The reviewer concluded that the consideration of the alloy-dependence of the fractures/failures seen at the lower warm stamping temperatures (on Slide 10) needs attention and asked if there are specific microstructural mechanisms that require greater control at the lower warm stamping temperatures.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer stated that warm formed 7000 Al at $2/lb. saved provides significant opportunity to reduce vehicle mass which will result in in fuel reduction and environmental benefit.

Reviewer 2:

The reviewer remarked that high strength Al is critical to reducing mass and thus displacing petroleum.

Reviewer 3:
The reviewer agreed that vehicle mass reduction through judicious selection of component materials supports DOE objectives and added that in this case, warm stamped 7055 Al has a density that is less than PHS.

Reviewer 4:
The reviewer said that it demonstrates the viable use of a high-strength Al alloy that can assist in significantly reducing the weight of a vehicle and improve fuel efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer praised the great mix of OEM, Tier 1 and Tier 2 suppliers, and DOE national laboratory resources.

Reviewer 2:
The reviewer said there are sufficient resources to complete the project.

Reviewer 3:
The reviewer stated the resources appear to be sufficient.

Reviewer 4:
The reviewer remarked that without having access to financial data and the statement of work (e.g., hours needed to accomplish tasks, charge rates, and materials cost), it is difficult to make this assessment accurately and added that there is also no matrix/presentation of data on money spent versus work done to assist.

Presentation Number: lm109
Presentation Title: High-Throughput Combinatorial Development of High-Entropy Alloys for Lightweight Structural Applications
Principal Investigator: Jeroen van Duren (Intermolecular)

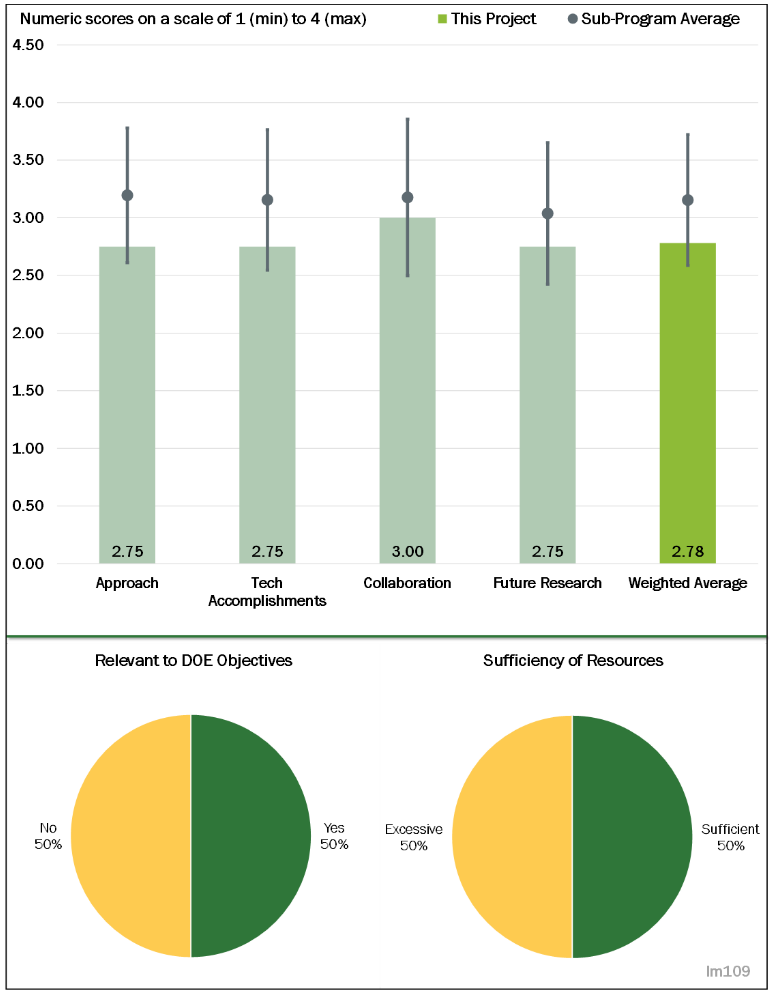

Figure 7-14 - Presentation Number: lm109 Presentation Title: High-Throughput Combinatorial Development of High-Entropy Alloys for Lightweight Structural Applications Principal Investigator: Jeroen van Duren (Intermolecular)

Presenter
Jeroen van Duren, Intermolecular

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer explained that the approach is to overcome technical barriers by demonstrating the viability of low-density, high-entropy alloys as a lightweighting approach for vehicle applications. The reviewer observed that these materials have potential for alloys with greater strength than traditional alloys and design flexibility to address corrosion and processing challenges. The reviewer elaborated that the project is well designed and considers all expects of development including efforts to investigate phase diagram modeling for candidate materials, high-throughput screening and optimization of alloy families, lab-scale bulk studies, single-element substitution studies, manufacturability, scale-up, and material validation. The reviewer concluded that this approach is feasible and should integrate well with other efforts for lightweight metals R&D.

Reviewer 2:
The reviewer commented that the approach is exciting to look at a large unexplored metallurgy space for new alloys and that the stretch objectives are impressive. However, the reviewer remarked that while the approach of combined computational and different experimental studies is interesting, for this investigation there needs to be more experimental effort.

Reviewer 3:
The reviewer stated that the overall approach adopted to perform the work is reasonable, adding that the work is complicated and other ways to do it can always be suggested/found. The reviewer explained that the rating is an acknowledgement of the degree of difficulty rather than a criticism of the approach and that successful completion of all the task laid out will lead to useful results. The reviewer then listed a few concerns.

Regarding the use of thin film to measure some materials properties, materials properties such as hardness from thin films are difficult to correlate to those of bulk properties. For one, thin films do not provide constraints to instruments like indenters like bulk specimens do. Care must therefore be exercised as far as the measurements and the use of the data is concerned.

The validation and acceptance criteria used to screen experimental data (from the databases used during the phenomenological alloy design step) for quality and pedigree, a more robust protocol is required to forestall the use of bad data in simulations and model development.

Finally, only one alloy met desired targets after screening 150 billion possibilities. The reviewer pointed out that this is a risk to success because if this alloy fails to meet all criteria, what is that alternate approach?

Reviewer 4:

The reviewer noted that this project is aimed to study high-entropy alloys with high strength and low cost and that the presentation claims that one alloy was chosen from 150 billion possible combinations. The reviewer suggested it would have been better to have selected a group or family of materials. The reviewer also cautioned that relying on reported results without cross-checking the validity seems to be not prudent and added that while the difficulties of using models in alloy selection is understood by the project team, solutions have not been provided or sought. Finally, noting that the approach has been stopped and an alloy system randomly chosen to evaluate the performance, the reviewer asked what was the rational for the alloy selection.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer observed that the phase diagram work appears to be on track for success and offered that the improvements to the literature data are worth the cost of this project on its own. The reviewer praised this as nice work. The machine learning to find potential alloys uses methods that this reviewer has not seen before. The reviewer wished the team good luck for the rest of the project.

Reviewer 2:

The reviewer stated that significant progress and technical accomplishments have been made with data collection and analysis of a multitude of compounds but that the usefulness of the models used for a wide range of alloys outside of the current high-entropy alloys database requires validation to move forward with optimization and single-element substitution studies. Although performance indicators (milestones) have been met, the reviewer cautioned that the progress in meeting the DOE goals for production materials has yet to be demonstrated and has significant technical and cost challenges that are high risk.

Reviewer 3:

The reviewer commented that the work, in the current format, may not achieve the intended goal and added that the team accepts this conclusion and is trying to seek the best possible system under the current circumstances. The reviewer remarked that development of the modeling procedure to downselect alloy systems is good but could be improved to make the process robust. However, the reviewer cautioned that validating the process need to be done, adding that a reverse engineering approach could be used to validate the current alloy selection process.

Reviewer 4:

The reviewer replied that technical accomplishments are promising but added that a lot of work still has be carried out. The reviewer directed the reader to the future work section for additional comments.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that the clear roles and responsibilities of each team member have added to the success achieved so far and that the team is using the best of each contributor.

Reviewer 2:

The reviewer noted that project collaboration involves a research company, two universities, a tier 1 supplier, and an automobile manufacturer and that the work done to date has been primarily in data analysis and early stage material development. The reviewer also noted that the equipment manufacturer has only been involved as an advisor and there is no indication in the presentation that a high-entropy alloy will be accepted and transitioned to the manufacturer.

Reviewer 3:

The reviewer commented that the bulk of the modeling work seems to have been carried out by one entity. Observed that this work is modeling intensive, the reviewer stated that one wonders if any improvements can be made in the division of labor but regardless, there are clearly defined roles within the collaborative group.

Reviewer 4:

The reviewer said that the project is more fundamental work and the involvement of universities is quite understandable. However, the reviewer also commented that the role of the automotive OEM is not quite explained other than in the technical specification, but that this was already set by DOE even before the proposal submission.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the proposed future work to complete the project appears to address the key open issues for the last six months of the project.

Reviewer 2:

The reviewer agreed that the proposed future research is good but added that it must ensure a robust model validation is carried out after model development is complete, noting that many models fall short when used to predict behavior or outcomes for datasets or specific conditions not used in their development. The reviewer added that a clear and technically sound protocol for model validation needs to be developed.

Reviewer 3:

The reviewer commented that the project has demonstrated a well-planned and logical approach to performing data analysis and material property characterization but that the challenges and barriers have not been resolved. The reviewer also remarked that the future work presented to explore more novel microstructure for low-density, high-entropy alloys (a reversal from high-density high-entropy alloys) and focus less on face center cubic and body center cubic 4/5-element designs seems to mark a total change in direction that has high risks as an alternate development pathway. The reviewer added that future efforts to populate and experimentally validate these alloys in the current database would be worthwhile if there is a material that successfully meets DOE goals developed in conjunction with the database.

Reviewer 4:

The reviewer stated that given the inability of current databases and published literature to develop models for alloy selection, more effort needs to be focused on these areas and remarked that developing randomly chosen alloys is not a useful process as it will only provide random datasets.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that this is a great example of a project to look "outside the box" for lightweight materials for automotive applications.

Reviewer 2:
If the work is successful, the reviewer commented, the approach and models developed will be a powerful tool(s) for the development of lightweight alloys that would impact fuel efficiency in vehicles.

Reviewer 3:
The reviewer reflected that this is a long-range project and the fuel savings may not be immediate.

Reviewer 4:
The reviewer replied no, elaborating that although the stated barriers and objectives of this project addresses the overall DOE objectives of petroleum displacement by fuel efficiency of lightweight vehicles, there has been no result or product from this project that can meet the DOE objectives. The reviewer clarified that while there is a lot of good materials science in this project, it lacks a technology that will solve the problem of developing a lightweight material to replace currently used lightweight materials in the automotive industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer replied that sufficient resources are available to complete the project.

Reviewer 2:
The reviewer remarked that without having access to financial data and the statement of work (e.g., hours needed to accomplish tasks, charge rates, and materials cost), it is difficult to make this assessment accurately and added that there is also no matrix/presentation of data on money spent versus work done to assist.

Reviewer 3:
The reviewer commented that the work plan does not seem to justify the high cost of the proposal.

Reviewer 4:
The reviewer observed that for a $3 million investment with high DOE cost share over 3-year period and milestones that are primarily studies, the costs seem to be rather high for the results produced which are primarily academic research that has no near- or mid-term solution to challenges identified by DOE.

Presentation Number: lm110
Presentation Title: *In-Situ* Investigation of Microstructural Evolution During Solidification and Heat Treatment in a Die-Cast Magnesium Alloy
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

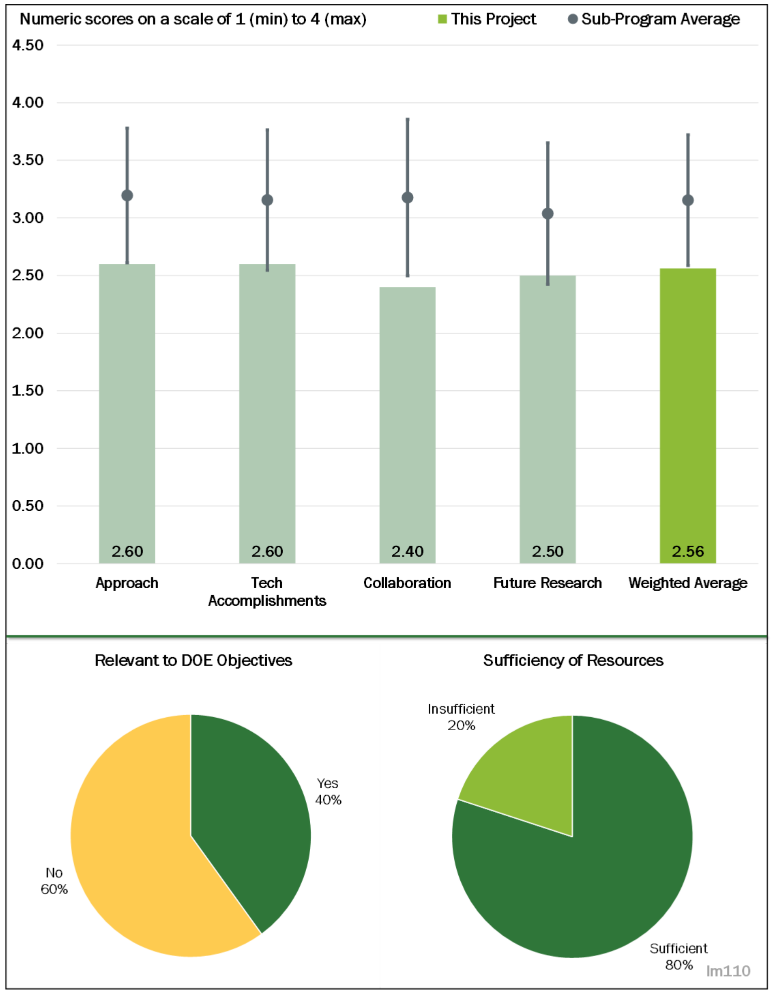

Figure 7-15 - Presentation Number: lm110 Presentation Title: *In-Situ* Investigation of Microstructural Evolution During Solidification and Heat Treatment in a Die-Cast Magnesium Alloy Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the project is interesting but it does not directionally further the development of Mg alloys by solving two fundamental issues (corrosion and ductility).

Reviewer 2:

The reviewer commented that the overall approach adopted to perform this work is reasonable, adding that the work is complicated and other ways can always be suggested or found. The reviewer rating is an acknowledgement of the degree of difficulty of the work rather than a criticism of the approach. The reviewer expressed some concerns. Firstly, the use of deposited thin films for this work since deposited thin films do not usually mimic bulk materials properties and so correlation of results from thin films (to bulk material properties) might therefore be difficult. Secondly, this reviewer noted a lack of temperature measurement data, which means cooling rate assessments will be affected.

Reviewer 3:

This reviewer noted that this project was redirected late in the performance period to do atomistic modeling to provide adequate predictive tools that will enable the low-cost manufacturing of lightweight structures. The reviewer pointed out that the challenge is to provide data on the microstructural evolution during solidification at high cooling rates which is not available to validate existing models. While agreeing that the approach presented to achieving project objectives is well-designed and feasible if the instrument challenge to studying the cooling rates can be overcome, the reviewer cautioned that if this challenge cannot be overcome, then there will remain an inability to measure rapidly changing temperatures of the material sample.

Reviewer 4:
The reviewer stated that the approach of mixed experimental and modeling to understand the solidification is reasonable but added that the potential tools to be developed are only of marginal value to the automotive lightweighting community.

Reviewer 5:
The reviewer asked how the atomistic calculations are connected with the experiments in this project. The reviewer commented that the dynamic transmission electron microscope (DTEM) experiment looks really interesting but will apparently not be available for this project and asked how ESI uses the atomistic simulation results. The reviewer further remarked that it is debatable as to whether the atomistic simulations are really modeling microstructural evolution. While this reviewer appreciates the complexities associated with kinetics modeling, how was microstructure accounted for above the realm of a few hundred, thousand, or tens-of-thousands of atoms regime. The reviewer also asked how the atomistic simulations are connected with the cellular automata mentioned on Slide 8. The reviewer is struggling to understand how all of the pieces of this project fit together to meet the DOE-required deliverables. The reviewer asked what is being done with all of the data (experimental and computational) generated in this project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer agreed that the project deliverables were met so the accomplishments are good, adding that the shift due to the equipment delays was reasonably good. The reviewer remarked that the technique desired for the project was great for in-situ solidification and the current period accomplishments that are on atomistic modeling also helps inform the solidification in high-pressure die cast (HPDC) Mg. The reviewer characterized this as a good recovery.

Reviewer 2:
The reviewer stated that *in situ* solidification modeling is an interesting topic and the atomistic modeling could help, but only if directed at solving the key issues with Mg, namely, corrosion and ductility.

Reviewer 3:
The reviewer responded that the major technical accomplishment is the development of the Atomistic-Kinetic Simulations of Microstructural Evolution self-learning simulation tool while others accomplishments include the study of Al and Mg vacancy exchange and how Al diffuses through Mg. However, the reviewer is finding it difficult to assess the impact of these findings on how they will directly affect the cost of Mg and its wider use in the automotive industry.

Reviewer 4:
The reviewer observed that the technical accomplishments presented were scientific only and focused on the effects of vacancies that affect atomistic diffusion in Mg. Furthermore, the only accomplishments presented were ProCAST calibration parameters for secondary dendrite arm spacing; grain-size in AZ91 was determined; and a methodology was developed that can be applied broadly to hexagonal close packed systems for more rigorous and accurate calculation of solute diffusivity. The reviewer pointed out that these are academic and do not demonstrate progress toward directly meeting any DOE goals and surmised that this might be due to the fact that the project was redirected late in the schedule.

Reviewer 5:
Without experimental data for comparison, the reviewer found it difficult to judge how accurate the computational results are and added that development of the DTEM would really have helped this project. The reviewer concluded that the project seems to be struggling somewhat.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that collaboration with ESI appears to have been successful and that the efforts on the thermal modeling and ProCAST looks reasonable. The reviewer added that the small project team limited collaboration but eased project planning.

Reviewer 2:
The reviewer noted that there was only one company presented for collaboration and that appears to be a subcontractor who was funded to do modeling studies.

Reviewer 3:
The reviewer remarked that an industrial partner, a supplier, or OEM, could provide technical input and direction to the team and set it on a path of relevance

Reviewer 4:
The reviewer replied that it is not clear what specifically ESI is doing or how PNNL work is coupled with the ESI work. For example, the reviewer asked if these are two separate projects altogether.

Reviewer 5:
The reviewer observed that there is only one partner in this work and that partner is a sub-contractor, but added that it is clear this partner contributed to the modeling effort. However, the reviewer stated it is difficult to gauge how much work was carried out by PNNL and how much was carried out by ESI.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer replied that since little time is left, future work should address the remaining deliverables.

Reviewer 2:
The reviewer remarked that atomistic modeling is a good field and suggested a concentration on basal plane pinning as a mechanism to improve shear strength and ductility.

Reviewer 3:
The reviewer stated that there is no proposed technical work except for preparing a manuscript, presumably for publication. At a minimum, this reviewer would have liked to have seen some model validation work with data not collected from this work.

Reviewer 4:
Other than publishing a paper, the reviewer asked what is to be done with the data to suggest (for example) new alloys and who is going to use the data to make a new material that is better than the existing casting materials. The reviewer said it is not clear if there will be any substantive legacy to this project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied yes.

Reviewer 2:
The reviewer said that Mg and Mg alloys still have the potential to deliver weight savings.

Reviewer 3:
The reviewer stated that while Mg is one of the lightweight alloys available for lightweighting automotive structures, this project only marginally helps with Mg casting. The reviewer noted that the limited use of Mg in autos is not directly dependent on the casting models and that corrosion and joining are much larger hurdles limiting the use of Mg.

Reviewer 4:
The reviewer remarked that this project was a study of atomistic effects and modeling of in-situ melting and solidification of Mg and so there is no direct relationship to DOE objectives for petroleum displacement.

Reviewer 5:
The reviewer is not clear about how the model developed will improve the price of Mg/Mg alloys for automotive use. From a technical point of view, the reviewer elaborated, it is unclear how the solidification and diffusion data, as well as the predictive model derived from this work, will be favorably applied to solve solidification and diffusion issues in Mg and Mg Alloy processing, and how that will impact processing/price of the material. The reviewer added that how these tools predict microstructure accurately is also not clear from the presentation. The reviewer also cautioned that the way the results are presented does not lend itself to an easy understanding of the extent to which the current work has contributed to the closure of this knowledge gap, adding that no inferences are drawn between the current results and how much the knowledge gained improves our understanding about how to solve the challenges identified. The reviewer said it is therefore difficult to gauge how far along the work moves us to the solution of the challenge(s) and wondered how these data would be used by sheet metal or die casting manufacturers to solve the challenge, and would these data result in the cost saving sought. The answers to these questions are conspicuously missing, the reviewer concluded but added that perhaps all these will be clear in the paper.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer replied that the amount of funding is adequate for the amount of research performed over a four-year period.

Reviewer 2:
The reviewer stated that the resources are sufficient to complete this project.

Reviewer 3:
The reviewer commented that the project is 90% complete and there is no reason to believe funds will be insufficient to write a paper. The reviewer added that there are no data on remaining funds, so it is impossible to judge whether the remaining funds, if any, are excessive.

Reviewer 4:
The reviewer remarked that it seems that this project is suffering a bit from the resource standpoint and that it is unclear what ESI is doing and how the work is coupled with PNNL. The reviewer wondered whether additional resources would have helped solve the problems with the DTEM.

Reviewer 5:
This reviewer would not fund this area beyond the conclusion of the project.

Presentation Number: lm111
Presentation Title: Phase Transformation Kinetics and Alloy Microsegregation in High-Pressure Die Cast Magnesium Alloys
Principal Investigator: John Allison (University of Michigan)

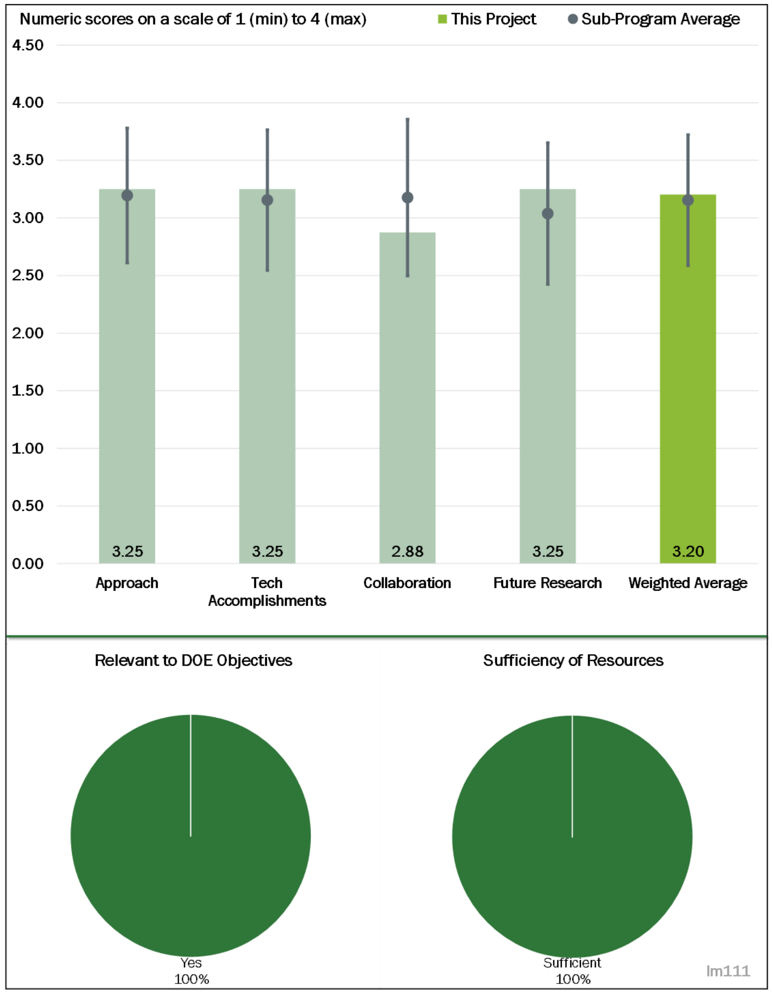

Figure 7-16 - Presentation Number: lm111 Presentation Title: Phase Transformation Kinetics and Alloy Microsegregation in High-Pressure Die Cast Magnesium Alloys Principal Investigator: John Allison (University of Michigan)

Presenter

John Allison, University of Michigan

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised the solid approach to an essential problem (understanding phase transformation and segregation behavior during solidification) in advancing development and processing of Mg alloys. The reviewer had no real concerns and saw no obvious weaknesses within the context of the objectives and funding levels.

Reviewer 2:

The reviewer remarked that the approach as detailed on Slide 5 is comprehensive and covers key topics/tasks that will lead to the required deliverables and that providing the missing data in the plot at the upper right of Slide 8 is a very valuable contribution. The reviewer also stated that the ICME approach of Slide 18 is sound and certainly very interesting. One question the reviewer had pertains to whether or not the ICME approach can lead to a new cast alloy with improved properties once the database has been suitably populated. Otherwise, the reviewer asked if the ICME approach will always depend upon an existing material.

Reviewer 3:

The reviewer stated that the overall approach adopted to perform this work is reasonable, adding that the work is complicated and other ways can always be suggested or found. The reviewer’s rating is an acknowledgement of the degree of difficulty of the work rather than a criticism of the approach.

Reviewer 4:

The reviewer observed that the micro and macro segregation in Mg castings was estimated and measured and remarked that the impact of rapid solidification during die casting is a serious problem and the segregation is not fully explained. The reviewer added that this work is planned well with experiments complementing the modeling and thermodynamic calculations.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the excellent progress with many interesting and useful results. The only lingering question the reviewer had is how others will use the data (or if they will use the data) to improve existing casting processes.

Reviewer 2:
The reviewer remarked that the technical progress made includes HPDC simulation, phase quantification, and certain materials characterization including grain distribution and electron probe micro-analyzer (EPMA) analysis of micro-segregation. However, the reviewer further remarked that a bit of work needs to be done to conclude the project including completing the micro-segregation and phase transformation characterization and development of the models to predict microstructural evolution during heat treatment. The reviewer added that these are very important aspects of the work, without which value would not be realized.

Reviewer 3:
The reviewer stated that making such a dataset publicly available is extremely valuable to elevating the future development of improved Mg alloys. The reviewer elaborated that trends in many of the micro-segregation results (such as location dependent segregation) are anticipated from general solidification theory, but the quantification and modeling of such effects for this class of alloys is of great value and will accelerate future development. Having partition coefficients defined and models validated via EPMA analysis is particularly valuable, the reviewer added, as is definition of the limits of the Scheil approach during rapid solidification. However, the reviewer remarked that it was somewhat disappointing to see that there were no remaining challenges and barriers (one always hopes that the work is difficult or novel enough that such issues are always present) with 18 months remaining in the project, but the experience and skill of the PI and the limited scope of the effort make this almost understandable.

Reviewer 4:
There reviewer commented that there are many obstacles to the process of alloy optimization for Mg die casting alloys, adding that one of the is the segregation of alloying elements during the rapid cooling and noted that effect of heat treatment on the composition is less understood. The reviewer observed that this work is trying to solve these particular problems encountered during solidification. The reviewer also observed that there are other issues encountered during fluid flow and pressurization contributes to the complex issue but were not evaluated as part of the work. The reviewer cited as an example the formation of externally solidified crystals, which is controlled by the temperatures, alloy composition, and flow time which, in turn, affect the final segregation pattern and said that this may need to be evaluated in the future.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer responded that close collaboration between Ford and the University of Michigan is evident.

Reviewer 2:
The reviewer commented that only one industrial partner involved is in this project but that the level of cooperation is significant with the industrial partner making castings and providing commercial software for the work.

Reviewer 3:
The reviewer stated that this work is being carried out in partnership with Ford Motor Company, which provided the super vacuum die casting plate casting. The reviewer added that most of the modeling work seems to have been carried out at the University of Michigan.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer agreed that the proposed future work to complete this effort and transfer the knowledge to the research community through the National Institute of Standards and Technology is high value and a good investment by DOE.

Reviewer 2:
The reviewer stated that the proposed future research appears to be relevant to the project deliverables.

Reviewer 3:
The reviewer replied that the work being proposed, if successfully completed, will yield useful results. However, the reviewer would like to see model validation included in the future work and the model should be validated with data not used to develop the model in order to ensure the model will not breakdown when used to predict results from other tests or other datasets. The reviewer elaborated that at present, cooling rate measurements are not possible but instead predicted. The reviewer would like to see a better grasp on how to more accurately determine/control the cooling rates. Right now, they are predicted to be between 100 and 300ºC/s.

Reviewer 4:
The reviewer stated that the last year of the work is trying resolve some of the unanswered questions, as well as ensure effective knowledge transfer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied that increased lightweighting, via increased, effective use of Mg, will accelerate petroleum displacement and that the type of work being conducted in this study is foundational to enabling the industrial materials community to advance design and manufacturing of Mg alloys.

Reviewer 2:
The reviewer responded that Mg can contribute to the weight saving of vehicles and added that it is known that lightweighting reduces fuel consumption and greenhouse gas (GHG) emissions. In case electric vehicles, the reviewer concluded, lightweighting can improve the range of operation.

Reviewer 3:
The reviewer replied yes.

Reviewer 4:
The reviewer agreed but said that the way the results are presented does not lend itself to an easy understanding of the extent to which the current work has contributed to the closure of this knowledge gap. In addition, the reviewer said no inferences are drawn between the current results and how much the knowledge gained improves our understanding about how to solve the challenges identified. The reviewer said that it is therefore difficult to gauge how far along the work moves us to the solution of the challenge(s) and asked how would these data be used by sheet metal or die casting manufacturers to solve the challenge, and would these data result in the cost saving sought. The reviewer said that the answers to these questions are conspicuously missing.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer responded that the resources are sufficient.

Reviewer 2:
The reviewer replied that there is $132,000 in FY 2017 (which ends Sept, 30, 2017), but there appears to be no funding at all for FY 2018 (October 1, 2017 to September 30, 2018) yet the stated end of project is October 2018, which is FY 2019. The reviewer added that the work is 80% complete, but the lack of funding to FY 2018 is hard to understand unless a no cost extension has been granted.

Reviewer 3:
The reviewer had no comments.

Presentation Number: lm112
Presentation Title: Cost-Effective Magnesium Extrusion
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

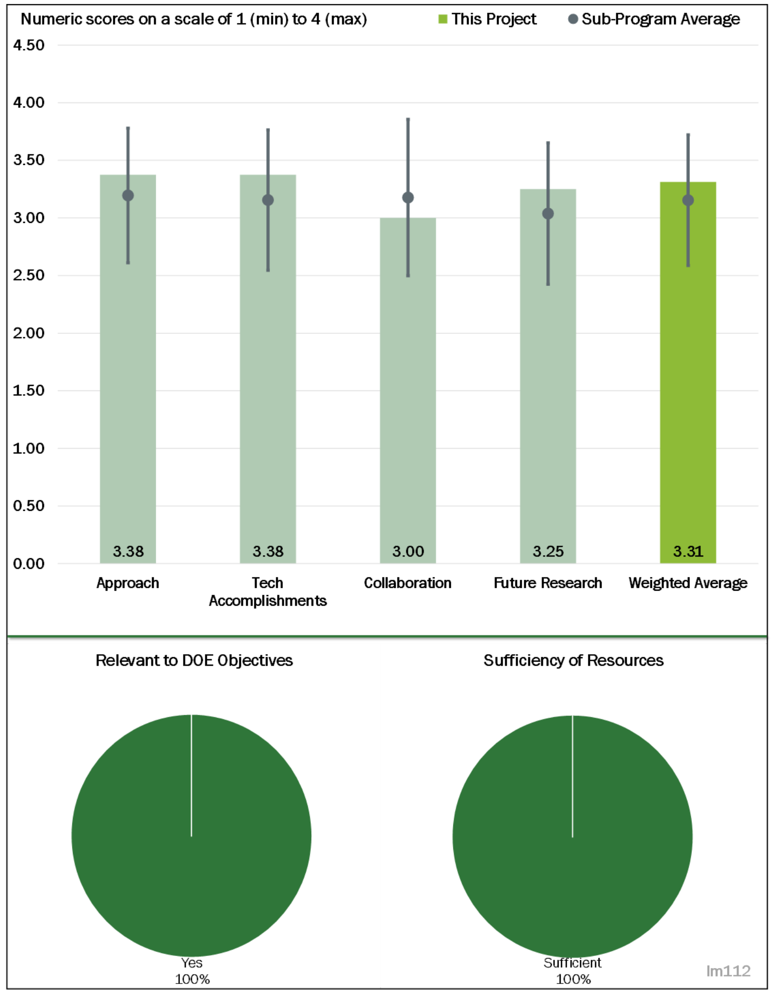

Figure 7-17 - Presentation Number: lm112 Presentation Title: Cost-Effective Magnesium Extrusion Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter

Vineet Joshi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said the approach for this project addresses the technical barriers for use of Mg alloys in automotive applications limited by strength, ductility, and energy adsorption. The reviewer characterized the project as well-designed and one that will provide feasible results for first-order modeling and detailed thermal simulations; extrusion system development; materials characterization and model validation; scale-up of a mature extrusion process; design and integration of a bridge die for direct extrusion of a Mg alloy; and development of process parameters for Mg extrusion using the bridge die. The reviewer added that this approach integrates well with other efforts to increase lightweight metals such as Mg into automotive applications.

Reviewer 2:

The reviewer commented that this is an experiment-based project in which the back extrusion of Mg billet using the basic principle of FSW is being evaluated. The reviewer noted that the friction during the process increases the temperature, possibly to the semi-solid region, which makes the flow easier and reduces the force required. The reviewer concluded the experiment is planned and executed well.

Reviewer 3:

The reviewer stated that the approach is quite unique considering microstructure changes in Mg but would like to see if mechanical properties get affected due to the new extrusion process.

Reviewer 4:

The reviewer said there are not many applications for Mg tube extrusions, but if it is continuous and cost effective, a replacement for an instrument panel beam is possible.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer replied that the technical accomplishments and progress for this project has demonstrated significant contribution to the DOE goals for using lightweight metals such as Mg in automobile components. The reviewer found that all performance indicators (milestones) were met with exception for one delay due to equipment procurement lead time. The reviewer praised the outstanding progress made in the use of shear-assisted processing and extrusion technology to manufacture Mg tubing that can be made in production quantities with up to 50% increase in elongation compared to conventional extrusion processes.

Reviewer 2:
The reviewer praised the approach as sound and well thought out, adding that it really looks like the team is operating in the SSF temperature range and thus the lower pressure and unique microstructure that does look promising.

Reviewer 3:
The reviewer commented that this is a patented process and the technical development in the year of review is the finding on the importance of flutes in the tool surface. The reviewer added that this geometry makes the process easier in certain cases although the reason for the process improvement is not fully explained yet. The reviewer concluded that use of alloys without rare earth (RE) elements is a good development as this reduces the dependency on foreign supply.

Reviewer 4:
The reviewer said that the accomplishments are quite reasonable.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer responded there was a good mix of national laboratory and industrial partners.

Reviewer 2:
The reviewer observed that project collaboration included a national laboratory and performing partners from a university, a tool fabricator, and a tier 1 supplier, adding that each provided a significant contribution to the project objectives. While no automobile manufacturers were involved as a direct collaborator, the reviewer noted the tier 1 supplier was in routine contact with manufacturers.

Reviewer 3:
The reviewer stated that the tier 1 supplier is involved by providing specifications and time for in-kind contribution while the academic partner is involved in characterization efforts. Basically, the reviewer said, this project is a development of PNNL, which applied for IP protection.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer affirmed that the future efforts for completion of this project are effectively planned in a logical progression with appropriate decision points and considerations for overcoming potential barriers to transitioning the technology to industry. The reviewer added that risks are minimal based on progress to date and no alternative development pathway is needed. The reviewer explained that future efforts involve

production of several feet of tubing (pre-production levels) of Mg tubing; identification of the parameters for extruding Mg under steady-state conditions; extruding at rates relevant to industry; demonstration of system repeatability and robustness; and development of extrusion parameters to create desired grain size and texture to maintain physical properties. The reviewer remarked that all of these efforts are designed to transition the technology to industry.

Reviewer 2:
The reviewer agreed that proposed future research connects the ongoing work. The reviewer would be interested to see results next year.

Reviewer 3:
The reviewer observed that scaling up is the next phase and procurement of equipment is in the plan with installation and production of larger quantity of tubes the focus for next year.

Reviewer 4:
While seeing limited applicability, this reviewer replied yes to a recommendation for future funding in order to explore the R&D.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
This reviewer stated that the project is focused on producing Mg components using a novel extrusion process, and since Mg is a leading lightweight material used in automobile parts, this project definitely supports the DOE objectives to reduce U.S. dependency on petroleum through application of lightweight materials in automobile design.

Reviewer 2:
The reviewer observed that Mg can contribute to the weight saving of vehicles and added that it is known that lightweighting reduces fuel consumption and GHG emissions. In case electric vehicles, the reviewer stated that light weighting can improve the range of operation.

Reviewer 3:
The reviewer commented that while there is limited potential for Mg extruded tube, it would still deliver weight savings. The reviewer added that percent elongation looks promising.

Reviewer 4:
The reviewer was unsure of the most relevant application to displace petroleum.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer agreed that funding of $1.2 million and personnel from four organizations involved in the execution of this project is sufficient to meet the project goals and DOE objectives to overcome the barriers and challenges for using Mg in automotive applications. The reviewer concluded that all milestones have been met to date with the exception of an equipment procurement delay and future milestones are on target.

Reviewer 2:
The reviewer answered that funding is appropriate.

Reviewer 3:
The reviewer had no comments.

Presentation Number: lm113
Presentation Title: Magnesium Corrosion Characterization and Prevention
Principal Investigator: Mike Brady (Oak Ridge National Laboratory)

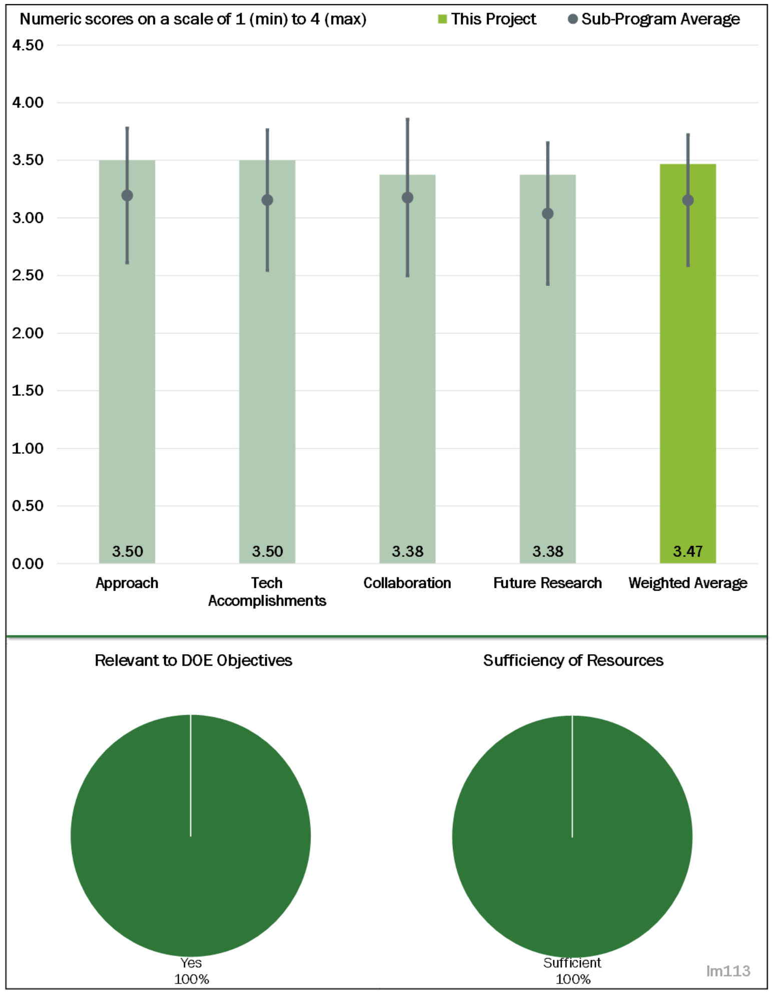

Figure 7-18 - Presentation Number: lm113 Presentation Title: Magnesium Corrosion Characterization and Prevention Principal Investigator: Mike Brady (Oak Ridge National Laboratory)

Presenter
Donovan Leonard, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer explained that the project uses a four-pronged approach to study Mg corrosion phenomena to include assessing the impact of other metallics and secondary phases on aqueous corrosion/film formation and hydrogen and oxygen uptake; focus on two key phenomena of unexpected rapid hydrogen ingress into Mg alloys; and establishment of substrate alloying segregation tendencies on state-of-the-art electro-ceramic coatings. The reviewer commented that the experiments are well designed and the project has a feasible approach to completing investigations for Mg corrosion characterization that will provide corrosion-resistant Mg alloys that can be used in production, performance, maintenance, repair, and recycling of Mg components.

Reviewer 2:
The reviewer replied that it is very interesting to see the characterization techniques used in this manner and that the new techniques will help with future research into this area. The reviewer added that this is a great addition to the research community in overcoming Mg challenges.

Reviewer 3:
Thee reviewer observed that the role of hydrogen in the corrosion of Mg is investigated and commented the experimental plan is good and executed very well. Noting that the experiments were conducted for four hours, the reviewer said that longer exposures would have revealed more information.

Reviewer 4:
The reviewer replied that the project is using some state-of-the art experimental tools to explore corrosion in Mg and that the work is certainly sound and there are some interesting results coming out of the work with

much data. In the end, however, the reviewer wondered how all of the great data coming out of this project are going to be used to design future Mg alloys that are more corrosion resistant.

The reviewer also asked why is there no substantive component of this project that delves to one extent or another into these questions. The reviewer further wondered what the reason is for the hydrogen/deuterium (H/D) ingress into alloys with zirconium (Zr). The reviewer urged that this be addressed as soon as possible, asking if this a fundamental property of the group-4 metals. The reviewer surmised that this is evidently it is not a function of grain size and wondered if this some type of precipitate Zn_2Zr_3-induced field that enhances diffusion (such as dislocations attracting solutes in Al-Mg alloys because of the enthalpy).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer replied that good progress has been made in meeting the performance indicators (milestones) which are fundamental studies of Mg corrosion that has resulted in two technical papers over the past year. The reviewer agreed that significant technical accomplishments have been achieved in developing an understanding of Mg corrosion through application of multiple new characterization approaches; identifying rapid hydrogen uptake in Mg alloys after short-term aqueous exposure; discovering significant implications for SCC and fundamental corrosion mechanisms; and establishing the relation of corrosion to alloy composition and nanostructure to provide a basis for corrosion-resistant designs. The reviewer offered that all of these will contribute to the success of using Mg as a lightweight material in automobile components that will meet DOE goals for lightweight materials development. The reviewer added, though, that more research is needed in coating effects.

Reviewer 2:

The reviewer said that accomplishments with the various experimental approaches are very impressive. The reviewer would like to see how all of the data can be used to suggest improvements to Mg alloys designs for corrosion resistance and need to find out why the Zr-enhanced H/D ingress. The reviewer wondered if this also occurs with the relevant RE elements, e.g., cerium, neodymium, europium (Eu), erbium, etc.

Reviewer 3:

The reviewer stated that it was very interesting to see the results of the deuterium penetration study.

Reviewer 4:

The reviewer replied that the measurement of hydrogen in Mg using various techniques was useful and that efforts to crosscheck the results from one investigation using other techniques is commendable. The reviewer added that the role of Zr and other RE elements on hydrogen diffusion in Mg need to be examined further.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer described excellent international academic team investigating a fundamental work, adding that the team is good. The reviewer also said the role of industrial partners in supplying raw materials and coatings for the work is commendable. The reviewer said that the role of the auto tier 1 supplier is not well defined but shows its interest in the subject.

Reviewer 2:

The reviewer lightheartedly asked who is not involved with this project, noting that everything seems to be covered and everyone has their own expertise for every aspect of this project. The reviewer characterized the collaboration as very good.

Reviewer 3:

The reviewer affirmed that overall, collaboration is excellent within the performing organization, elaborating that since this project address fundamental research in Mg corrosion, the primary collaboration and coordination is with researchers within the performing organization with some outside collaboration involving four universities and two tier 1 suppliers of Mg and coating materials while a second tier 1 supplier is used for technical input. The reviewer noted that no equipment manufacturers are involved but this is not a major concern at this stage of the research.

Reviewer 4:

Noting that the collaborators are listed on Slide 19, this reviewer has the impression that the vast majority of the work is being done at ORNL and asked if this is in fact the case. The reviewer said it would have been helpful if throughout the presentation the various collaborators' contributions were called out instead only of listing them at the end (which, the reviewer noted, is required by DOE).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that future efforts within the time remaining for this project involve primarily the continuation of studies on hydrogen uptake by Mg but that some work will begin on understanding coating effects on Mg substrates. The reviewer added that these efforts appear to be effectively planned in a logical manner with appropriate decision points in the project schedule. The reviewer identified no risks and concluded that no alternate development pathways are necessary for these studies beyond what is already planned.

Reviewer 2:

The reviewer said it will be interesting to see the results of the coatings and that the H/D uptake phenomena relative to film formation study will help researchers with the next level of needed research into this topic.

Reviewer 3:

The reviewer said that information on the role of coating to prevent hydrogen intake is necessary but the effect of hydrogen in the Mg need to be studied further. The reviewer remarked that while the statement that only four hours are necessary for hydrogen infusion into Mg sounds ominous, many Mg components are being used in real life and exposed to humidity and other sources of water. The corrosion of these components is not catastrophic, the reviewer stated, and the significance of this finding need to be explained more clearly.

Reviewer 4:

The reviewer remarked that the proposed future work is interesting, and asked what is to be done with all of the data, and who is going to steer the data to the appropriate groups focused on developing more corrosion-resistant Mg alloys. The reviewer concluded that it seems that there is a lot of great scientific work going on in this project but its applicability/relevance to commercial alloys is questionable.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

This reviewer agreed that the project supports the overall DOE objective of using lightweight materials such as Mg for reducing the weight of future automobiles and therefore reducing the U.S. dependency on petroleum. By solving the problems with Mg corrosion through a better understanding of corrosion phenomena, the reviewer elaborated, the automotive industry is more likely to consider Mg in future vehicle designs.

Reviewer 2:

The reviewer commented that understanding corrosion effects on Mg will accelerate its adoption into the automotive world and that once these effects are known, mitigation strategies can start to be developed.

Reviewer 3:

The reviewer said the role of Mg in reducing the weight of vehicles could be significant (more than 30%) and that weight reduction can help to reduce fuel consumption and GHG emissions while also helping to improve the range in electric vehicles.

Reviewer 4:

The reviewer replied yes, Mg is a light weight metallic material being looked at for vehicle mass reduction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer characterized resources, both experimental and personnel, as outstanding.

Reviewer 2:

The reviewer stated that every one of the collaborators is playing an important role in fulfilling the entire scope of this project and that everything is on track for completion as expected.

Reviewer 3:

The reviewer agreed that funding is sufficient to support the number of researchers involved in the project for the three-year performance period providing FY 2018 funds are available and that all future milestones are anticipated to be met if funded at the projected levels.

Reviewer 4:

The reviewer had no comments.

Presentation Number: lm114
Presentation Title: Friction Stir Scribe Joining of Carbon Fiber Reinforced Polymer to Aluminum
Principal Investigator: Blair Carlson (General Motors)

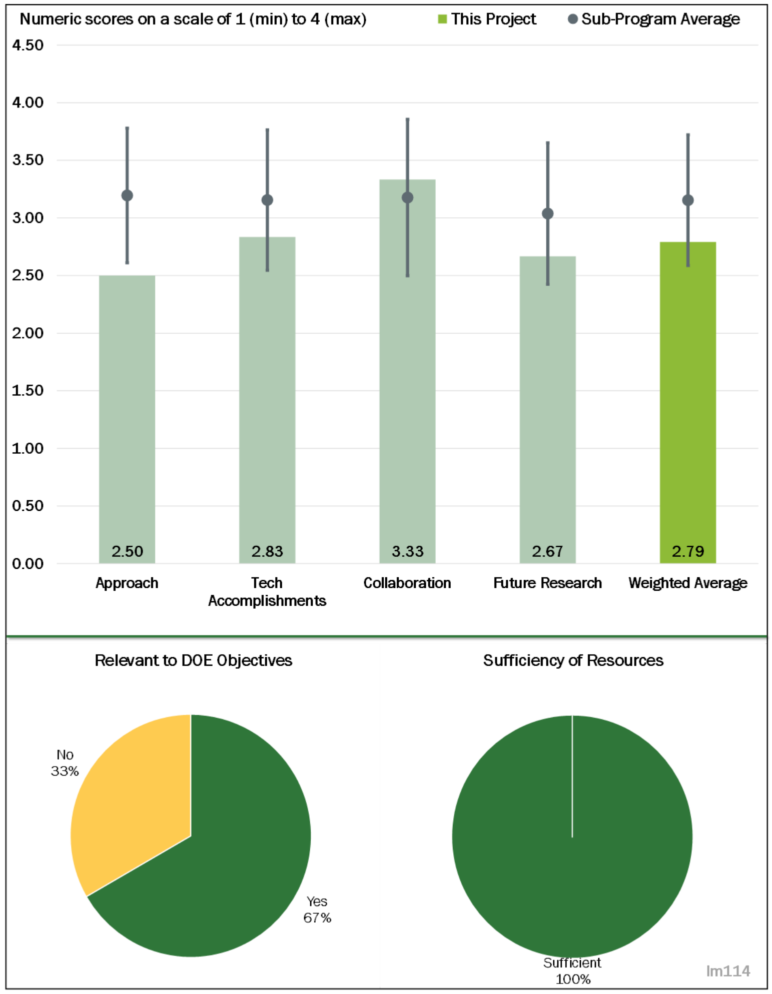

Figure 7-19 - Presentation Number: lm114 Presentation Title: Friction Stir Scribe Joining of Carbon Fiber Reinforced Polymer to Aluminum Principal Investigator: Blair Carlson (General Motors)

Presenter
Blair Carlson, General Motors

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that the project seeks to develop joining technique for Al and CFRP using mechanical/metallurgical bonding, adding that the procedure is routine process development

Reviewer 2:
The reviewer identified the main weakness as the lack of sufficient go/no-go points, observing that the only go decision is based on strength while an important factor such as corrosion is omitted from the go/no-go decision.

Reviewer 3:
The reviewer said that joining CF composites to Al is technically very challenging and commented that the proposed research is high-risk.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the project as having made excellent progress in trying to make strong joints, but noted that the joint strength is still very low, indeed, considerably below the project target.

Reviewer 2:
The reviewer said that very good progress has been obtained on tool design and process optimization but the fact that corrosion has not been evaluated early in the project is a significant concern. The reviewer elaborated that if it were evaluated, the project could have identified this technical challenge early so that the materials design could have been optimized or planned for the future.

Reviewer 3:
The reviewer remarked that the finding of degradation of fibers after mechanical stirring is expected and the resultant loss in strength is predictable but this has not been foreseen by the project team nor was it modeled. The reviewer added that no other significant findings are reported.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the outstanding collaboration with suppliers and universities, as well as the very efficient team work.

Reviewer 2:
The reviewer stated that all partners seem to be contributing.

Reviewer 3:
The reviewer remarked that the team has good integration and the tasks are well defined. The reviewer also noted that other similar projects are ongoing with the team members making this a subset of those other projects.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer replied that reversing the joining sequence (from Al to composite) should be systematically tried as this potentially can be a good solution.

Reviewer 2:
The reviewer said it should be underlined that by not having identified the issue of corrosion early on in the project, the future work does not have an effective solution to this problem. The reviewer added that with a major materials problem at hand, some of the prototyping activities can be in vain.

Reviewer 3:
The reviewer commented that the joints did not meet the property requirements in the first phase and that this is due to the fact that one of the materials in the joint degraded during thermo-mechanical processing. The reviewer warned that this will be the result of any future processing and the future proposal does not offer any resolution.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer praised this as an excellent first step to using Al with fiber composites which can revolutionize lightweight vehicle construction. Through lightweighting, the reviewer added, it can help minimize gasoline use and enable the effective construction of electric vehicles.

Reviewer 2:
The reviewer said it is enabling vehicle lightweighting.

Reviewer 3:
The reviewer remarked that use of lightweight materials such as CFRP and Al will always result in improved fuel efficiency but warned that the focus of the current research as planned will not result directly on fuel savings.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer replied that budget and resources are adequate and it is also to be commended that useful budget details were included in the presentation.

Reviewer 2:
The reviewer stated it seems to be on budget and on time.

Reviewer 3:
The reviewer remarked that this project appears to be a subtask of other similar projects.

Presentation Number: lm115
Presentation Title: Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites
Principal Investigator: Dave Warren (Oak Ridge National Laboratory)

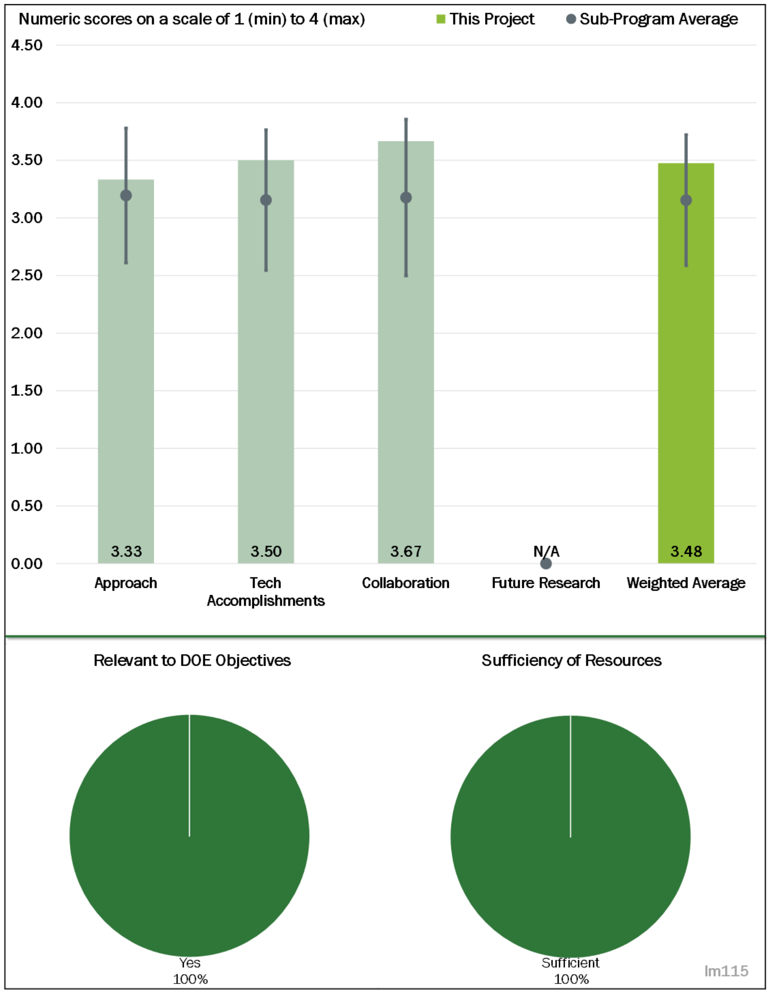

Figure 7-20 - Presentation Number: lm115 Presentation Title: Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites Principal Investigator: Dave Warren (Oak Ridge National Laboratory)

Presenter

Dave Warren, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised the excellent progress made in accomplishing the planned tasks for the project.

Reviewer 2:

The reviewer attested that a good methodology and work plan was established and followed.

Reviewer 3:

The reviewer replied that the approach to work performed was thoughtful and comprehensive and agreed that the choice of complex parts and the stage gate (go/no-go) approach was appropriate for the work being undertaken. The reviewer added that the techniques developed to evaluate specimens using ellipsoidal filament cross-sections very innovative. The reviewer would have appreciated (but acknowledged that a limited budget may have precluded) a more robust theoretical foundation regarding flow orientation and resulting fiber orientation, as well as effects of screw design on fiber loading levels and resulting fiber length. The reviewer remarked that insight and development of analytical or physical models would help improve predictions and design of final part.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the excellent progress during the last performance year and is very pleased to see the predictions are very close to experimental results for the fiber orientation and length.

Reviewer 2:

The reviewer affirmed that the project accomplished what it had set out with well-presented results and explicit recommendations. The reviewer remarked, though, that the costing exercise would have been more valuable with some discussion and insight into the added value of the applications chosen (i.e., beyond weight savings, does extended fatigue or corrosion resistance bring additional consumer value or aid assembly through part reduction, etc.).

Reviewer 3:

The reviewer observed that it appeared project team faced challenges with development of appropriate fiber length attrition models and screw design and added that integration issues between process and structure relationships require further attention.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer praised the well-balanced teams with excellent collaboration between them.

Reviewer 2:

The reviewer said there was good collaboration with other industry/academia partners.

Reviewer 3:

The reviewer agreed there was a strong collaborative research effort between public, private, and academic stakeholders, remarking that the national laboratory drew upon resources and expertise in a particularly meaningful way. The reviewer added that the use of a major OEM (Ford) and material supplier (BASF) adds significant meaning to the results.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer replied the recommendation for future research is well documented.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked that the use of higher specific property materials where applications can support the low cost of injection molding is an important factor in successful commercial applications. The reviewer explained that this leads to the most affordable path to weight reduction and as the presenter commented, represents the “lowest hanging fruit” to harvest vehicle weight savings that ultimately improves fuel mileage and emission reductions.

Reviewer 2:

The reviewer replied yes, explaining that the deliverables of this project will enable more lightweight injection molded composite parts in to an automobile for lightweighting, which will increase fuel economy of an automobile and thus reduce the consumption of petroleum.

Reviewer 3:

The reviewer said yes, elaborating that the project painted an appropriate picture of the usage of such materials for variety of applications in the automotive space, adding that the project findings aligned with the needs of the overall industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer declared that the project resources are just right.

Reviewer 2:
While agreeing that resources were adequate for the work completed, the reviewer added that this illustrates that more funding of this type of activity is still required to realize the potential of these materials to expand their range of application and drive downward the cost of weight reduction.

Presentation Number: lm116
Presentation Title: Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites
Principal Investigator: Leo Fifield (Pacific Northwest National Laboratory)

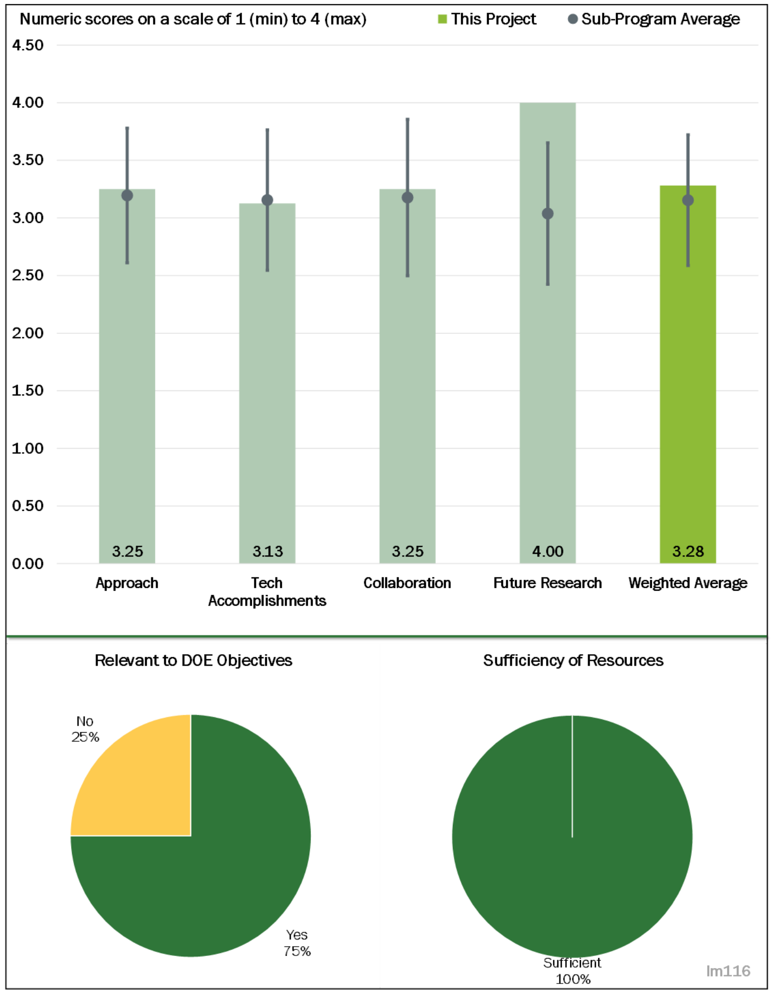

Figure 7-21 - Presentation Number: lm116 Presentation Title: Predictive Engineering Tools for Injection-Molded, Long Carbon Fiber Thermoplastic Composites Principal Investigator: Leo Fifield (Pacific Northwest National Laboratory)

Presenter
Leo Fifield, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer characterized the work as excellent.

Reviewer 2:
The reviewer praised the well-constructed approach rooted in experimental mechanics and translated to solid analytical formulations that has resulted in useful results from industry can draw.

Reviewer 3:
Noting that the project is over, the reviewer agreed that the basic approach was good, but questioned the way the analyses were done, namely, comparing the experimental results (which have errors that were not shown) and the prediction. The reviewer asserted that the comparison can be a bit more complicated than as indicated.

Reviewer 4:
While agreeing that the initial portion of the approach technically valid, the reviewer found the estimation of weight savings at the vehicle level was not well thought through and as a result the findings were inconclusive.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer praised the excellent technical progress and solid verification of results. This reviewer's expectation is those results deviating from prediction demonstrate the current need for significant improvement in the micro-mechanics models for resin dominated properties rather than any inherent flaws in the accuracy of

the flow modelling. Regardless, the reviewer believed the results illustrate the ability to provide useful design results with existing approaches, adding that while improvements will be made, the project has demonstrated several important advances. This reviewer would have appreciated more detail associated with the cost exercise and the assumptions that were made.

Reviewer 2:
The reviewer stated that the team should have been allowed to improve models not just "see how good they are."

Reviewer 3:
The reviewer asked if stiffness is the best way to correlate physical properties with the length and the orientation of the fibers. While agreeing stiffness is important, the reviewer wondered if it is the most relevant physical property for the problem at hand. The reviewer thought there should have been a discussion about the choice for that physical property.

Reviewer 4:
The reviewer remarked that one cannot use stiffness performance to measure the effectiveness of mass savings in the vehicle.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer replied good job.

Reviewer 2:
The reviewer said it was a good team.

Reviewer 3:
The reviewer described the team as well rounded to include strong analytical skills from PNNL, the contributions of a major OEM and tier 1 supplier, and the support of software and material suppliers. The reviewer remarked that it is useful to see the contribution of universities. As part of the industrial base, this reviewer would also like to see the number of graduate/undergraduate students that participate and the number of degrees issued where the content was an important part of the advanced degree.

Reviewer 4:
The reviewer commented that the collaboration from Toyota in guiding the project team to use the findings for assessing overall mass and cost savings was not very obvious. However, the reviewer stated there was good collaboration for predictions of flow.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated this is not applicable since the project is over.

Reviewer 2:
Noting that no future work is proposed, the reviewer replied the team cannot be marked down for that since the project is over.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer declared yes, of course.

Reviewer 2:

The reviewer offered that use of high-specific property materials, and in particular discontinuous fiber thermoplastics for injection molding, will be early entry points for lightweighting steel and Al components. Clearly, the reviewer elaborated, lower vehicle weight is a key means of reducing emissions and extending range to displace petroleum and expand the use of plug-in BEVs. The reviewer concluded that improving the fidelity of analytical tools to model vehicles is an important part of successful adoption and use of these materials and that this work advances this aim.

Reviewer 3:

The reviewer replied yes, allowing the use of CF composites is important to vehicle weight reduction.

Reviewer 4:

The reviewer disagreed that the findings of the project were relevant and instead found the findings inconclusive due to the assumptions made for mass and cost savings.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer replied that the resources were sufficient for the described project.

Reviewer 2:

The reviewer remarked that successful completion of this work has demonstrated that resources were available to achieve much of the stated goals. However, the reviewer believed that the remaining gap between target cost and actual cost in terms of dollars per pound of weight saved remains a vexing problem and suggests resources are needed in the development of affordable materials with higher performance and manufacturing systems for lower cost conversion.

Reviewer 3:

The reviewer said the team got the work done but was underfunded.

Reviewer 4:

The reviewer commented that collaboration and contribution from Toyota was not very obvious.

Presentation Number: lm117
Presentation Title: Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications
Principal Investigator: Venkat Aitharaju (General Motors)

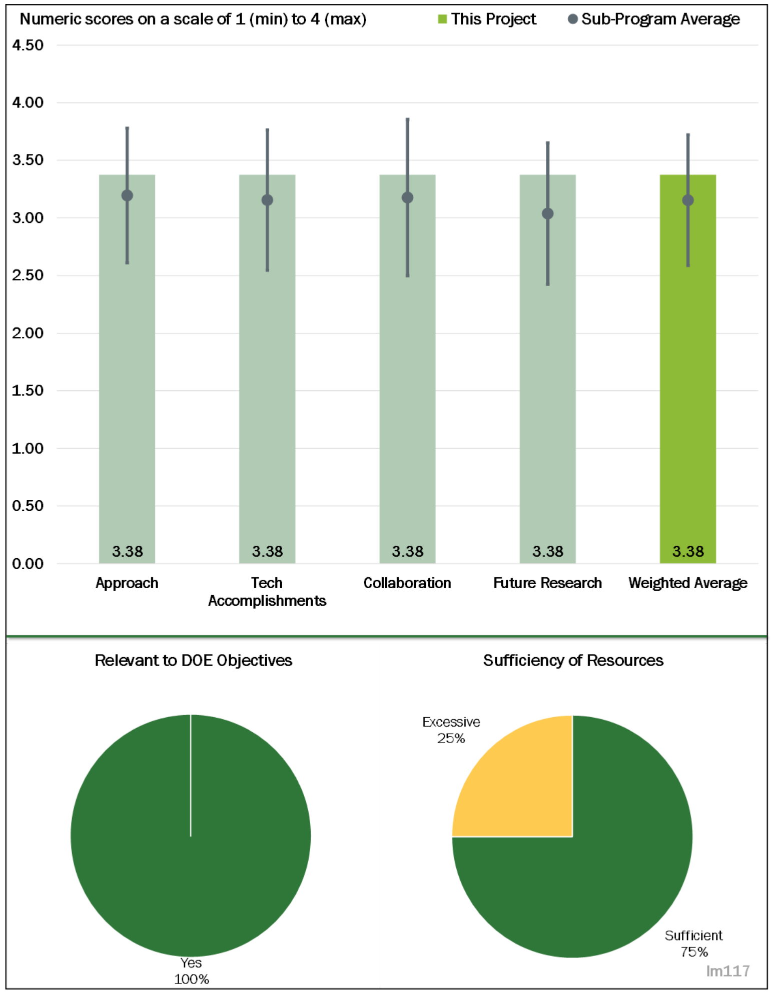

Figure 7-22 - Presentation Number: lm117 Presentation Title: Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications Principal Investigator: Venkat Aitharaju (General Motors)

Presenter
Venkat Aitharaju, General Motors

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer characterized the approach of integrating manufacturing process simulation and performance simulation as being of great importance.

Reviewer 2:
The reviewer replied it was a very logical approach developed and followed through.

Reviewer 3:
The reviewer described it as an integrated approach based on the state-of-art ICME consisting of a diverse team across the entire automotive supply chain that has been used to predict manufacturing and structural performance of automotive CF composites. The reviewer added that the project is well-designed and feasible and noted that 45% of work has been completed by the first-half of the project duration.

Reviewer 4:
The reviewer asked if the project will model the seven baseline assemblies examined in FY 2016 and calculate their respective weight savings and cost per pound saved. The reviewer also wondered whether a model with stochastic simulations always give the same answer, e.g., for energy absorbed during crash, or instead will a model based on stochastic behavior provide a probability distribution of values as the answer.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer was very pleased to see the level of technical accomplishment and progress towards use of high-pressure resin transfer molding (HP-RTM) composites.

Reviewer 2:
The reviewer noted that several major technical accomplishments during FY 2016 have been achieved such as simulation tool development and validation in addition to mapping of manufacturing outcome onto structural models. The reviewer stated that this progress should allow the project team to address remaining challenges and barriers during the remaining 2 years of the project in terms of design and optimizing the automotive assembly in a virtual environment.

Reviewer 3:
The reviewer replied that a number of presentations have been made and that it would be beneficial to the community if the material models generated in this project could be shared and adapted into various commercial software packages.

Reviewer 4:
The reviewer asked whether the fabric and weaves used for draping studies are the same as will be used in eventual assemblies or can the model(s) predict what the "best" weave needs to be for a given performance (i.e., inverse problem). Alternately, the reviewer wondered, will the model(s) be able to handle weaves that are different than those used in the model development stage. Finally, the reviewer inquired what the output is of the multiscale designer software.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer characterized as excellent the collaboration and coordination with other institutions led by an OEM, leading to a recommendable list of accomplishments during the first-half of the project.

Reviewer 2:
The reviewer agreed that the team includes a good combination of industry and academia to address the project challenges and that leveraging DOE-funded Scientific Discovery through the Advanced Computing Institute seems very beneficial to model development. The reviewer added that it would be useful to describe how such a large program is managed with regards to meetings, internal project reviews, data sharing, etc.

Reviewer 3:
The reviewer affirmed that it appears a very nice collaboration with project partners exist and that the tools in use are continuously being refined to increase the degree of accuracy in predictive tools.

Reviewer 4:
The reviewer replied there is good collaboration with software companies and a research university.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the proposed future work seems logical in terms of extending the validated tools towards the development of designs and to optimize virtually the automotive assembly.

Reviewer 2:

This reviewer proposes that the project team further validate the technical flow of information for modeling process and predicting structure performance. The reviewer said it was not very obvious whether how the information flow would take place between all the simulation software being used. This reviewer would like to see addressed LS-DYNA related issues for predicting part performance from a structural point of view for future proposed research since LS-DYNA is the dominant analysis tool in the automotive industry. The reviewer suggested that perhaps cross-collaboration with Ford's DOE ICME project could be used to reduce the impact on time and resources.

Reviewer 3:

The reviewer replied that more details about future work would be appreciated.

Reviewer 4:

The reviewer remarked that it is unclear who will perform the cost modeling. Of the baseline assemblies studied in FY 2016, the reviewer would like to know which of these will be addressed in FY 2017 and FY 2018 and what the basis for selection is.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer replied yes, lightweighting is an extremely important to vehicle fuel economy and petroleum displacement.

Reviewer 2:

The reviewer explained that the project focuses on HP-RTM and wet compression RTM, which are the dominant process techniques used by European Union OEMs and will also gain traction in the United States. The reviewer stated that it is very nice to see the project team focus on such a process application method.

Reviewer 3:

The reviewer agreed that this project facilitates overall DOE objectives of petroleum displacement in terms of demonstrating the viability of lightweight automotive designs in a virtual environment.

Reviewer 4:

The reviewer remarked that lifecycle analysis will be useful to compare the use of petroleum-based precursors (for CF and the resin) versus the fuel economy due to lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer responded that available resources have been appropriate and timely so far to achieve the stated project milestones.

Reviewer 2:
The reviewer agreed the funding is sufficient.

Presentation Number: lm118
Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly
Principal Investigator: Srikanth Pilla (Clemson University)

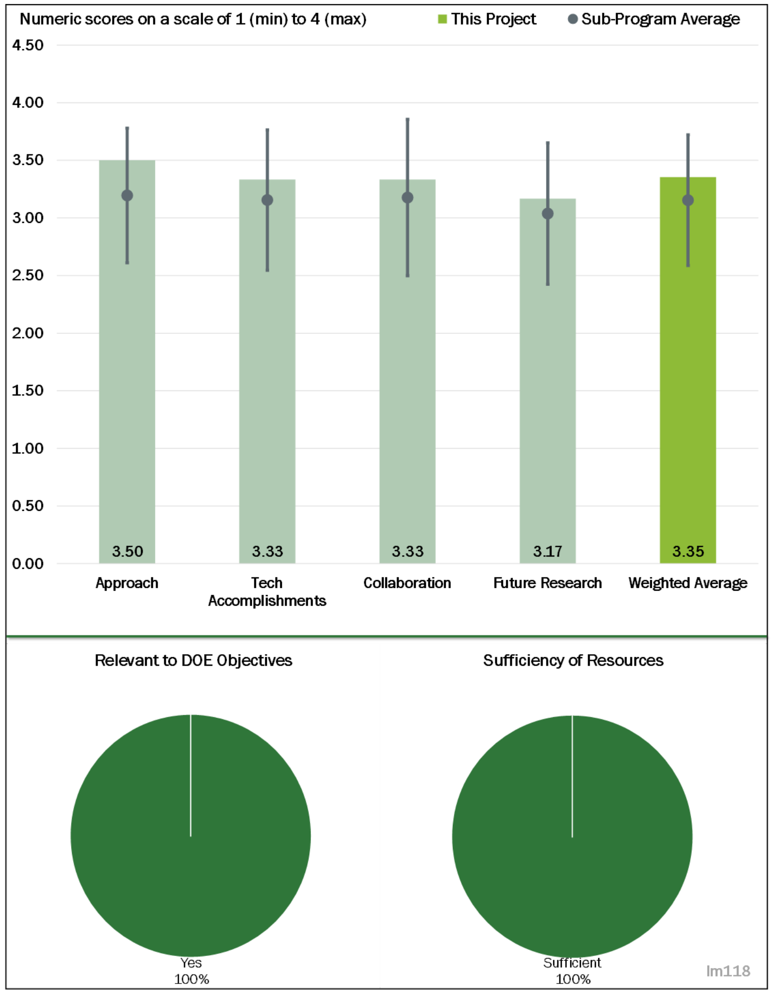

Figure 7-23 - Presentation Number: lm118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University)

Presenter

Srikanth Pilla, Clemson University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised the systematic approach and rational development with good understanding of performance requirements as well as specific targets and action plans. The reviewer added that the project was very well presented.

Reviewer 2:

The reviewer described the project as well designed to explore lightweighting of a door assembly using thermoplastic materials.

Reviewer 3:

The reviewer remarked that the program presentation was based on some rather broad overviews, but it generally showed a thoughtful approach to the downselection process and the justification behind the chosen path. However, the reviewer remarked that the overall concept of lightweighting a door seems to fly in the face of the first characteristic that needed to be maintained (namely, strong open and close) and asked how does one make a light door feel heavy. The reviewer added that perhaps listing this first overemphasized it as a critical parameter, but it was not addressed further in any detail.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the excellent progress on concept and design development based upon understanding the performance requirements and materials data and added there was good progress on cost analysis.

Reviewer 2:
The reviewer replied that it seems there is good progress on this project from the AMR talk. The reviewer hopes to see more information from this project after clearing protected IP terms from the team members.

Reviewer 3:
The reviewer began by remarking that the technical progress is largely based on faith in the presenter since the details quickly become proprietary and were subsequently "blurred out" in the presentation. The reviewer said that whether there has been some transformational or even novel development is – pardon the pun – not clear. The reviewer asked why not take credit for advances in technology regarding ancillary weight savings opportunities (such as speakers). The reviewer added that 3-kg attributed to these features seems excessive, even if there is no plan to do anything other than outsource that to a different vendor. The reviewer next commented that Slide 18 required considerably more of a detailed discussion, adding that items identified at the extremes of the "hard" and "easy" scale was difficult to rationalize. The reviewer surmised that if throughput to match steel is "easy," there is not much of a barrier to immediate deployment despite the fact that the earlier comparison table identified thermoplastic composites as being very slow with regard to joining speed, with a "to be determined" (TBD) takt time. On this note, the reviewer remarked, the presentation of the proposed shop floor layout seems well outside the scope of a lightweight materials program (assuming that this part of the analysis is what drove the production time to the "easy" part of the scale). The reviewer pointed out that the specific layout for manufacturing processes are entirely at the discretion of the manufacturer. As far as crashworthiness, the reviewer cautioned, if this portion of the program is still considered a substantial barrier, then it is difficult to judge whether any significant progress has been made. The reviewer concluded that more time spent on this slide really would have helped alleviate some of these questions.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer described as excellent the collaboration between the lead, OEM, universities, material suppliers, and prototype suppliers.

Reviewer 2:
The reviewer replied that good interaction and collaboration between partners are evident, adding that consultation and collaborative decision-making are noted for various tasks.

Reviewer 3:
The reviewer agreed that the collaborators are certainly up to the task at hand. The reviewer noted, though, that the presentation listed specific collaborators as well as a number of other entities that are contributing and wondered whether this a group of companies are simply being contracted. The reviewer remarked that the line between collaboration and indirect involvement through sales is not specifically delineated (as an example, the reviewer wondered if Microsoft is a contributor because the presentation is in PowerPoint). The reviewer concluded, however, that the two universities and Honda alone are a solid team.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said a clear rational plan is provided for future research, adding that it is highly feasible.

Reviewer 2:
The reviewer stated that the meat of the program is still looming, so the future work is critical to any sort of success of the program. Up until this point, the reviewer concluded, specific progress is largely conceptual.

The reviewer's relatively neutral grade in this category is reflective of that rather than a negative view of the program's mission.

Reviewer 3:

The reviewer said vigilant about the Class A surface requirement for the door outer.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked that targets from DOE are entirely specific in this area (i.e., target weight savings and cost per mass unit increase). The reviewer concluded that deploying a lighter major chassis component with no critical sacrifices in safety or performance is clearly supportive of efficiency goals.

Reviewer 2:

The reviewer said that use of CF composites will reduce vehicle weight which will lead to fuel economy or contribute to the development of electric cars.

Reviewer 3:

The reviewer replied yes, explaining that this project will help potentially lightweight a door assembly by 13 kg for each door of an automobile and added that these weight saving can translate to reduction in consumption of petroleum.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that resources are perfect to accomplish the project tasks.

Reviewer 2:

The reviewer commented that it would appear that Honda is extremely invested in this program and that this is clearly a positive reflection on the team.

Reviewer 3:

The reviewer stated that the budget details show that there is adequate funding to complete the remaining tasks.

Presentation Number: lm119
Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration
Principal Investigator: Nate Gravelle (TPI)

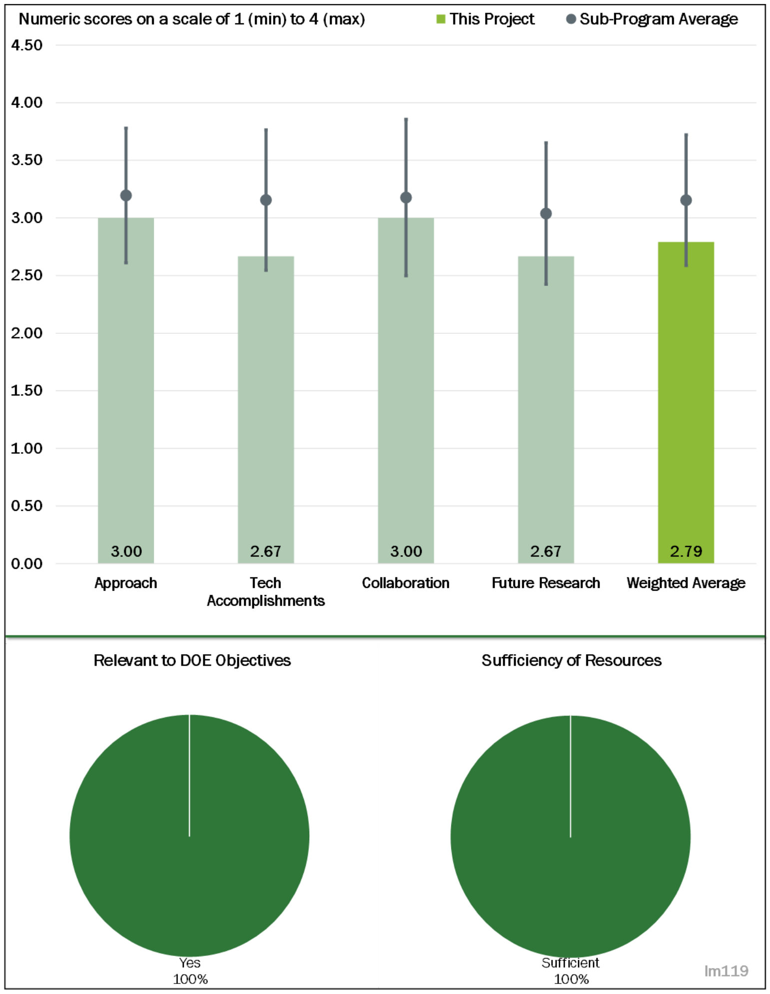

Figure 7-24 - Presentation Number: lm119 Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration Principal Investigator: Nate Gravelle (TPI)

Presenter
Nate Gravelle, TPI

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that the approach is what would be expected from a company with expertise in composites in order to achieve the lightweighting goals (in this case, of an automotive door) using composite materials optimized to meet specific targets. The reviewer clarified that this is not a drawback or a strength as there is nothing novel in the approach, but added there is ample reason to believe that the program can be very successful.

Reviewer 2:
The reviewer commented that the team started with composite panels for the design, which limited the scope of design. The reviewer suggested the team consider integrating metals in the design for the best use of each material.

Reviewer 3:
The reviewer replied that the approach to meet the target vehicle weight of 42.5% based only on composites limits the cost-effective vehicle lightweighting opportunities. However, the reviewer added it will demonstrate at least what can be achieved if lightweighting is limited only to composites.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the potential success of the program is dependent upon targets that have not been met, despite the program being at the halfway point and the identification of all target milestones as having been completed. While agreeing that the investigators clearly have expertise in this area, the reviewer said that the progress toward cost targets indicate that they will be difficult to achieve, and the critical

characteristic of a final design (safety and performance of the composite door) has not yet been proven. The reviewer elaborated that the latter point is a natural condition for a program that is only halfway through its lifecycle, but it would be expected that a means for achieving cost and weight targets is the first hurdle that must be overcome quickly in order to move to the performance validation phase. The reviewer warned that Slide 21 contains some deflating revelations for a program at this level of progression, adding that a more detailed presentation of the planned approaches for putting the targets back on track would have been compelling.

Reviewer 2:
The reviewer concluded that after 50% project completion to date, an actual approximately 15% versus planned 42.5% weight reduction has been demonstrated. The reviewer said there was no indication given to how close to the final mass reduction while meeting the DOE target of cost of mass saving will be achieved. The reviewer stated that it is important that a multi-material composite-intensive design be considered in order to achieve both DOE mass reduction and savings targets. The reviewer noted, though, that some validation activities such as material characterization and door laminate design optimization have been completed.

Reviewer 3:
The reviewer replied that the current design has not achieved the mass/cost targets.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer affirmed that collaboration is strong for both industry and university partners including among the companies.

Reviewer 2:
The reviewer found that there is some confusion over who is actually collaborating and who is simply performing subcontracted services or are the two treated equally. The reviewer surmised that one would have to believe that there is no distinction, as there are considerable fractions of the funding effort coming from sources other than the DOE, adding that the group of “partners” is substantial.

Reviewer 3:
The reviewer replied that collaboration and coordination have been limited to less than ten institutions and that the role of each institution in the overall project goal was unclear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the “barriers” that have been overcome thus far in the program seem to be limited to the downselection of several structural geometries and the ability to model specific characteristics of the door assembly in order to optimize system performance. While acknowledging that these are no small achievements, the reviewer stated that there is not a clear path for novel approaches that are more favorably indicative that the basic cost and/or weight targets will be met.

Reviewer 2:
The reviewer stated that the plan for future work includes full scale door and vehicle testing which indicates that no alternative designs will be considered to meet the DOE technical targets.

Reviewer 3:
The reviewer replied that it is not clear whether the future research will achieve the project goals of 42.5% mass saving and less than $5 cost increase per pound saved.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied yes, lightweighting is an important strategy for petroleum displacement.

Reviewer 2:
The reviewer stated that DOE objectives are specific for this program with regard to weight savings and cost.

Reviewer 3:
The reviewer agreed that this project supports the overall DOE objectives of petroleum displacement but added that the petroleum displacement potential with the proposed lightweight door design is yet to be quantified.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer replied that funding is sufficient.

Reviewer 2:
The reviewer stated that all milestones are complete as shown by the PI, so by this measure the program is progressing as planned. The reviewer characterized this as a positive reflection on the resources allocated, but added that the ability to meet the stated targets is still an outstanding barrier. The reviewer offered that this may be an indication that the resources were not sufficient vis-à-vis the approach to achieving DOE goals, but added that with a substantial portion of the program remaining, there is reason to believe that the achievements to date can be built upon in order to achieve those goals.

Reviewer 3:
The reviewer observed that resources allocated to this project is less than what has been available to the Vehma International Ultra-Light Door Design project.

Presentation Number: Im120
Presentation Title: Ultra-Light Door Design
Principal Investigator: Tim Skszek (Vehma International)

Presenter

Tim Reaburn, Magna

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

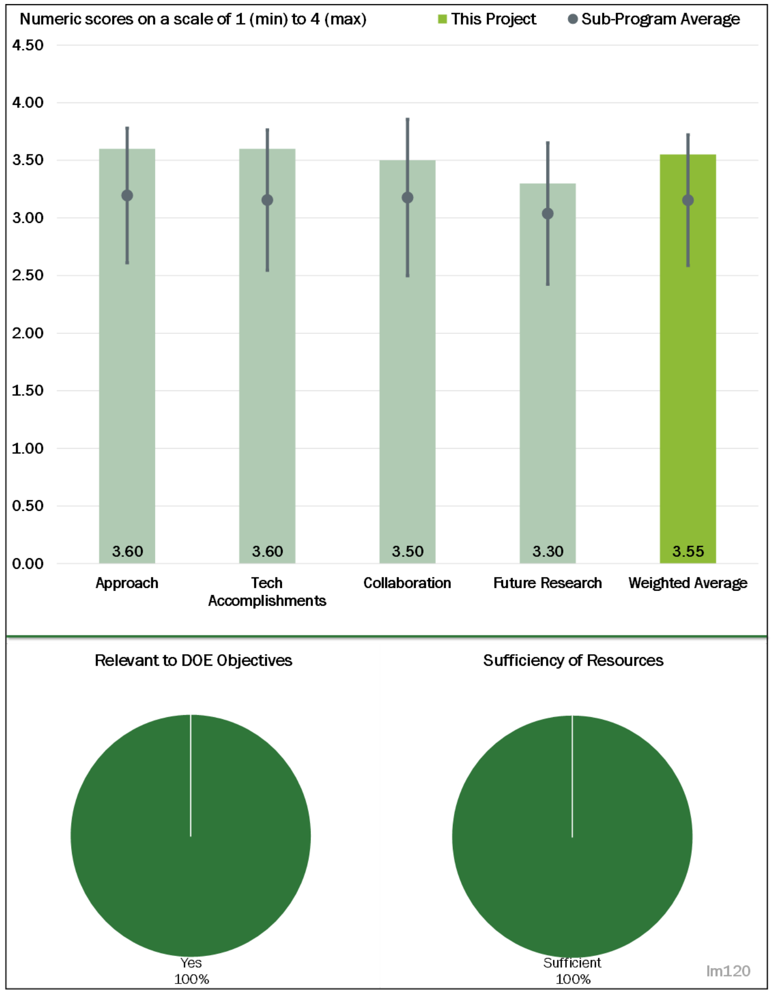

Figure 7-25 - Presentation Number: Im120 Presentation Title: Ultra-Light Door Design Principal Investigator: Tim Skszek (Vehma International)

Reviewer 1:

The reviewer described the approach as outstanding, pointing out that the team realized that lightweighting only the structure would not reach the overall goal so that the team looked at every component in the door assembly. The reviewer explained that the team developed commercially-viable designs for reducing weight from every component and subsystem. This reviewer especially liked the electronic latch which saves 0.77 kg (between the latch and handle), adding that this is in line with the industry move to electronic parking brakes for the same reason, namely, to save weight. The reviewer also said the use of Gorilla glass along with thinner exterior glass are great ideas.

Reviewer 2:

The reviewer remarked that the “no stone left unturned” approach was effective based on the proposed results. While noting the frame lightweighting targets were not as aggressive as with other technologies, the reviewer offered that the consideration of other weight-saving technologies is providing a level of success that has not been achieved in similar door lightweighting programs.

Reviewer 3:

The reviewer explained that the systematic selection approach by taking into consideration major technical barriers was used for the final concept design. The reviewer said it would have been useful to know what specific criteria and the evaluation method were used while evaluating various alternative concept designs.

Reviewer 4:

Noting that the project started with three concepts of different materials to include Al, Mg, and CF composites, the reviewer suggested that the downselection process and decision matrix be provided to the review process and published if possible.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer pointed out that the project team has exceeded DOE goals and within a 1.5-year timeframe developed multiple designs, completed the analysis, and built full working prototypes.

Reviewer 2:
The reviewer observed that the project achieved 40% mass saving at $2.59 per pound saved for the Al-intensive design and praised this is an outstanding accomplishment.

Reviewer 3:
The reviewer praised the technical achievement to date as superb as shown by an actual door demonstration at the review. The reviewer noted that an actual prototype demonstration was ahead of the schedule and within the budget.

Reviewer 4:
The reviewer explained that with roughly six months remaining in the program, a relatively minor level of weight loss will result in the lightweighting target being achieved, and with the projected cost increase already significantly below the stated goal, there is a substantial amount of allowable expense "banked" for this specific cost reduction strategy, whatever that might be. The reviewer stressed that a clear presentation of the actual costs in each of the component technologies would have been extraordinarily welcome in the presentation, as the program's accomplishments to date are in stark contrast to the cost and weight savings analyses that have been performed by other entities that indicate an "alloy-only" (particularly Al-only) approach will not be capable of meeting stated targets. The reviewer wondered if this indicates that the impending performance/safety targets will not be met or that the cost estimates are egregiously optimistic. The reviewer concluded that the significant accomplishments of this group indicate that this is not the case, but added that any doubts might have been alleviated with a more substantial raw material and/or production cost breakdown.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer enthused that the team has set the bar for working together with eight organizations (give outside of Magna) to complete new designs and prototypes for multiple subsystems. This reviewer does not believe anyone within the industry could have done this any faster.

Reviewer 2:
The reviewer stated that the project has clearly been a team effort with investment by a number of research entities (as underscored by the signed door diagram). The reviewer praised this as a solid overall project with enthusiastic support by stakeholders.

Reviewer 3:
The reviewer praised this project's excellent collaborations among several companies that has produced great results. The reviewer added that it would be great if a university team can join the project since it is important to train students (our next generation of workforce) on how to design with lightweight materials.

Reviewer 4:
Noting that several institutions collaborated on this successful project, the reviewer said the excellent collaboration among them is evidenced by the project's overall timely success. The reviewer added that an OEM participation as one of the collaborators would have been useful.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the relatively benign "good" ranking is more an indication that the program as presented indicates there is little left to accomplish. Outside of needing less than 1kg of weight savings to achieve the stated DOE goal, the technology seems ready to deploy at a price point well below the perceived balance point for cost effectiveness.

Reviewer 2:
The reviewer commented that future research is the testing of a large number of prototype doors with evaluation of the design and prototypes after each test. The reviewer added that the team will have test results in time to make any recommendations for improvement.

Reviewer 3:
Although the team has achieved a great design of 40% mass saving at $2.59/lb. saved, the reviewer suggested it explore additional mass saving opportunities such as Mg or CF composite inner panels to report dollars per pound saved for those opportunities.

Reviewer 4:
The reviewer stated that the project is expected to be completed by the end of CY 2017 and no future plan in terms of commercialization has been discussed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer replied yes, a lightweight door is an excellent demonstration of lightweighting opportunities for other vehicle subsystems.

Reviewer 2:
The reviewer answered yes, elaborating that the project has demonstrated a mass reduction of 55-kg per vehicle and that using the normal expectation for weight reduction (including engine downsizing), this would result in a 0.22-L per 100-km fuel economy improvement.

Reviewer 3:
The reviewer agreed that this project supports the overall DOE objectives of petroleum displacement by demonstrating the overall 40% mass reduction in an ultralight automotive door design resulting in an estimated 0.22 L per 100-km of fuel consumption over the vehicle lifetime.

Reviewer 4:
The reviewer responded that DOE goals are reasonably clear in this area, and the project is indicating successful progress toward those goals. The reviewer commented, though, that the emphasis on specific fuel savings per kilogram saved seemed overstated in the presentation (despite the direct references to DOE literature). The reviewer wondered why not agree that those are workshop numbers based on a fleet scale and focus instead on specific platforms. The reviewer added that the project seems quite well-equipped to do that with specifics up to and including door trim details. The reviewer remarked that time was wasted on this type of generality that could have been better directed at cost breakdowns and justifications. Additionally, the reviewer said, it can be argued that the allowable cost per mass unit saved is more of a quality of consumer sensitivities and marketability of new technology versus the price point of fuel (rather than economic savings versus greenhouse gases). The reviewer reiterated that this is unnecessary as a point of emphasis.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Remarking that the project is well staffed, this reviewer doubted anyone could have accomplished these goals along with prototyping any faster than this team has.

Reviewer 2:
The reviewer commented that a total budget of about $8.5 million for this fast-tracked two-year project was sufficient to achieve the stated DOE objective and added that a 50% cost share provided by industry was crucial in meeting the stated milestones in a timely fashion.

Reviewer 3:
The reviewer replied that the proof is in the quantified progress figures versus the stated goals of the program.

Reviewer 4:
The reviewer replied that the project was on budget and on time.

Presentation Number: lm121
Presentation Title: Carbon Fiber Technology Facility
Principal Investigator: Dave Warren (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

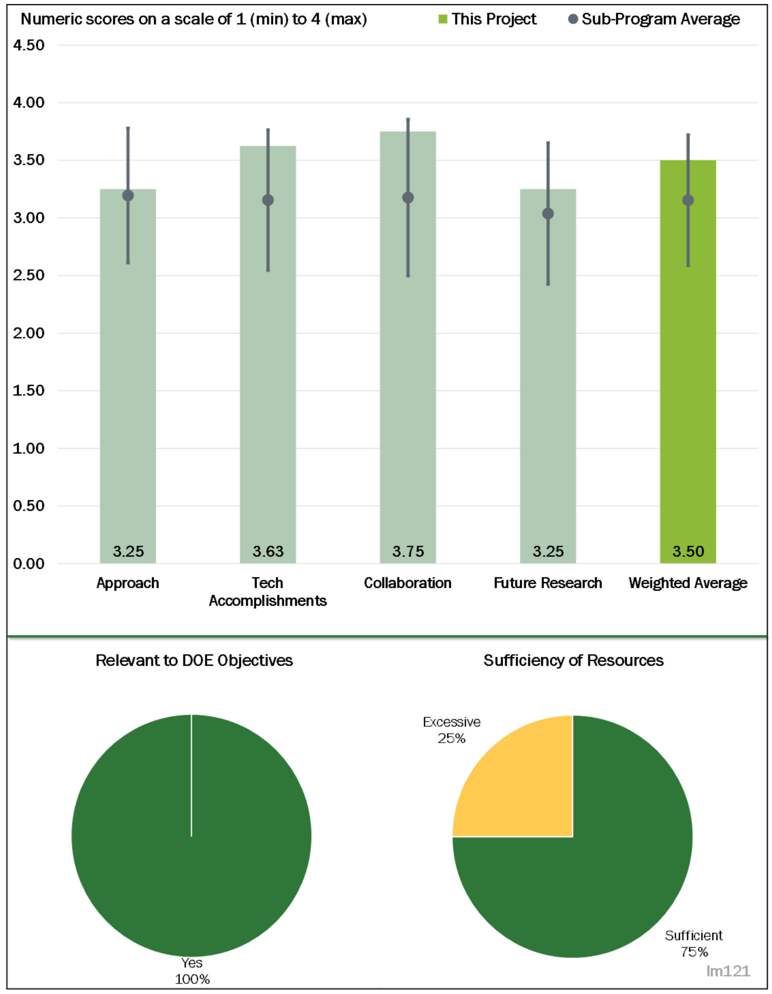

Figure 7-26 - Presentation Number: lm121 Presentation Title: Carbon Fiber Technology Facility Principal Investigator: Dave Warren (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the team showed an excellent understanding of the barriers that need to be addressed such as the different stretch of the fiber and location where fiber can be obtained.

Reviewer 2:

The reviewer replied there were great examples and output from textile polyacrylonitrile (PAN) and lower cost precursor material, adding that the overview of the precursor historical output in mechanical properties was presented very nicely with well-documented historical performance data.

Reviewer 3:

The reviewer said there is a “feel” that the approach is “shotgun,” with the identification of “commercial” textile grade precursors and the trial/error approach of evaluating being rather costly. Given the market size for using precursor, addressing opportunities to “design” a precursor that optimizes molecular structure (while maintaining the fundamental advantages of low-cost through high-volume, large tow manufacturing) would feel better. The result would be expanded applications, greater consistency, and larger market share to further drive-up volume and further reduce cost.

Reviewer 4:

The reviewer replied it was an effective stepwise approach being used starting with materials and added that there has been much focus on commercialization and less on the technical and scientific aspects of the process. The reviewer said that collaboration with parts users (OEMs) is missing.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer replied the technical accomplishments and identification of the breakthroughs in development of large-volume CF fiber production, including textile PAN precursors.

Reviewer 2:
The reviewer said the property data generation, process development, and commercialization activities are very good and that the cost reduction in production and energy consumption is interesting.

Reviewer 3:
The reviewer stated that since the team was already able to make a licensing agreement with LeMond, it has met the goals of putting the system into production

Reviewer 4:
The reviewer observed that the pilot-scale manufacturing of 600,000 tow and the demonstrated properties exhibit the potential of this project to yield commercially successful results. The reviewer added that ORNL's licensing to LeMond is further testimony to its accomplishments. The upward trend in mechanical properties is encouraging, but this reviewer would like to see a reduction in variance and focus on a specific material system that yields the most attractive combination of specific stiffness and specific compressive strain (as well as tensile strength) in the lowest possible cost per kilogram tow. The reviewer added that it would be reasonable to expect a tight technical specification be established for the precursor and ask industry to meet that specification and identify costing (as well as means to further drive cost down).

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer replied that an impressive list of technical collaboration projects (over 50) has been provided.

Reviewer 2:
The reviewer observed that with CF shipped to 13 different companies for evaluation in many different aspects shows tremendous collaboration and enthusiasm for this project

Reviewer 3:
The reviewer commented that the broad base of technical collaborators presented is impressive and demonstrates the effort the PI has made to enlist the broadest range of technical expertise possible. The reviewer added that the strong number of participants in the supply chain is represented and an extensive number of convertors and end users have contributed to this effort. The reviewer suggested it would be useful for the PI to provide specific information regarding feedback received. In addition, this reviewer would like to see more active collaboration with existing CF manufacturers, remarking that it seems unfortunate that such a resource is underutilized by this sector. More insight into the reason for this gap would be helpful, the reviewer said.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said there is a well-thought-through set of recommendations on future proposed research and development steps.

Reviewer 2:

The reviewer observed that the research appears to be almost completed and may be moving to the plant level, adding that in order to continue the project in a research environment, the approach to the fundamental science should be better defined.

Reviewer 3:

The reviewer recommended a focus on specific mechanical properties and setting a bar requiring that these properties be met. The reviewer also recommended that a specification or possibly multiple specifications for a range of products should be established based on industry feedback along with associated cost targets. The reviewer added that identifying the specific opportunities for cost reduction, as well as identifying the fundamental barriers, should be included such that the work focuses on those elements that can be tuned to meet target specifications and costs.

Reviewer 4:

The reviewer replied that collaboration with part users (OEMs) seems to be missing.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer enthused that this is a key enabler for addressing many of the technical challenges and efforts such as this further accelerates the use and understanding of CF composites for variety of applications. The reviewer characterized it as a great cornerstone for collaboration among industry partners and an excellent enabler for educating the future workforce needed for the country.

Reviewer 2:

The reviewer observed that the price/demand curve of CF is quite steep and that any movement in terms of cost reduction for a fixed performance will expand the use of CF in automotive applications and have the knock-on effect of expanding other industrial applications (such as wind power) that further displaces petroleum and hydro-carbon consumption. The reviewer conclude that this is essential work that should be supported.

Reviewer 3:

The reviewer offered that the cost of CF is perhaps the largest barrier to its use in automotive applications. The reviewer elaborated that the strength, stiffness, and weight of CF composites make it an excellent "lightweighting" material, but the cost is prohibitive. The reviewer affirmed that trying to use textile materials as a precursor to making CF must be one of the best ways to reduce CF cost, adding that this project attempts to do this and it appears to have been successful.

Reviewer 4:

The reviewer agreed it will contribute to vehicle lightweighting for gasoline and electric cars.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The Carbon Fiber Technology Facility at ORNL was clearly able to produce the product to make materials for companies to evaluate.

Reviewer 2:

The reviewer noted that the operation of a CF facility is extremely expensive and that capital expenditures, raw materials, and staff and all that is associated with these require significant resources. The reviewer said that this is clearly understood by DOE and ORNL, adding that the level of funds expended are high but the potential reward is similarly great. As previously discussed by this reviewer, more collaboration with the established fiber suppliers would be very helpful to offset some of the resource requirements and may lead to measurable results in the short term.

Reviewer 3:

The reviewer said the project seems to be just a little underfunded (by $140,000).

Presentation Number: lm122
Presentation Title: Close Proximity Electromagnetic Carbonization (CPEC)
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

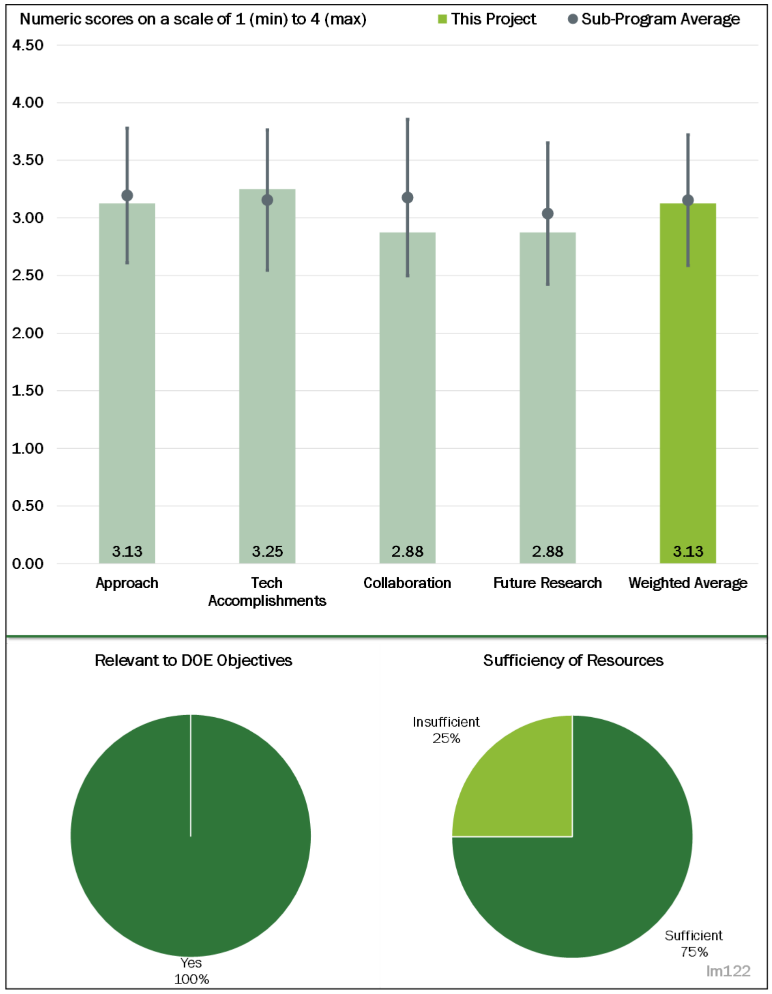

Figure 7-27 - Presentation Number: lm122 Presentation Title: Close Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Truman Bonds, RMX Technologies

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer described a well-thought-out approach with project milestones established.

Reviewer 2:

The reviewer remarked that the PI provided good background and useful fundamental physics behind the approach to using electromagnetic coupling to achieve thermal input for carbonization of PAN fiber. The practical steps to be pursued were more blurred, the reviewer commented, but some of this is a result of the restrictive nature of public disclosure for this technology. The reviewer added that the project motivation is well expressed and the tasks outlined are adequate.

Reviewer 3:

The reviewer stated that the project is positioned to solve most processing problems effectively, but added that there is less indication as to how the technical challenges with respect to ensuring consistent properties (along and across the fiber) are addressed.

Reviewer 4:

The reviewer observed that although dielectric heating initially appears as a method to efficiently carbonize polymers strands, the variability in the impedance of the fiber causes significant variability in the localized temperature in the fiber. As shown in Slide 16, the reviewer explained, the resistance along the strand varies from 76-ohms to 1295-ohms, more than an order of magnitude. Furthermore, the resistance values do not trend in one direction along the fiber but fluctuates. The reviewer noted that the team uses an average resistance to tune the energy source and as a result, the source frequency will be significantly off resonance for most of the fiber. The reviewer said that what this will mean is that part of the fiber will heat up too much (melting was observed) or not heat enough and therefore the fiber will not be carbonized.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer said there is an excellent benefit from the use of computation electromagnetic modeling and evaluations of design concepts prior to designing and building a prototype.

Reviewer 2:
The reviewer described excellent progress on milestones 1 to 5, but added that it was difficult to judge from the property data presented if milestone 6 on fiber properties is likely to be achieved.

Reviewer 3:
The reviewer stated that the contractor has demonstrated the feasibility of the approach and made solid progress in application at a very limited level. The results, however, suggest scalability and demand follow up. The reviewer commented that while the trend of increasing modulus (and degree of carbonization) versus peak strain at failure suggests a level of risk (i.e., insufficient peak strain), it must be understood that other critical process parameters are not in play (such as fiber tension, etc.). The reviewer concluded that the suggestion that the technology may also be applied in the range of high-temperature carbonization represents additional cost reduction opportunities and must be further explored.

Reviewer 4:
The reviewer replied that as outlined in the milestones, the team has accomplished its tasks and have now created a system for testing. However, the reviewer questioned the go no-go milestone 4 (M4) question. In particular, the milestone claims stable processing of the fiber, but in the speaker's own words, there was melting of the fiber.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer agreed that the project partner is well suited based on the project needs and objectives. The reviewer noted that future project partner selection was also identified to carry on project findings for larger scale up.

Reviewer 2:
The reviewer stated that while the depth of collaboration is limited (ORNL and RMX Technologies), the fundamental skill sets for success development of the technology is adequate. The reviewer suggested it might be helpful to include collaboration with an academic institution to support material characterization or provide specific targets for material performance.

Reviewer 3:
The reviewer observed that only two partners, ORNL and RMX Technologies, are involved with two other RMX collaborators and said that more partners (such as OEMs, composite manufacturers) should be sought.

Reviewer 4:
The reviewer remarked that the team collaboration with RMX on the electrical side appears to be going well, noting that they have been able to make the equipment. However, the reviewer said there appears to be lack of collaboration with a partner that can quantify the efficiency and losses of the conventional process for the low temperature carbonization stage.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer agreed that the proposed future research is very consistent with the end goals of the project and scale up.

Reviewer 2:
The reviewer remarked that although the proposed future research identifies the further measurement of the fiber for strength, what really needs to be researched is what are the local time and temperatures that exists along the fiber given the variability of the process. The reviewer asked what is causing the temperature spikes that cause melting and how is the efficiency of the electrical system being measured.

Reviewer 3:
The reviewer commented that the proposed effort contains little detail with respect to specific technical details but is adequate to suggest that current technical gaps will progress toward a solution or at least a resolution. This reviewer would like to see more specific targets for "require mechanical properties," and that an explicit target based upon properties of fiber produced with conventional thermal processes would be useful. In addition, the reviewer said a complete cost model that provides detail on the opportunity for cost reduction in terms of dollars per kilogram would be very useful to assess value of work.

Reviewer 4:
The reviewer cautioned that it is not clear if the technology can provide consistent fiber properties across the tow, across the fiber cross section, and along the fiber length. In addition, the reviewer said that the future research does not explain how these consistent properties can be obtained with the current technology when scaled-up.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that any research focused on reducing the cost of processing CF supports the stated DOE objective because CF cost is one of the most significant barriers to expanded use of these high specific property materials. The reviewer added that cost reduction of any magnitude will expand applications and enable applications in automotive structure, thus reducing weight and displacing the use of petroleum.

Reviewer 2:
The reviewer replied that carbonization of CF is certainly one of the key elements contributing to the overall cost and that the project certainly supports future developments of reducing cost of CF composites, adding that the research continues to pave ways for further evaluation of precursors as well.

Reviewer 3:
The reviewer noted that the project tries to reduce energy in the production of CF and that if successful, it may potentially lower the cost of CF and increase the use in automotive applications.

Reviewer 4:
The reviewer said it will be contribute to cost reduction in vehicle lightweighting but cautioned that with no OEM or composites manufacture present as partners, the project may not have a sharp focus.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

While agreeing that resources appear adequate, this reviewer is not fully aware of the costs required to scale the bench tests to continuous fiber conversion but added that the work is significant enough that the reviewer encourages DOE and industry to support this effort.

Reviewer 2:

The reviewers affirmed that there are sufficient resources (budget and expertise) to produce a scaled-up Close Proximity Electromagnetic Carbonization (CPEC) furnace, adding that ORNL can, of course, provide the expertise on the materials characterization aspects.

Reviewer 3:

The reviewer replied that currently the team appears to lack the ability to accurately measure the localized physical properties of the fiber in a consistent manner. The reviewer also noted that it was also pointed out by the speaker that the team does not have enough details on the expected properties or process of the commercial low-temperature carbonization process, which might make it difficult to truly evaluate the fiber properties and make an overall efficiency comparison.

Presentation Number: lm123
Presentation Title: Safety Statistical Analysis
Principal Investigator: Tom Wenzel (Lawrence Berkeley National Laboratory)

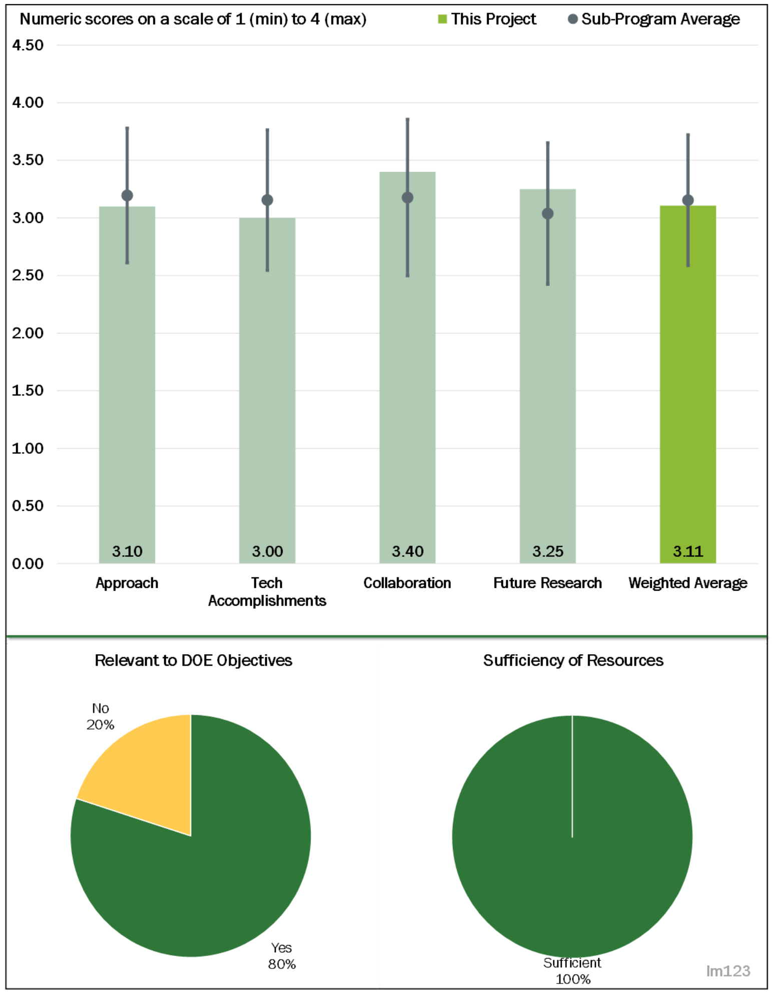

Figure 7-28 - Presentation Number: lm123 Presentation Title: Safety Statistical Analysis Principal Investigator: Tom Wenzel (Lawrence Berkeley National Laboratory)

Presenter

Tom Wenzel, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project is focused upon facilitating collaboration among the primary regulatory and policy agencies, validating, and enhancing relevant analyses, elaborating that activities are tightly targeted at informing decision-making related to specific requirements such as the mid-term review for light-duty fuel economy.

Reviewer 2:

The reviewer observed that the team's approach to consider factors impacting vehicle fatalities based on vehicle weight, styles, and occupancy can be used both to influence automotive manufacturers' decisions and also decisions of the public. The reviewer noted that the team used a combination of data sources and studied many different combinations of potential causes. Finally, the reviewer suggested that if something could be improved, it would be to get a bigger dataset, although this may not be available.

Reviewer 3:

The reviewer commented that the project seemed to be well-designed and was extremely interesting, although the dataset was limited and the degree of accurate representation of the whole was not clear. The reviewer commented that it would have been helpful to know which 13 states were represented and where they ranked in terms of key metrics such as annual traffic fatalities and serious injuries per population and rate of crash per miles driven per year. The reviewer suggested a few possible improvements for presenting to a more general audience might include the following: what and who defines a serious injury and is that definition consistent from state to state; separate serious injury from fatalities and determine how casualty rankings change, both in the 13-state population and over the 50 states; and whether it matters where in the vehicle that mass is removed. The reviewer elaborated that, for instance, as there have been mass reductions in the body, frame, and engine, there have been concomitant increases in mass due to comfort, safety, automation, entertainment, and communications.

The reviewer remarked it would be interesting to compare the effect of lightweighting in more detail in a future study where subsets of vehicles with certain structural mass reduction strategies (but overall minor changes in total weight) are considered. The reviewer expressed concern that there is more impact of lightweighting than is obvious since it matters where the mass was removed as much as mass being removed. The reviewer clarified that if structural mass is reduced but weight is added for non-structural items, then the vehicle might not appear to be lightweighted on a total mass basis. When this vehicle is compared to the population of cars that saw more of a total mass reduction (perhaps due to less non-structural additions, as well as due to international structural lightweighting), it would be the case that the outcomes of the population of lightweighted vehicles might look very similar to this vehicle in the heavier class because structurally they are similar. The reviewer realizes it might not be possible to account for such nuances, but without analyzing for them, the comparisons and conclusions may be questionable. This may also help to better predict future outcomes.

The reviewer asked that because more SUVs and larger cars are selling more recently, and if a larger portion of older cars are smaller, if the data and analysis are skewed. The reviewer inquired if because younger drivers tend to drive older, cheaper (often lighter) cars built with lower safety standards, it these factors also influence the age/gender/etc. (although that influence is not necessarily actually free of lightweighting). The reviewer asked if the likelihood of younger drivers in older, lighter cars was accounted for.

Vehicle velocity seems to have not been emphasized. It would be interesting to bin the data, based on crash analysis (which would not have specific velocity at time of impact data but would have qualitative data) into low, medium, and high velocity, and asked whether lightweighting is more impactful as a function of velocity (i.e., did the crash occur on an interstate at 70 mph or on a backroad at 35 mph). This would be particularly interesting on a state-to-state basis, and would also be interesting to separate by age, gender, and era of vehicle.

Reviewer 4:

The reviewer stated that the project does not present an argument as to why safety is related to mass and suggested perhaps a survey should be conducted first on this question. The reviewer also remarked that the analysis does not consider a number of variables such as the use of cell phones, mass times velocity, the impact strength of the materials in the body construction, time of the year, road conditions, or day of the week. The reviewer noted that 2016 and 2005 have very different driver behaviors and further suggested perhaps two sub groups, 2005-2010 and 2011-2016 can be compared.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that a lot has already been accomplished under an aggressive schedule. The reviewer added that while this schedule was necessary to meet regulatory requirements (such as the mid-term review), nevertheless, a lot has been completed and (just as importantly) properly disseminated.

Reviewer 2:

The reviewer concluded that the project seemed to have accomplished its goals within the limits of data availability. The reviewer reiterated that again, it seemed to be a very well-constructed and executed data analysis, but added how representative it is of the whole is obviously still unclear.

Reviewer 3:

The reviewer remarked that much data analysis has been performed but that more effort should be spent on identifying variables.

Reviewer 4:

The reviewer commented how the project will help achieve a 40% reduction is fuel consumption is questionable, adding that for one thing, it will be difficult to prove in the short term that people will purchase lighter vehicles based on this study. However, the reviewer also stated that this analysis is important and should be done because vehicle safety is obviously critically important. The reviewer concluded that processed data like this will influence how future vehicles are designed, making them safer and hopefully lighter at the same time.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that under this project, the DOE Lawrence Berkeley National Laboratory is collaborating with the National Highway Traffic Safety Administration (NHTSA), the U.S. Environmental Protection Agency (EPA), and the California Air Resources Board (CARB). The reviewer enthused that these are exactly the appropriate parties to work with on this effort, as they are the ones making regulatory decisions.

Reviewer 2:

The reviewer remarked that there is good collaboration with NHTSA, EPA, and CARB.

Reviewer 3:

The reviewer noted that the team collected data from large public entities to generate as much information as possible. Although more data would be better, the reviewer acknowledged that as highlighted by the speaker, it is currently unavailable. The reviewer added that this type of work may increase the amount of data collected in the future, for example, having all states collect vehicle identification numbers when vehicles are registered.

Reviewer 4:

The reviewer stated there is collaboration with NHTSA, EPA, and CARB, adding that a question comes to mind if data from other parts of the world can be used or used to compare.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the project focus is well laid out and intends to collect more data as it becomes available.

Reviewer 2:

The reviewer observed that there is a specific list of remaining activities, tightly focused upon regulatory requirements. The reviewer also noted that the project is 90% complete and is scheduled for completion in September 2017, so there are not that many activities remaining, and those that are appear to be important pieces in need of development.

Reviewer 3:

The reviewer stated that the project ends this year.

Reviewer 4:

The reviewer asked how will the results be verified and can they be validated.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer remarked that as vehicles are designed to reduce weight to reduce petroleum consumption, safety cannot be compromised. The reviewer further remarked that this research does a statistical study of auto fatalities and highlights that other factors beyond vehicle weight are the greatest influence on vehicle safety. Observing that it has also shown that it is not overall mass that influences safety but the differences in mass that have a greater impact, the reviewer praised this type of research as invaluable and said it should be continued on a longer term bases to observe the trends in fatalities.

Reviewer 2:

The reviewer replied yes, adding that the project is focused on the impact of changes in vehicle weight and size. The reviewer elaborated that changing these parameters requires looking at results upon both safety and fuel economy (and thus overall energy consumption) and that the increased emphasis upon fuel economy is driving opportunities for implementation of VTO technologies, particularly lightweight materials for increasing efficiency without necessarily changing vehicle size.

Reviewer 3:

The reviewer said yes, adding that the project allows DOE to quantitatively assess the health and safety aspects of vehicle lightweighting, which is a key piece in the strategy to displace petroleum.

Reviewer 4:

The reviewer commented that the project can only contribute to lightweighting if the outcome is that light weight vehicles are not a safety risk, but since the outcome cannot be predicted, this project might or might not support DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer replied that funds appear sufficient.

Reviewer 2:

The reviewer said no comment.

Reviewer 3:

The reviewer remarked that the funding might be sufficient for the work planned, but it certainly is not sufficient for reaching a convincing outcome.

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Acronyms and Abbreviations

°C	Degree Celsius
µm	Microns
3GAHSSS	Third-Generation Advanced High-Strength Steel
Al	Aluminum
AMR	Annual Merit Review
BEV	Battery Electric Vehicle
CAE	Computer-Added Engineering
CARB	California Air Resources Board
CF	Carbon Fiber
CFRP	Carbon Fiber-Reinforced Polymer
CPEC	Close Proximity Electromagnetic Carbonization
CY	Calendar Year
DOE	Department of Energy
EPA	U.S. Environmental Protection Agency
EPMA	Electron Probe Micro-Analyzer
Eu	Europium
EV	Electric Vehicle
FBJ	Friction Bit Joining
FCA	Fiat Chrysler Automobiles
FLD	Forming Limit Diagram
FSS	Friction Stir Scribe
FSW	Friction Stir Weld
FY	Fiscal Year
GHG	Greenhouse Gas
GM	General Motors
H/D	Hydrogen/Deuterium
HAZ	Heat-Affected Zone

HPDC	High-Pressure Die Cast
HP-RTM	High-Pressure Resin Transfer Molding
ICE	Internal Combustion Engine
ICME	Integrated Computational Material Engineering
IP	Intellectual Property
LCA	Life-cycle analysis
MD	Molecular Dynamics
Mg	Magnesium
Mn	Manganese
MYPP	Multi-Year Program Plan
NDE	Non-Destructive Evaluation
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PAN	Polyacrylonitrile
PHS	Press-Hardening Steels
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RE	Rare Earth
SCC	Stress-Corrosion Cracking
SUV	Sport Utility Vehicle
TWB	Tailored-Welded Blanks
UHSS	Ultra-High Strength Steels
USAMP	United States Automotive Materials Partnership
VTO	Vehicle Technologies Office
Zr	Zirconium

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8. Propulsion Materials

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Propulsion Materials (PM) activity supports research to develop higher performance materials that can withstand increasingly extreme environments and address the future properties needs of a variety of relevant high-efficiency powertrain types, sizes, fueling concepts, and combustion modes. PM applies advanced characterization and multi-scale computational materials methods, including high-performance computing, to accelerate discovery and early-stage development of cutting-edge structural and high-performance materials for cleaner, more efficient powertrains. Research areas include Higher-Strength Materials for Elevated Temperatures; Lightweight Powertrain Alloys; and Integrated Computational Materials Engineering (ICME) Tools that combine high-performance computing capabilities, multi-length material models, and boundary-layer resolved thermos-kinetic models.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: lm000 Presentation Title: Material Technologies – Overview
Principal Investigator: Felix Wu (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer stated that the current program area for Materials Technology was covered very thoroughly including background, overarching strategy, focus areas and program goals. The current approach to address strategic future challenges and significant opportunities is somewhat dated; however, the presentation indicated that revisions are underway. The presentation addressed materials research that is ongoing to reach VTO goals by 2030 including the types of materials and where they will be used in commercial vehicles. The presentation also described the trend for increasing fuel efficiency using weight reduction and materials research in the area of internal combustion engines (ICE).

Reviewer 2:

The reviewer said that the strategy was well-stated.

Reviewer 3:

The reviewer commented that the program area was adequately covered for ICEs. However, the scope needs to be broader to identify material challenges for electrified vehicles.

Reviewer 4:

The reviewer noted that the Materials Technology program contains two portfolios (lightweight and powertrain). The issues related to the two portfolios are presented and the outcomes from the past were discussed. The future direction of the portfolios including budget were presented. Even though the future budget is yet to be confirmed, planning for the program had been presented. Inputs were sought from participants during a separate discussion in the evening.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:

The reviewer said that the balance between near-term and mid-term R&D is well balanced to address the challenges in materials research as defined in the VTO Multi-Year Program Plan (MYPP). The long-term R&D requirements are currently being restructured and should be based on the revision of the Materials Technology roadmap that will address any new challenges and R&D opportunities over the next 5-10 years.

Reviewer 2:

The reviewer observed that the objective is well balanced between near-, mid- and long-term activities.

Reviewer 3:

The reviewer suggested that the presenter provide a roadmap that shows the near-mid-long term research clearly with timeline.

Reviewer 4:

The reviewer stated that because the lightweighting portfolio is relevant even when complete electrification of vehicle propulsion occurs, it is necessary to look into the long-term future. While the work on aluminum (Al) alloys caters to the near- and mid-term focus, the research on magnesium (Mg) and carbon fiber-reinforced polymer (CFRP) caters to the long-term future. In case of powertrain materials, the reviewer remarked that the development of materials for high temperature stability is the only area of focus which will benefit in near- and mid-term goals. The program is not planning to work on long-term research.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer stated that the issues and challenges for the current program were adequately addressed and that the major accomplishments supported how the program has addressed these issues. Future issues and challenges are currently under review in order to properly structure the program to address new issues and challenges.

Reviewer 2:
The reviewer said that the benefit and importance of this program is well stated.

Reviewer 3:
The reviewer remarked that issues and challenges were addressed to some extent. The reviewer would like to see gaps and/or challenges identified and presented for existing projects moving forward.

Reviewer 4:
The reviewer noted that the fuel efficiency improvement is the major challenge; this is the focus of the two portfolios. The powertrain materials research focuses also on emissions.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer remarked that plans were identified for addressing issues and challenges. The presenter addressed the current plan to update and revise the matrix for future opportunities, critical challenges, and impacts of a variety of materials and issues that may arise for incorporating materials into vehicle lightweighting projects. The presenter also stated that a meeting of representatives from industry, academia and government was being held during the Annual Merit Review (AMR) to start changes to the matrix. These inputs will assist in updating the matrix so that it can be used for development of a revised Materials Technology roadmap to aid in funding future research projects.

Reviewer 2:
The reviewer said that the future program identifies the possible areas of research for both portfolios (lightweighting and powertrain).

Reviewer 3:
The reviewer stated that no plan was presented for addressing issues and challenges.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
The reviewer noted that there were five areas addressed that benchmarked progress in terms of accomplishments that has occurred over the last year. In each case, the innovations and impacts of the accomplishments were detailed.

Reviewer 2:
The reviewer stated that the major achievements in five different projects were presented highlighting the past achievements. No roadmap was presented explaining the current developments against the older ones.

Reviewer 3:
The reviewer remarked that accomplishments were presented but not in an incremental manner relative to last year.

Reviewer 4:
The reviewer was not able to connect fiscal year (FY) 2017 results to FY 2016. The presenter focused too much on the innovation aspect which is "ok" but difficult to compare the progress from last year.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer said that the projects in the Materials Technology area are addressing broad problems and barriers in the VTO such as reducing the weight of an ICE vehicle by 10% to improve fuel economy by between 6% and 8%, and achieving a 13% improvement in freight efficiency from a 6% reduction in vehicle structural weight. Also, research in catalysts will help to improve combustion efficiencies for highly efficient gasoline engines. Progress is being accomplished through projects for lightweight metals, composites and multiple-material joining methods for these materials as well as new high temperature alloys and catalysts for more efficient combustion.

Reviewer 2:
The reviewer stated that both problems of fuel efficiency and emissions are addressed by the portfolios.

Reviewer 3:
The reviewer would like to see electrified vehicles to broaden the scope.

Reviewer 4:
The reviewer did not feel that the projects were addressing the broad problems and barriers. The propulsion material projects do not include lightweight driveline.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer commented that the Materials Technology program is focused on addressing the need to provide lightweight material and propulsion systems solutions to the automotive industry that will achieve fuel savings in future vehicle designs. The ICME efforts demonstrated excellent collaboration between academia, the national laboratories and industry (original equipment manufacturers (OEMs) and suppliers). Considering the small budget for the number of projects, the program appears to be well managed and is very effective in achieving the goals in the current VTO MYPP.

Reviewer 2:
The reviewer agrees that the program appears to be focused, well-managed, and effective.

Reviewer 3:
The reviewer stated that the focus for both portfolios is on Integrated Computational Materials Research and computer aided decision making. The work on CFRP may be over extended with many projects during the review process.

Reviewer 4:
The reviewer remarked that the group headcount of two persons was insufficient to achieve a focused, well-managed portfolio.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer noted that the key strength of projects in this program is the focusing on the correct material solutions for addressing lightweighting of vehicle structures and combustion engines. An additional strength is the highly effective collaboration between academia, national laboratories and industry that is resulting in good transition of lightweight materials technologies and ICME products to the automotive industry. The weaknesses of projects in this program are the lack of defined transitions in certain areas of propulsion materials and the slow execution of specific projects; e.g., a 2013 FOA project that has only reached 50% of its goal after 4 years of research. Projects are normally not funded for more than 5 years.

Reviewer 2:

The reviewer identified the key strength as reducing cost and weight using a multiple-prong approach. The primary weakness identified was not including electric vehicles (EVs) to reduce the weight (e.g., cables or motor).

Reviewer 3:

The reviewer identified the key strengths as the work on development of ICME tools for metals, and low-cost carbon fiber (CF). The reviewer identified the key weakness as the joining of CFRP with other metals using mechanical joining. The destruction of CF reduces the effectiveness of joining. This has been understood for a long time but still there are a few projects or tasks studying this effect.

Reviewer 4:

The reviewer noted the key strengths as an understanding that progress is made with a vertical supply chain project team. The primary weakness identified by the reviewer was that the funding awards include large consortium projects which include many universities, several DOE national laboratories, several OEMs and several suppliers. Felix even stated “the Friction Stir Welding project is a great demonstration of a well-balanced project team, which delivers results.”

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer noted that in some cases the approach is very novel. For example, joining methods for dissimilar metals using high temperature fusing technology and tailored welds, ICME design and crash validation of structural components made of lightweight metals and composites, and next generation three-way catalysts to improve combustion efficiency at lower temperatures.

Reviewer 2:

The reviewer stated that the approach taken for the projects is quite unique and would forward to seeing future progress in the next meeting.

Reviewer 3:

The reviewer commented that some projects are quite innovative in the use of current testing and computational expertise. The examples include the hydrogen intake in Mg and ICME of steel alloy development.

Reviewer 4:

The reviewer said that these projects represent novel and/or innovated ways. The reviewer further noted that ICME and science-based projects have achieved incremental progress.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer remarked that, for the projects presented, there was outstanding collaboration between academia, the national laboratories, manufacturers, automotive partnerships, and first-tier suppliers. The slides that showed the organizations' logos and described the program partnerships is an excellent example of collaboration. The description of the Lightweight Materials Automotive Consortium is another good example of how to connect industry with a network of 10 national laboratories.

Reviewer 2:
The reviewer stated that the program has engaged appropriate partners.

Reviewer 3:
The reviewer said that overall, the number of partners involved in the projects is healthy. However, in some projects the partners do not contribute significantly to technical expertise of other resources. The partners seem to get involved only for in-kind cost contribution.

Reviewer 4:
The reviewer said that the program has engaged appropriate partners, just too many on the same project.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer stated that, based on the technology transitions described, the program appears to be collaborating very effectively in the majority of the projects. This appears to be occurring with hardware as well as software developers and suppliers.

Reviewer 2:
The reviewer considered it difficult to comment due to limited information.

Reviewer 3:
The reviewer did not feel the program collaborated with partners effectively. The lack of staff (two total) does not enable sufficient time to collaborate.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer noted that the only possible gap would be the current lack of definition and prioritization of research efforts in the Materials Technology Program for the next five to 10 years. With the potential for reduced budgets, it is important that the proper areas of research be defined to allow funding to be applied in those areas. Hopefully this will be resolved with the revision to the significant opportunities and critical challenges matrix.

Reviewer 2:
The reviewer would prefer to see the scope extended beyond ICEs.

Reviewer 3:
The reviewer said that a major review of the current state-of-the-art may be needed. The last review was done a few years ago.

Reviewer 4:
The reviewer identified driveline and technology projects to overcome commercialization barriers as the key gaps.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

The reviewer noted that the overview presentation did not allow time for a description of the full Materials Technology portfolio. In general, all areas of materials research (metals, CF and composites, methods of multiple-material joining, integrated computational materials engineering, high temperature materials, and materials to improve propulsion systems) adequately address the needs to meet VTO goals.

Reviewer 2:

The reviewer identified life cycle analysis (LCA) as a topic not adequately addressed. Cradle to grave analysis needs to be part of every project. This methodology identifies CO_2 associated with production, use and recycling. Every recipient must be forced not to ignore LCA.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer noted that the program is described as addressing problems with well-known materials (Al, Mg, high-strength steels, and CFs) where automotive manufacturers and first-tier suppliers have the most interest. Future materials will use nanotechnology to provide better properties and characteristics that will be applicable to the automotive industry. The reviewer suggested that some investment should be made in those areas to further meet or exceed VTO programmatic goals.

Reviewer 2:

The reviewer recommends considering EVs.

Reviewer 3:

The reviewer noted that the research on propulsion materials to reduce emissions will be useful.

Reviewer 4:

The reviewer identified the area of lightweighting relative to driveline and transmission systems. Demonstrating efficiency related to mass reduction versus general engine downsizing should be considered, which results in 6% for every 10%.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer stated that the current approach is very good for addressing near-term and mid-term barriers and challenges. New challenges will prevail for the long-term over the next decade and the program should be prepared to address them. Research organizations that are developing cutting-edge technologies should be solicited for input as to what will be the future generation of materials and how they may apply to VTO future goals. Until there is an update to the VTO MYPP, this may be a difficult task.

Reviewer 2:

The reviewer commented that the course being taken by the current team is good; international collaboration and funding to support could improve the pace of research.

Reviewer 3:

The reviewer would like to see a broader view of the material technologies in terms of the roadmap along with describing the challenges associated with each area. The reviewer said that less focus should be placed on describing innovations.

Reviewer 4:

The reviewer recommended LCA as a new way to approach the barriers, using metrics such as total manufactured cost at volume of 100,000 or 250,000 units per year.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer remarked that, overall, the Materials Technology program is very effective. A few of the projects have poor execution and should be re-directed to better meet the goals and milestones of the research. Some projects do not have transition partners identified in the early stages of the projects and the principal investigators should be encouraged to identify partners in the first year of their projects.

Reviewer 2:

The reviewer recommended increasing the size of the group in order to better manage and engage with projects instead of simply monitoring them. This reviewer strongly advised that the program MUST stop funding several programs that have not met go/no-go objectives.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 8-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
pm053	High-Temperature Engine Materials: Valve Materials Subtask	G. Muralidharan (ORNL)	8-12	3.50	3.60	3.50	3.50	**3.55**
pm057	Applied Computational Methods for New Propulsion Materials: Future Engine Requirements	Charles Finney (ORNL)	8-16	3.40	3.30	3.10	3.40	**3.31**
pm060	ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications	Mei Li (Ford Motor Co.)	8-21	3.50	3.38	3.00	3.25	**3.34**
pm061	Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines	Mike Walker (General Motors)	8-25	3.30	3.20	3.40	3.10	**3.24**
pm062	High-Performance Cast Aluminum Alloys for Next-Generation Passenger Vehicle Engines	Amit Shyam (ORNL)	8-29	3.80	3.80	3.70	3.60	**3.76**
pm066	Innovative SCR Materials and Systems for Low-Temperature Aftertreatment	Yong Wang (PNNL)	8-34	3.25	3.19	3.13	3.19	**3.20**
pm067	Next-Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines	Christine Lambert (Ford Motor Co.)	8-39	3.17	2.83	3.17	3.00	**2.98**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
pm068	Sustained Low-Temperature NO_x Reduction (SLTNR)	Yuhui Zha (Cummins)	8-42	3.14	3.36	3.36	3.29	**3.29**
Overall Average				**3.37**	**3.35**	**3.30**	**3.30**	**3.34**

Presentation Number: pm053
Presentation Title: High-Temperature Engine Materials: Valve Materials Subtask
Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

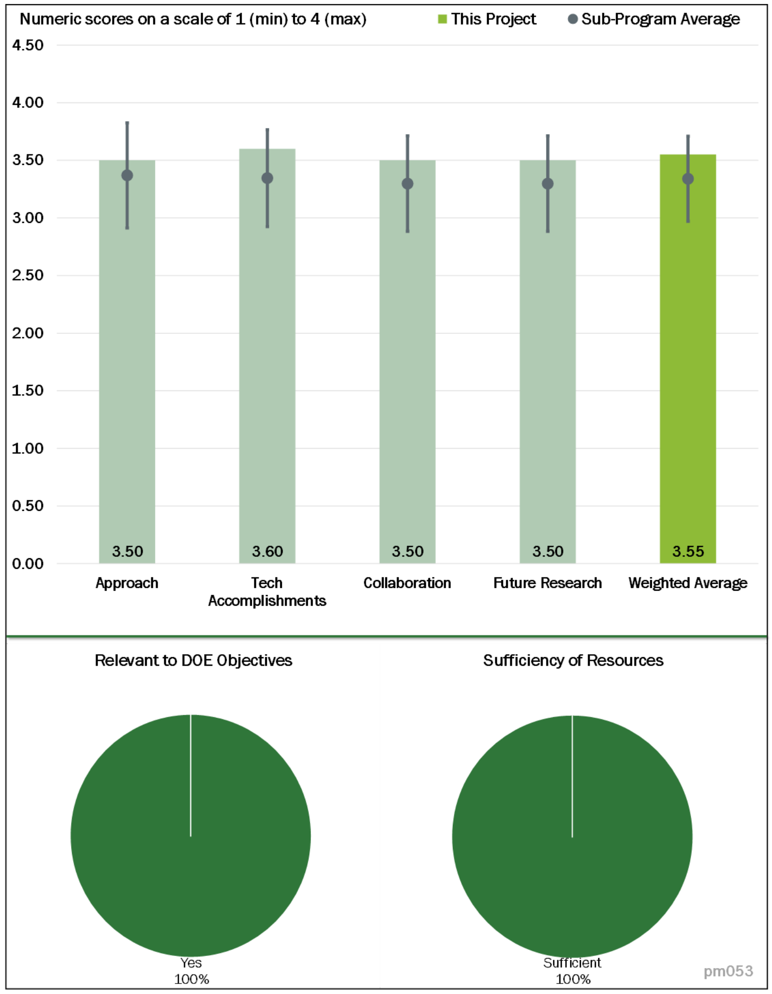

Figure 8-1 - Presentation Number: pm053 Presentation Title: High-Temperature Engine Materials: Valve Materials Subtask Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Presenter
G. Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed,

Reviewer 1:
The reviewer stated that the project looks well designed and has identified both the technical and cost barriers associated with the chromia- and alumina-based valve materials for high-temperature applications.

Reviewer 2:
Though not a materials scientist, the reviewer declared that the approach for the project was good and that the presenter did a good job explaining the motivation for the approach of the project.

Reviewer 3:
The reviewer remarked that the principal investigator (PI) addressed the comments from previous reviews to focus this new project effort on finding new alumina-forming alloys for exhaust valves. The reviewer noted that oxidation resistance was an issue at high temperatures so, to address this issue, an increased percentage of alumina was added to the alloy to offset oxidation; however, doing this lowers the strength of the material. The reviewer commented that the project team used a computationally guided approach to investigating alloys that balanced strength, oxidation resistance, and cost, which are needed to achieve the end targets. The reviewer stated that cost constraints and targets must be met for success and that mechanical property improvements may be obtained via heat treatment and possibly other techniques.

Reviewer 4:
The reviewer believed that the team's approach appeared to be focused upon overcoming specific barriers associated with increasing exhaust gas temperatures. The reviewer commented that the baseline material does not appear to have significant strength above 850° Celsius (°C), which will be required in the future. The reviewer identified one concern in the approach, which was that the project is focused overall upon providing increased performance materials while remaining cost-effective; however, there did not appear to be any

specific cost targets identified for the project. The reviewer noted that several proposed alloys appear to have comparable or slightly better costs than the baseline. The reviewer stated that the project should identify if comparable cost is the target, or if there is a price premium that might be considered acceptable to ultimate users.

Reviewer 5:

The reviewer commented that the basic premise for the project was that newer engine technologies will require higher exhaust temperatures and that currently available, relatively affordable alloys were limited in strength to 870°C. Newer alloys with sufficient strength at higher temperatures, up to 950°C, are required.

The reviewer agreed that newer engine combustion concepts mandate operation at higher in-cylinder pressures, but stated that the requirement of operational capabilities of the valves at higher temperatures was new information. The reviewer proposed that the presenter should share the supporting background information for this newer specification (i.e., what source provided this requirement).

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the activities appear to be progressing in accordance with the plan. The reviewer noted that some alloys meet or exceed certain performance criteria (such as strength), while others meet other criteria (such as oxidation resistance). Thus, the reviewer remarked that the project was looking at how to balance the compositions versus performance criteria. It was apparent to the reviewer that the project team was getting closer to achieving this balance by demonstrating revised alloys that appear to show significantly better performance, but “yield strength” improvements, without losing oxidation resistance, were still required.

The reviewer also stated that project has identified some gaps in availability of needed predictive models.

Reviewer 2:

The reviewer surmised that because existing alloys cannot meet the requirements at 950°C, the project team had identified cost, high-temperature strength, and oxidation resistance to be the three critical parameters. The reviewer believed that through trials of optimizing these three characteristics, the project team opted for alumina scale-forming alloys instead of the current chromia scale-forming ones. The reviewer commented that the project team managed to develop two alloys that meet the requirements.

Reviewer 3:

The reviewer affirmed that for the amount of funding allocated for this effort, significant progress has been accomplished. The reviewer concluded that was due in part to leveraging previous research to focus the effort of this project on a targeted alloy. The reviewer noted that the material downselect was successful and that further improvements to mechanical properties would be achievable through heat treatment and other processes.

Reviewer 4:

The reviewer noted that the project team was well able to differentiate the two alloying materials and create new material compounds with lower cost that achieve most targets.

Reviewer 5:

The reviewer stated that the project team’s technical accomplishments were very good.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the team was working well with collaborators, obtaining valve materials for comparisons, and carrying out tests, such as the work done with Gleeble.

Reviewer 2:
The reviewer stated that the project had excellent team partners, who possess the requisite expertise and access to relevant developmental facilities.

Reviewer 3:
The reviewer said that the collaboration was good and the collaboration partners were appropriate.

Reviewer 4:
The reviewer noted that the project partners include two materials suppliers and Argonne National Laboratory, and that the partners were appropriate given the stage of the project. The reviewer commented that later efforts might require working with component or engine manufacturers to allow for evaluation of the material in an actual valve application.

Reviewer 5:
The reviewer believed that the national laboratory and industry collaboration was excellent; however, the addition of academia would improve collaboration even further.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found the project team to be properly focused on the alumina formers while trying to increase temperature and strength. The reviewer commented that the project team has identified limitations of both alloys and is designing new alloys and processes to find an optimum, which does appear to be the most logical direction for the project.

Reviewer 2:
The reviewer stated that the remaining efforts appear targeted at achieving project goals and, given progress to date, the reviewer believed that the project would succeed.

Reviewer 3:
The reviewer commented that the projected future research was a natural extension of the work performed so far.

Reviewer 4:
This reviewer believed that the future work appeared to be a reasonable extension of the current status.

Reviewer 5:
The reviewer noted that the focus of future work should include mechanical property improvements prior to investigating alternative alloy configurations, which would maintain focus on achievement with a realistic timeline. The reviewer stated that the mechanical property improvements appeared to be obtainable via microstructure improvement techniques, like heat treatment. Finally, the reviewer suggested that this be the initial focus of the future research prior to investigating alternative alloy configurations and that the project team needed to continue to look for opportunities to leverage previous work into this project.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that engine efficiency can be increased by increasing temperature and pressures in the combustion chamber, but this requires materials capable of operating at higher temperatures without significantly added cost. The reviewer believed that this project aims to increase the temperature capabilities of valve materials without significant cost additions, which is in alignment with DOE goals.

Reviewer 2:
The reviewer commented that the project effort was focused on improved engine valve materials to allow for higher efficiency operation. The reviewer believed that the expectation in the industry is that exhaust gas temperatures will continue to rise, requiring higher performance materials; therefore, this project is relevant work.

Reviewer 3:
The reviewer observed that the high-temperature alloys developed in this effort would enable newer combustion concepts that, in turn, lead to reduced petroleum consumption. As a result, the current project aligns with DOE goals.

Reviewer 4:
The reviewer stated that materials that maintain their strength at higher engine temperatures will facilitate improved engine performance; therefore, this is very relevant work.

Reviewer 5:
The reviewed noted that high operational temperatures enable higher efficiency engine operation, which aligns with DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the researchers are making good progress and have defined the appropriate list of tasks for the budget they have.

Reviewer 2:
The reviewed observed that the resources are commensurate with the projected effort.

Reviewer 3:
The reviewer believed that the funding appeared sufficient for this project.

Reviewer 4:
The reviewer did not identify any funding concerns.

Presentation Number: pm057
Presentation Title: Applied Computational Methods for New Propulsion Materials: Future Engine Requirements
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

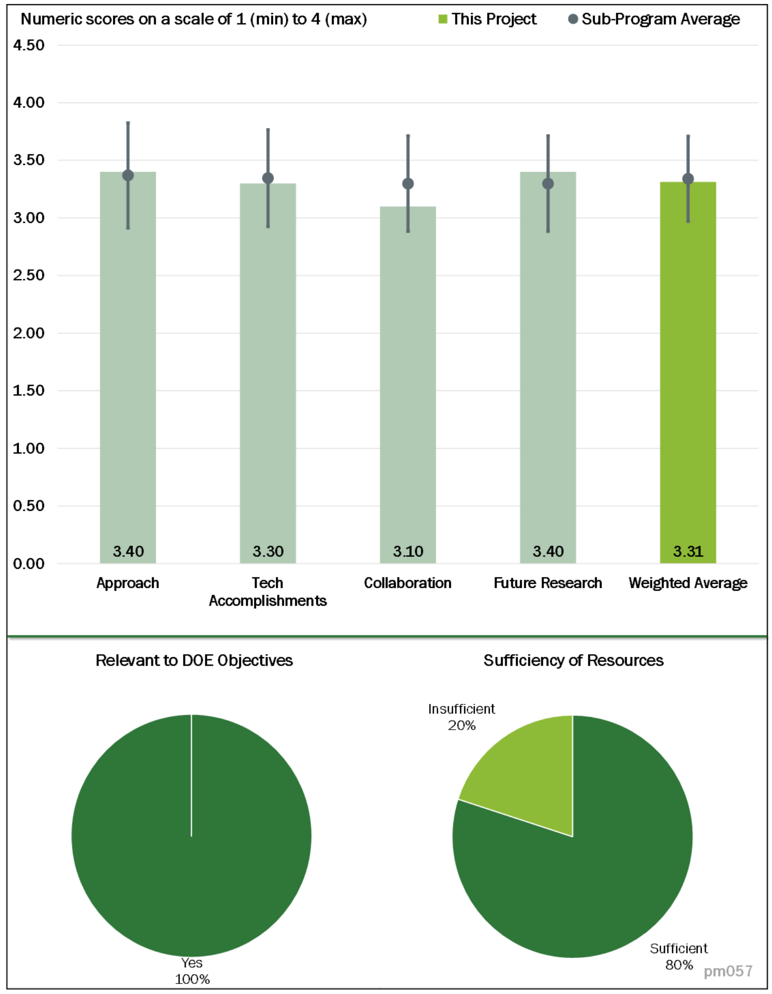

Figure 8-2 - Presentation Number: pm057 Presentation Title: Applied Computational Methods for New Propulsion Materials: Future Engine Requirements Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that approach is starting to show very solid signs of bringing computational fluid dynamics (CFD) and finite element modeling (FEM) together effectively, which was a good reflection on the overall program plan. The reviewer highlighted that the pressure was on to close the project out over the next year or so and really take the complexity to the next level. This step was important in order to prove that all critical factors are being included. The reviewer expressed that the mono-material model of the head, for example, would be extraordinarily beneficial as componentry is added with varying properties.

Reviewer 2:

The reviewer observed that the project was using applied computational methods to investigate solutions to engine material requirements for high-efficiency heavy-duty (HD) engines, and investigating possible material configurations to solve material property degradation (yield strength, fatigue life, creep, and corrosion) caused by the higher temperatures needed for increased efficiency engines. The reviewer commented that this effort directly targets material barriers identified in the VTO Multi-Year Project Plan (MYPP).

The reviewer recognized that through the project efforts, a conjugate heat transfer model was developed and is being refined as well as an FEM for the 15-liter (L) engine to evaluate pressure and thermal effects on engine cylinder components: head, valves, and liner. Also, fatigue has been modeled to achieve materials properties targets.

The reviewer affirmed that the approach used expanded the model beyond cylinder-cylinder head-intake to all areas surrounding the cylinder to get heat transfer effects from other parts of the engine and that material characterization was well underway. The reviewer stated that the project was making good use of computer capabilities in the laboratory to run models and explore multiple combustion strategies. The reviewer concluded that the modeling was being used to identify materials development (guiding the gap analysis) to help with selecting materials of the future that could be used to meet the targeted properties.

Reviewer 3:

The reviewer noted that this work was developing a computational tool and powerful analysis techniques that could be very helpful for developing or choosing materials for extreme in-cylinder conditions. The reviewer concluded that if this work was successful, it would allow combustion systems to be developed that are not currently feasible.

Reviewer 4:

The reviewer observed that the modeling activity of this project appears to combine CFD and FEM into a predictive model for determining the in-cylinder temperature and pressure effects on component integrity. The reviewer commented that there was good coupling with engine efficiency targets, which require higher temperature materials to reach the efficiency levels that would be needed going forward. The reviewer stated that obtaining an understanding of where high-temperature events are impacting the cylinder components and how the material reacts was very important to the survivability of both HD and light-duty (LD), highly efficient engines that can work at higher temperature and pressure regimes. Therefore, the reviewer opined that this work was very appropriate for accelerated advanced material development. However, the reviewer expressed some concern that predicting these effects only using “un-aged” samples may not capture important elements of the failure mechanism related to chemical exposure.

Reviewer 5:

The reviewer remarked that the current project was attempting to tie together three different computational efforts, namely conjugate heat transfer CFD, FEM, and fatigue modeling to determine the material requirements of future high-efficiency engines. While this goal is laudable, the reviewer was concerned that given the uncertainties in computational methods and the fact that the high-efficiency combustion schemes are still evolving, the effort is open-ended. Instead, the reviewer recommended that the team collaborate with a specific OEM and concentrate on one specific high-efficiency combustion scheme that is limited by material properties.

The reviewer did not agree with some of the basic assumptions of this effort, such as the projected future peak cylinder pressures would be 300 bar (the actual pressures could be much lower to attain nitrogen oxide (NO_x) targets); some of the stress points cannot be overcome through design modifications and existing castable alloys are inadequate.

The reviewer highly recommended close partnership with OEMs and use of the knowledge base established through cut-and-try methods, rather than purely relying on computational efforts. The reviewer had an additional concern that this project was trying to establish a capability that already exists with industries, such as Nemak.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the base level work appeared well-grounded and focused. The reviewer highlighted that the use of both the CFD and FEM computational elements, to better assess and predict “hot spots” and fatigue risk in cylinder component material, was worth support from a manufacturing and engineering standpoint. The reviewer stated that the predicted results appear to be fundamentally sound and consistent from experimental results and, as this was an evolving tool, the continued validation of the model with appropriate testing was needed to increase the accuracy and confidence in the results. The reviewer remarked that this work was already driving material improvements and alternatives at the manufacturing level. Also, the reviewer concluded that the project had good coupling with engine efficiency targets that require higher temperature materials to reach the efficiency levels needed going forward.

Reviewer 2:

The reviewer noted very good progress in developing the analysis techniques.

Reviewer 3:

The reviewer acknowledged some performance issues identified with selected material compacted graphite iron 450 (CGI450); however, the model was developed, which identified this issue during the testing. The reviewer commented that this failure may not be within the operational range expected in future engines as understanding these limitations present an opportunity to integrate thermal barrier materials into future engine designs.

Reviewer 4:

The reviewer noted that the progress against DOE goals as a general assessment was excellent, but the practical progress of the effort thus far is lagging a bit, which was identified by the presenter. The reviewer noted concern in that the critical components of the program are naturally toward the end and because the mechanical verification testing has been completed, the modeling and simulation portion has to start closing all of the loops. The reviewer was unsure whether there was a plan to keep things on track.

Reviewer 5:

The reviewer stated that fairly good progress had been made in characterizing high-temperature material properties and in performing conjugate heat transfer CFD modeling followed by CFD modeling to predict the high-stress regions in one-cylinder geometry. However, the reviewer noted that the issue remains that though the feasibility of this computational method has shown progress, the target for the project was determined by the researcher without the appropriate input from collaboration partners and industry.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer highlighted that because this project was focused on the development of analysis techniques and a predictive program or model, the need for collaboration with outside entities was not extensive; therefore, the current collaboration effort seems good.

Reviewer 2:

The reviewer stated that because the OEMs providing engine support were unnamed, it was difficult to state whether those collaborators fit within the team structure effectively. The reviewer highlighted that the Oak Ridge National Laboratory (ORNL) team seemed to need little in the way of outside support; nonetheless, collaboration is critical to ensure that target parameters remain accurate. The reviewer also noted that the figures presented as “current” on the graph of Slide 6 seem a bit dated.

Reviewer 3:

The reviewer stated that the presentation mentioned that the team comprised two OEMs partners, but their identity was being withheld. The reviewer recommended that a consortium of LD and HD engine manufacturers be formed to guide this effort.

Reviewer 4:

The reviewer remarked that collaboration and coordination with HD engine manufacturers was expected and employed for this work. However, the reviewer noted that incorporating LD engine manufacturers, such as passenger car OEMs, would benefit from the usefulness of this approach and gather additional support for this project.

Reviewer 5:
The reviewer stated that the presentation called out collaboration with two unnamed OEMs though there was no apparent coordination with a material producer or university.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
An advanced modeling approach such as this approach needs little in the way of voiced support because the ability to effectively model systems in the way that is being worked out in this program will enable continued refinement and levels of complexity, further adding accuracy to future models.

Reviewer 2:
The reviewer proposed that the project leads engage LD counterparts in this project as the HD side was already well addressed.

Reviewer 3:
The reviewer stated that the project team had very good plans for the future work and suggested that the analysis of thermal barrier coating and thermal swing treatments of the in-cylinder surfaces be integrated into future project work.

Reviewer 4:
The reviewer noted that the proposed future research was a natural extension of the work performed so far. The reviewer mentioned that the plan includes further material property determination at high temperatures, and computational modeling for fatigue.

Reviewer 5:
The reviewer stated that the CFD model looks well developed and that the next steps in the program could include the definition of required performance to meet future operating conditions. The reviewer acknowledged that the existing graphite iron options are not sufficient to meet future operational parameters; therefore, by clearly defining targets (including temperature and cost), a future material might be identified using integrated computational materials engineering (ICME) and developed for this application. The reviewer offered that because practical engines need a cast-iron material, the ICME approach may not yield an appropriate material.

The reviewer surmised that thermal barrier materials should be investigated to help with thermal management. Multiple materials (current and future candidate materials) could be folded into the advanced simulation model. Modeling could be used to identify materials development (guiding gap analysis), which would help with the selection of materials in the future that could meet the all targeted properties.

The reviewer noted that another possible future research topic would be the effect of chemical invasion into the material as these effects are not well known.

The reviewer observed that the PI proposed moving this analysis into the LD vehicle realm and scanning to develop the engine model and the use of different operating conditions. The reviewer commented that the PI should investigate getting these types of data from an OEM and should look to leverage existing resources and data when available.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer believed that the project absolutely met the objectives of reducing petroleum consumption per unit of work extracted and that the program was based on assessing the ability of emerging designs to meet increased efficiency demands.

Reviewer 2:
The reviewer commented that improved component durability—under the more-demanding temperature and pressure conditions that are present in advanced, highly efficient engines—was of high importance to manufacturers who are required to meet longer lifetimes of vehicle subsystems.

Reviewer 3:
The reviewer believed that the results of this project would allow the development of higher efficiency ICE materials.

Reviewer 4:
The reviewer was unsure whether any enablers would result from this effort although the reviewer acknowledged that this exercise was likely to develop a computational methodology to evaluate some candidate materials for advanced engine concepts.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that despite seemingly minor delays, the program seemed to be on a good progression schedule.

Reviewer 2:
The reviewer believed that this project was appropriately funded and staffed.

Reviewer 3:
The reviewed remarked that the researchers seem to have defined a program that would produce useful outcomes and stay within the current budget.

Reviewer 4:
The reviewer commented that the project resources appear sufficient (including carryover funds) to accomplish the goals of this project.

Reviewer 5:
This reviewer stated that at least one full-time equivalent of funding was recommended for one more year.

Presentation Number: pm060
Presentation Title: ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications
Principal Investigator: Mei Li (Ford Motor Co.)

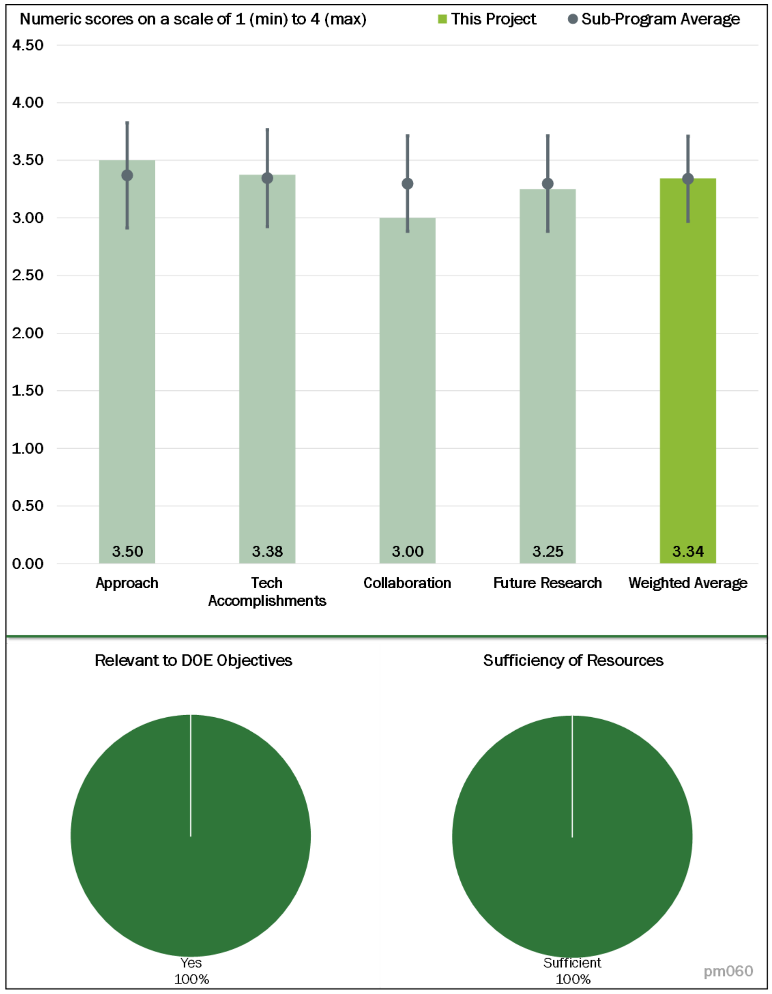

Figure 8-3 - Presentation Number: pm060 Presentation Title: ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications Principal Investigator: Mei Li (Ford Motor Co.)

Presenter

Mei Li, Ford Motor Co.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer noted that the program was very focused and well thought out and acknowledged that of the technical targets for new alloy development provided by DOE, the prime technical targets—tensile strength, yield strength, and fatigue strength at high temperatures (300°C)—were identified early on in the program. The reviewer noted that through the initial efforts of this project, two new alloys and the associated thermal processing methods had been developed.

Reviewer 2:

The reviewer believed that the project was an excellent integration of simulation, alloying experiments, and characterization focused on key path of precipitates.

Reviewer 3:

The reviewer acknowledged that the Ford approach was well organized, thoughtful regarding the proposed limits (110% cost), and generally effective and commended the project team. Despite the rather extraordinary credentials of the PI and the team, however, the reviewer stated that the real ICME element was not clearly identified. The reviewer believed that TC Prisma and Pandat were making excellent progress regarding accuracy, but that the project still had a long way to go in terms of reliable predictive capabilities.

The reviewer stated that it was difficult to imagine that the layout and execution of the experimental portion, which proved largely effective, was really overly strengthened by any ties with ICME, and that the reviewer was more convinced that a good experimental matrix approach was effective in selecting compositions and heat treatments of interest based on quality observations via use of transmission electron microscopy and dedicated composition analyses. The reviewer noted that this was not a drawback necessarily but left the proposed gap analysis somewhat underpopulated.

Reviewer 4:
The reviewer remarked that the team had limited background with this material and that their own comments would not be technically based. On the other hand, the team understood that materials were critical to pushing the limits of engine performance and represent a critical component in the cost of the engine.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer stated that the technical accomplishments were excellent. The project was following a well guided program plan where two alloys, whose properties met or exceeded DOE targets, had been identified. Subsequently, the reviewer asserted that during the project hardware effort, castings of a few cylinder components had been created and their mechanical properties were being tested. In parallel to the above effort, this reviewer noted that ICME methodology was followed to the extent possible to develop a model for rapid development of newer alloys and that gaps in the knowledge base were identified.

Reviewer 2:
The reviewer noted that project goals were being achieved with two materials, that the exploration of small angle X-ray to accelerate characterization appeared to be a nice innovation, and that it would be interesting to see final assessment.

Reviewer 3:
Though not a materials scientist, the reviewer noted that it was apparent that the research team was making good progress. The reviewer remarked that this program was not new this year yet the presenter did not show the standard slide addressing the previous year's reviewers' comments. The reviewer commented that having the prior year's comments would have been helpful in addressing this year's technical accomplishments. The reviewer surmised that the statements of the presenter and the comments from the audience indicated that this work will be useful and could be integrated into future production vehicles.

Reviewer 4:
The reviewer noted that the overall progress was clear from the results of mechanical testing against the experimental matrix; however, the reviewer was concerned with the project's inability to meet the proposed property improvements when the materials were exposed to the somewhat standard aging treatment (conditioning) prior to testing. The reviewer surmised that while it would appear that cylinder heads using the idealized alloy and heat treatment would be largely improved at engine assembly and bolt-up, if the material stability was lacking and the properties were lost after a reasonable amount of operation, then it was difficult to embrace the concept that real improvements have been made. The reviewer stated that these types of programs should discuss whether such post-aging (operation-based) needs to be part of the target property protocol and, if not, why that is an overly conservative treatment that is not reflective of engine operations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project team was composed of members who are highly regarded and have a history together. It was clear that this team would provide the core of a number of successful future projects in addition to this one.

Reviewer 2:
The reviewer acknowledged that Ford has partnered with Nemak, which is a leading provider of aluminum castings, and Alcoa, the world's largest provider of aluminum. Overall, the reviewer commented, that the team appears to have the right expertise and access to the required manufacturing and analytical facilities. The

reviewer remarked that the University of Michigan was also listed as a partner; however, their participation in the present effort was not very clear.

Reviewer 3:
The reviewer commented that the project team collaboration was reasonable though the presenter did not comment on the role being played by the collaborators who were presently engaged with the project.

Reviewer 4:
The reviewer stated that in an otherwise outstanding presentation, the roles and achievements of the various team members were not called out either in 2016 or 2017. Because collaboration is a scored criteria, the reviewer recommended that the presenter devote a slide to contributions from team members during future presentations.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Based on the material presented and current results, the reviewer stated that future plans seem good.

Reviewer 2:
This reviewer looked forward to the engine testing results, which will absolutely resolve any lingering doubt as to whether practical improvements have been made. The offer of further gap analyses is also of value. This reviewer suggested that the team should move past the use of these terms as a necessary offer when discussing ICME and embrace the fact that ICME approaches still lack considerable effectiveness in a number of areas. The reviewer strongly said to be critical here; it will help the overall ICME effort.

Reviewer 3:
The reviewer pointed out that the project is nearly complete and appropriately ends with completion of component level evaluation. The rig tests in progress are fine. The reviewer asked if there will there be engine tests.

Reviewer 4:
The reviewer noted that the two stated objectives—to develop comprehensive cost models to ensure that components manufactured with these new alloys do not exceed 110% of the cost using incumbent alloys A319 or A356, and to develop a technology transfer and commercialization plan for deployment of these new alloys in automotive engine applications—appear to have been forgotten.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer remarked that the ability to extend efficiency and performance of combustion engines through materials research that is readily deployable is absolutely within the goals of the DOE.

Reviewer 2:
The reviewer asserted that comments by the presenter indicated that the results of this work will be seen in vehicles on the road. That is great.

Reviewer 3:

The reviewer’s response was a “maybe.” The advanced alloys developed in this effort can potentially enable various advanced combustion schemes, which in turn may lead to reduced petroleum consumption in the United States.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the team has made great progress and appears to be on track to wrap the project up successfully.

Reviewer 2:

The reviewer stated that the project is near completion, with success.

Reviewer 3:

The reviewer said that the allocated funds are commensurate with the stated scope of work.

Presentation Number: pm061
Presentation Title: Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines
Principal Investigator: Mike Walker (General Motors)

Presenter
Mike Walker, General Motors

Reviewer Sample Size
A total of five reviewers evaluated this project.

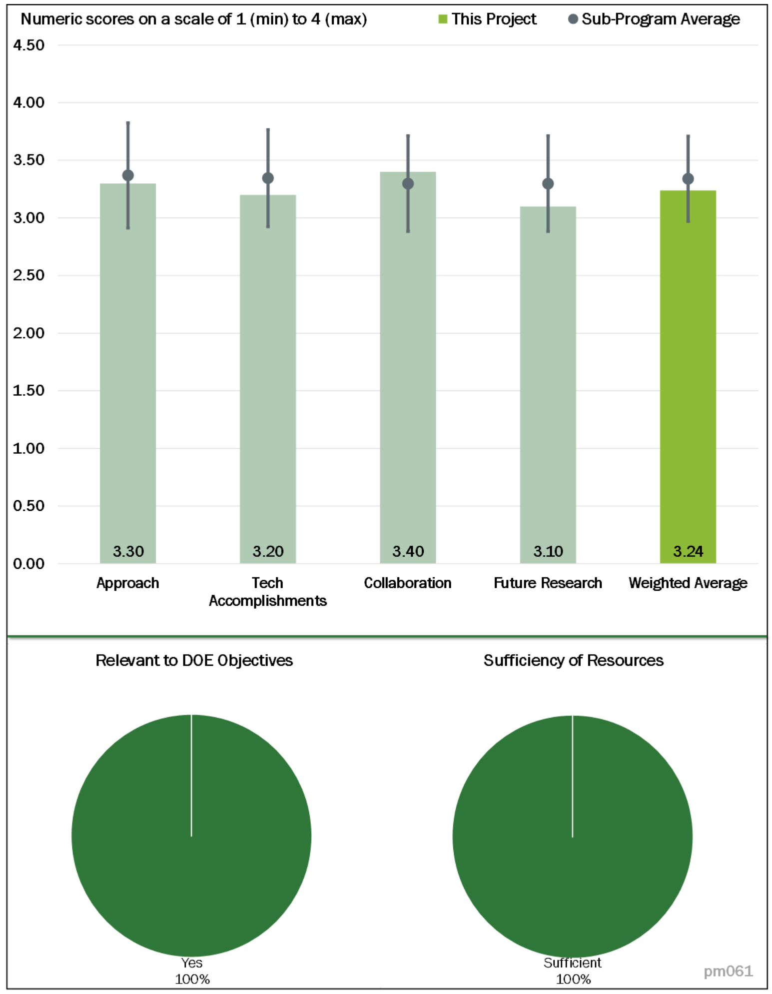

Figure 8-4 - Presentation Number: pm061 Presentation Title: Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines Principal Investigator: Mike Walker (General Motors)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer observed that the focus on the Q-phase has paid off and little is left to get to the casting stage. This comprehensive approach has all the classic material development steps: compositional evaluation, microstructure, modeling, mechanical testing, and castability, with a cast head end point to wrap it all up. Further work will be needed to tweak the room-temperature (RT) elongation work, but this is built into the approach.

Reviewer 2:
The reviewer stated that the researcher addresses the technical barriers of casting lightweight alloys and did good research overcoming those barriers.

Reviewer 3:
The reviewer commented that the approach looks to be sound and on a pathway to success.

Reviewer 4:
According to the reviewer, the project is showing good progress; the team and presentation of results reflect a commendable level of expertise. The ICME component seems to be largely underutilized, however. If Q-phase structure is the key to dialing up the stability and performance, the reviewer inquired about what other elemental additions outside of the normal list might stabilize it further. This reviewer further questioned whether Q based on known chemistry is really being embraced, and if it is hoped that minor changes to the DOE target properties will put the alloy over the top. The reviewer opined that, perhaps, the cost constraint is too much of a factor at this phase of the program, resulting in gentle nudges to the alloy rather than wholesale changes. The reviewer also saw a larger role for ICME in evaluating more widespread changes that can then be dialed back through experimental analyses. Overall, the program is doing extremely good work and making

progress toward the goal, but the reviewer would love to have seen some attempts at bold changes being evaluated (or at least being presented as having been considered) as a component of the program.

Reviewer 5:

Perhaps in hindsight, the reviewer remarked, the project may have lacked the computational breadth and "horsepower" to explore the necessary range of alloying options. Actual engine operation and tests do not appear to be part of the project completion. At least it is not conspicuous in the schedule and task list.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer said the researcher accomplished all of his goals to date.

Reviewer 2:

The reviewer found there to be good progress on the strength model development. Alloy 2 properties are approaching the DOE targets.

Reviewer 3:

The reviewer acknowledged that some technical accomplishments will add to the literature base—sub-lattice compositional work, stability range update, and strength modeling—and the reviewer liked to see this in government funded programs. All but two goals have been achieved: RT elongation and ultimate tensile strength (300°C). The goals were not easy, and the team is well on the way to achieving them.

Reviewer 4:

The reviewer expressed concern about the overall effect of the conditioning treatment and questioned whether this is a genuine representation of an engine with some operating time or an overly conservative view.

The properties following the conditioning treatment still seem to be a stumbling block, despite the fact that this drawback has apparently been identified previously and formally addressed by the team. The reviewer appreciated that the program is not complete and there are still ample months left to iron out additional improvements based on the adopted approach.

Reviewer 5:

The reviewer noted that the project has met most of its goals, but not all.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

According to the reviewer, the project is largely a "who's who" of ICME and OEM castings for automobiles. Hopefully, the program will provide something of a standard protocol for development efforts elsewhere.

Reviewer 2:

The reviewer stated that the success in technical accomplishments and the roles of the collaborators are matched. This shows good cooperation.

Reviewer 3:

The reviewer pronounced the team, with industry and academia included, to be very good.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer called for some more compositional work in order to hit all targets. The team seems to have a good grasp on this, and it is reasonable to expect that goals can be achieved.

Reviewer 2:
The reviewer agreed that the future work planned looks to be on a pathway to achieving the original project objectives and goals.

Reviewer 3:
The reviewer supported that the proposed research is to finish out the project.

Reviewer 4:
The reviewer noted that future work is key to the program's overall level of accomplishment and the reviewer wished the team success. It would be more inspiring if there were laboratory-level approaches that were clearly ahead of the property targets, and upcoming engine testing would determine their respective levels of viability. However, the reviewer appreciated that the team is taking a more measured approach and limiting the probability of surprises when they reach the final validation stage.

Reviewer 5:
The reviewer opined that commitment to full component-level validation and a commercialization plan are not evident. Perhaps this was not a contract requirement.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer had no issues with relevance. This project family (increased head performance) is exciting research in that the technology is so close to being ready for the production line. Real results will be available to the consumer in relatively short order.

Reviewer 2:
The reviewer observed that the project descriptions would be stronger if estimates were provided of how much engine efficiency or vehicle fuel economy would result from success with new material.

Reviewer 3:
The reviewer noted that lightweight engine components that meet more stringent requirements to deliver efficiency are a gap. This project begins to address this.

Reviewer 4:
The reviewer agreed that high-strength cylinder heads will enable higher efficiency ICEs, which directly support DOE's objective of petroleum displacement.

Reviewer 5:
The reviewer commented that this research will go a long way toward vehicle lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the group is making solid progress toward the identification of phase structures that will extend performance and stabilize properties. There is still considerable work to be done, but the reviewer was convinced that the direction and progress are within the program's planned schedule.

Reviewer 2:

The reviewer acknowledged that the delay because of the GM foundry was very unfortunate. It probably took out momentum and made the project less efficient. Nonetheless, the team seems to have recovered.

Presentation Number: pm062
Presentation Title: High-Performance Cast Aluminum Alloys for Next-Generation Passenger Vehicle Engines
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

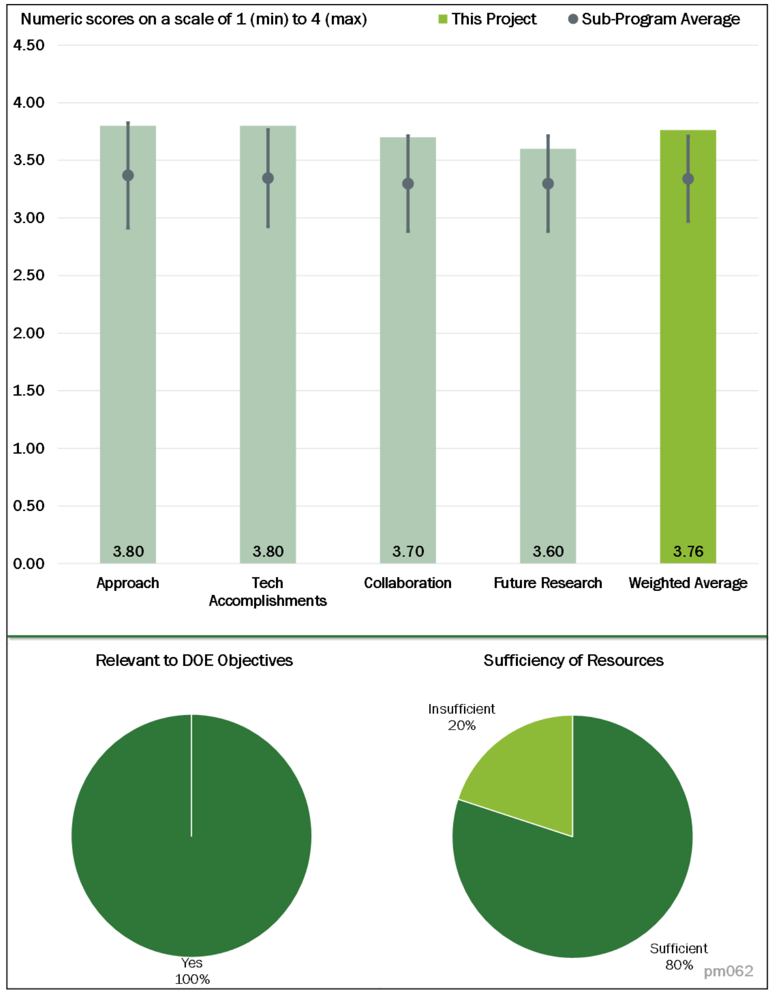

Figure 8-5 - Presentation Number: pm062 Presentation Title: High-Performance Cast Aluminum Alloys for Next-Generation Passenger Vehicle Engines Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter
Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer pointed out that the program is nearing completion and is presenting extremely promising results regarding project goals. It is difficult to find fault with an exemplary set of preliminary accomplishments. Very little of what the breakthroughs were regarding the modeling and ICME efforts were presented in detail, however, aside from the identification of the rather extraordinary capabilities at ORNL. In truth, all the compelling information presented regarding the newly developed alloys was based on limited mechanical properties testing (which was at face value quite impressive). The list of publications provides some indication, however, that the details in the modeling effort are well documented.

Reviewer 2:
The reviewer stated that the project was logically planned out to meet targets, which clearly emphasized putting together a team with the right partners. The accomplishments under this project clearly indicate the value of the selected approach.

Reviewer 3:
Early on in the project, the reviewer said that the key technical barriers were identified to be high-temperature mechanical properties, castability, and hot tear resistance. Subsequently, following a trial process that was assisted by computational modeling, a new set of alloys was developed that appears to meet or exceed the performance targets set by DOE.

In parallel to the above effort, gaps in our understanding of the material behavior (ICME) are being identified with a view to better develop tailor-made alloys for a given application.

Reviewer 4:

The reviewer found the objectives to be clearly stated. This reviewer noted that engine cylinder heads needed to be improved for temperature improvement and tensile and yield strength improvement (both more than 25%) at higher temperatures (250°C up to 300°C, which the reviewer described as very challenging) at a cost of no more than +10%. The team used the Titan supercomputer at ORNL to process the model and ICME to avoid a time consuming and resource consuming trial-and-error approach.

Reviewer 5:

The reviewer indicated a lack of expertise to comment on the technical approach the researchers are taking.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer stated that the proposed goals have largely been met with few (if any) exceptions outside of validation-level engine testing.

Reviewer 2:

In the reviewer's view, it appears that the researchers are making excellent progress.

Reviewer 3:

The reviewer asserted that the project has resulted in material that has exceeded all targets, some by significant margins. Over the past year, these results have been extended from bench-scale to full-scale components. Fifty cylinder heads have been fabricated with no issues. The project team views the results as representing a superior new alloy family for higher temperature applications. Shortcomings in available analysis models have been identified.

As efforts move toward higher temperature alloys, the PI believes this area will need investment for success.

Reviewer 4:

The reviewer mentioned that the team evaluated a stable microstructure rather than a transient microstructure. This was done by pre-exposing material for 200 hours prior to tensile testing. The alloy AlCuEx - v1 worked best with tensile testing at an acceptable temperature range. Alloy development continued by stabilizing grains to increase strength in creep testing, which allows tailoring of creep resistance. The reviewer also noted thermal conductivity (as high as possible) and hot tear resistance (as low as possible). This reviewer remarked that Alloy AlCuEx - v3 was the version that appeared to be the best of the modified alloys. AlCuEx - v3 was used to fabricate a cylinder head. To date, there was no evidence of cracks in the more than 50 cylinder heads made using the most complicated head design available to the team. There was also very little effect of quenching (water and air) on performance characteristics of the material. The reviewer pointed out that AlCuEx - v3 is a very balanced alloy, and it performs well on all factors—hardness, cost, hot tear resistance, thermal conductivity, and tensile strength. This alloy will be developed into a commercial material by the industry partners for cylinder head and other automotive engine applications.

Reviewer 5:

The reviewer stated that excellent progress has been achieved. A suite of new alloys, AlCuEx, with material properties—castability, hot creep resistance, tear resistance, and high-temperature strength—that exceed the DOE requirements were developed. The remaining targets, such as corrosion resistance, are projected to be addressed next year. While the presentation compares the properties of the alloys developed here with DOE-set goals, the reviewer indicated that sharing the genesis of needing newer casting materials would be helpful.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the team includes an engine manufacturer, a cylinder head supplier, and experts in manufacturing, casting, and analysis. Team composition has already allowed for transition of project management from ORNL to the industry partner Fiat Chrysler Automobiles (FCA).

Reviewer 2:
The reviewer commented that the collaborative team could not have been better. Each team member has complementary strengths, and the team appears to leverage each other's expertise very well. Overall, this team appears to have the right skills, strengths, and access to facilities to deliver the required high-temperature alloys.

Reviewer 3:
The reviewer observed that industry and national laboratory are well represented, and there is a cooperative research and development agreement (CRADA) with FCA and Nemak USA. This reviewer observed well-defined goals, strong management, ICME, access to a lab supercomputer, and good industry partners achieved excellent results. The Aberration Corrected Electron Microscope was available for use.

Reviewer 4:
The reviewer remarked that casting capabilities and OEM input complement the extensive modeling and test approaches very nicely.

Reviewer 5:
The reviewer stated that it appears that there is strong collaboration with relevant stakeholders.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the primary remaining efforts are completing the cost analysis and commercialization methodology based upon comparative analyses, both of which are highly necessary pieces to maximize the benefits from the project. The project has identified shortcomings in existing modeling tools.

Reviewer 2:
The reviewer mentioned that most of the barriers (i.e., castability, high-temperature strength, and tear resistance) were adequately addressed. In fact, a number of castings were also performed in association with industrial partners. The proposed future research to assess corrosion resistance and cost is a natural progression of this work. Additional effort to plug any gaps in the ICME model through the knowledge base developed in this effort is laudable.

Reviewer 3:
The reviewer pronounced the proposed future work to be consistent with the current status and the research objectives.

Reviewer 4:
The reviewer commented that it would appear that the program has achieved a rather remarkable breakthrough with regard to developing a cast alloy that meets the target performance levels. Some significant concerns remain, however, particularly regarding the specific knowledge of the program leads regarding the microstructural mechanisms and potential performance debit from an alloy that exhibits a surprising lack of elevated temperature ductility. It may well be moot in an engine that is not designed for any measurable levels

of plastic deformation anyway, but more detail behind the fundamental grounds for the observed mechanical properties would strengthen confidence in the level of success that might be expected from the project discoveries.

Reviewer 5:

The reviewer pointed out that documenting the cost and final report are the only remaining activities. All goals have been accomplished and many exceeded. The project is ending in December 2017, and project leadership is transitioning to industry (FCA) as planned. Commercialization of this alloy is expected to occur at the end of 2017.

ICME gaps still exist in evaluating microstructure evolution. Future work should investigate the integration of microstructure evaluations, which are important as higher temperature performance alloys are developed.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that the project is focused on developing higher performance materials for cylinder heads that allow for more efficient engine operation. This will result in petroleum reductions.

Reviewer 2:

The reviewer noted that the proposed effort leads to identification and development of alloys that can potentially lead to vehicle lightweighting and high-efficiency combustion strategies, which in turn will reduce our petroleum consumption. As a result, this project conforms to DOE's goal of petroleum displacement.

Reviewer 3:

The reviewer responded yes. The results of the project permit higher temperature combustion, which leads to higher efficiency.

Reviewer 4:

The reviewer said that the project enables more efficient operating conditions in ICEs.

Reviewer 5:

The reviewer stated that materials—strength, temperature capabilities, cost, weight, manufacturability—are a limiting constraint to improved engine performance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the researchers seem to be on track to meet their program objectives within their allotted budget.

Reviewer 2:

The reviewer opined that funding appears sufficient for remaining efforts.

Reviewer 3:

The reviewer commented that the project was sufficiently funded because the use of the CRADA provided additional needed funding outside of the DOE funding.

Reviewer 4:

The reviewer observed that the results, in principle, speak for themselves.

Reviewer 5:
The reviewer observed that after the initial selection of castable high-temperature alloys, the next phase of work involves assessing machinability, corrosion resistance, and performance of some cast cylinder heads along with their performance on production engines. It might be worth the investment to document and relay this additional knowledge base for others instead of relying on the commercial interests of the industrial partners.

Presentation Number: pm066
Presentation Title: Innovative SCR Materials and Systems for Low-Temperature Aftertreatment
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter
Craig DiMaggio, FCA

Reviewer Sample Size
A total of eight reviewers evaluated this project.

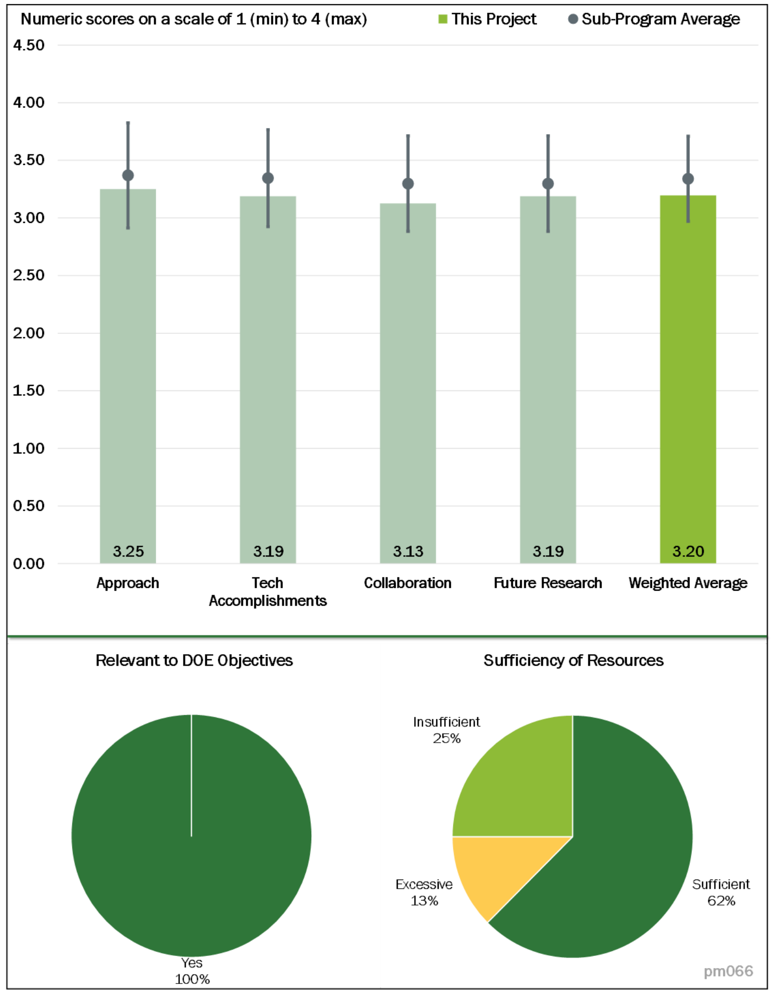

Figure 8-6 - Presentation Number: pm066 Presentation Title: Innovative SCR Materials and Systems for Low-Temperature Aftertreatment Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that it is very challenging meeting Tier 3 targets. This reviewer reported that this design is being used at ORNL as well. The three-way catalyst (TWC) plus a NO_x storage catalyst (NSC) plus passive selective catalytic reduction barely meet Euro 6 for midsize cars. However, the reviewer observed that impressive progress is being made. The reviewer remarked that the approach of doing new material development, with an eye toward ammonia (NH^3) generation and low-temperature selective catalytic reduction (LT SCR) is certainly reasonable. This reviewer added that aging and engine dynamometer work complete the picture.

Reviewer 2:
The reviewer stated that the approach is focused on improving emission control capability for lean-burn gasoline engines, which is seen as a fuel savings. The project is aiming to generate NH_3 via a TWC or NSC for a downstream SCR catalyst. Major aging mechanisms are included.

Reviewer 3:
The reviewer noted that the scope of the project is very complete and ranges from catalyst development all the way through engine system validation.

Reviewer 4:
The reviewer said very well presented.

Reviewer 5:

The reviewer pointed out that this project focuses on the LT aftertreatment system, which includes a TWC plus NSC placed upstream of an SCR catalyst. Although the capabilities of each component are reasonably well understood, the effectiveness of the total system in LT emission control depends on a lot of factors, including system thermal management and durability characteristics. For example, the TWC plus NSC system can provide additional functionalities beneficial for LT emission control, but their presence in the upstream section will delay the physical warm-up of the SCR catalyst located downstream. Also, conditions required for periodic desulfation process for the NSC (typically in a high-temperature reducing environment) are known to be detrimental to the durability of zeolite-based SCR catalysts. Thus, it seems critically important to direct more efforts toward a system-level approach to the problem (rather than focusing on trying to improve the SCR catalyst, with the NSC formulation and properties considered to be fixed, as indicated or implied in the current project plan).

Reviewer 6:

The reviewer pronounced the approach to the work to be good and strengthened considerably by FCA's ties to the university partner. The strategy for integration is well thought out, if difficult to achieve.

Reviewer 7:

The reviewer agreed that the general approach is technically sound, specifically with a new, second generation catalyst system introduced into the program. Hopefully, the initial results will continue to hold after aging for the future work.

Reviewer 8:

The reviewer opined that the focus of this project—enabling LT SCR catalysis—is important, and the approach is theoretically sound; however, the implementation is less than ideal.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer praised the technical accomplishments as impressive. The team achieved approximately 40 mg/kWh NO_x, which is roughly 10-15 mg/kWh without cold start (a big gap), but on a fresh system. Obviously the high-temperature SCR durability is an issue. The project is ahead of schedule, hitting the milestones more than three months in advance. The second-generation SCR (fresh) achieved 80% conversion at 150°C, just short of the target, for the standard SCR reaction. This is impressive. The TWC plus NSC characterization looks good. The reviewer asked why go for the same de-sulfur oxide (SO_x) temperature. The reviewer pointed out that Mercedes-Benz's commercial lean-gasoline NO_x system has the downstream lean NO_x control (LNC) (not SCR) deSO_x at a lower temperature, the SO_x from the first one passes through. It might be difficult to match a high-temperature LNC with a LT SCR deSO_x, but under rich conditions it might be possible. Obviously, the high-temperature durability gap is critical.

Reviewer 2:

The reviewer called out the excellent progress toward the LT performance goal and how the team is addressing issues as they come up, like deSO_x.

Reviewer 3:

The reviewer said that the project has shown some improvement in hydrothermally aged SCR performance, but only lean, steady state conversion was shown and stoichiometric aging was fairly destructive. There needs to be some element of lean rich aging and a strategy to modify the system or SCR technology to be more robust. A catalyst supplier is now involved to scale-up the SCR catalyst. Nothing was done to address added complexity and on-board diagnostics (OBD) requirements.

Reviewer 4:

The reviewer observed very good results for the second generation catalyst formulation and suggested that the team should continue looking at different aging conditions and amounts of copper.

Reviewer 5:

The reviewer noted that the project has achieved 80% conversion at 150°C and the early results from the second generation of catalyst is somewhat encouraging.

Reviewer 6:

The reviewer observed that some progress has been made in improving LT SCR catalyst performance after hydrothermal aging at 700°C in air, but it is not yet clear whether it will translate into significant improvement in the entire system performance under realistic conditions for the reasons mentioned in the Approach section.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the team is working well together with individual work followed by collective testing.

Reviewer 2:

The reviewer observed that there was good collaboration among Pacific Northwest National Laboratory (PNNL), FCA, and the University of Houston.

Reviewer 3:

The reviewer remarked that the partners seem engaged in the project, including an OEM, national laboratory, and university. A catalyst supplier is now involved but was not identified.

Reviewer 4:

The reviewer noted primarily PNNL activities so far, with some contribution from University of Houston. The reviewer did not see clear synergy between PNNL and the university activities and proposed careful, system-level assessment of the project concept and strategy, perhaps by FCA and/or the University of Houston, sooner than later in order to identify the primary paths to maximize the LT emission performance of the entire system under realistic operating conditions of lean-burn gasoline engines.

Reviewer 5:

The reviewer stated that the program would be stronger if it can get a direct partner from a catalyst supplier.

Reviewer 6:

The reviewer suggested that the collaboration with the catalyst expert should be clearer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that future plans hit all the most critical remaining questions.

Reviewer 2:

The reviewer stated that future plans cover what the project team needs to achieve for the program goal shown in Slide 21.

Reviewer 3:
The reviewer stated that future work is nicely focused on the right parameters, but suggested that the team may wish to consider adding a small urea system. If the NSC can take down NO_x and generate NH_3, the urea system size might be manageable.

Reviewer 4:
The reviewer remarked that there was a need to address the lean versus rich aging of SCR catalysts. Another need is to address the additional cost and complexity of a lean NO_x strategy for lean-burn gasoline, and if the OBD requirements make it unfeasible given the potential savings in fuel economy by going lean.

Reviewer 5:
The reviewer recommended that the team show fast and standard SCR reactions with a second generation catalyst similar to that of the first-generation catalyst. The team should continue to optimize the amount of copper that needs to be added to the SCR catalyst while looking at different aging conditions.

Reviewer 6:
The reviewer wanted to see future efforts directed more toward system-level performance and durability issues, as pointed out in the Approach section.

Reviewer 7:
The reviewer commented that future work, especially regarding the alternative catalyst, seems ambitious given the time remaining in the project. There is significant durability work remaining, which seems to be a more important area to focus on.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer pointed out that emission controls are mandatory enablers for developing and emerging high efficiency engines.

Reviewer 2:
The reviewer stated that lean gasoline control has gaps being addressed here.

Reviewer 3:
The reviewer observed that LNC technology is an enabler for higher efficiency engine using lean burn.

Reviewer 4:
The reviewer said yes, improving catalyst efficiency has a direct tie to improving fuel efficiency.

Reviewer 5:
The reviewer acknowledged that lean gasoline engines, the intended application for this project, offer better fuel economy than conventional stoichiometric gasoline engines, but one of the barriers for mass production is emission control.

Reviewer 6:
The reviewer said that achieving 150°C light-off temperature is part of the DOE program objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that, for what is being accomplished and the planned accomplishments, the funding is low by about 50%.

Reviewer 2:
The reviewer stated that resources seem sufficient. Most of the money is going to PNNL.

Reviewer 3:
The reviewer noted that the project team is ahead of schedule.

Reviewer 4:
The reviewer said yes, and wanted to see more involvement (or documented involvement) from the catalyst expert.

Reviewer 5:
The reviewer asserted that the project team gets what is needed.

Reviewer 6:
The reviewer commented that PNNL is funded in multiple ways for the same work. [DOE Program Clarification: PNNL has two teams working on NO_x reduction technologies, one with a LD engine company that is using lean gasoline combustion, and the other is working on low-temperature HD diesel exhaust. The exhaust compositions from the two systems are significantly different and the research of the two PNNL teams is separate and unique. There is no duplication.]

Reviewer 7:
The reviewer understood that the University of Houston has a modeling capability of individual components involved (e.g., TWC, NSC, and SCR). However, the reviewer was not sure they are able or willing to jump into the systems-level modeling and analysis that this project needs.

Presentation Number: pm067
Presentation Title: Next-Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines
Principal Investigator: Christine Lambert (Ford Motor Co.)

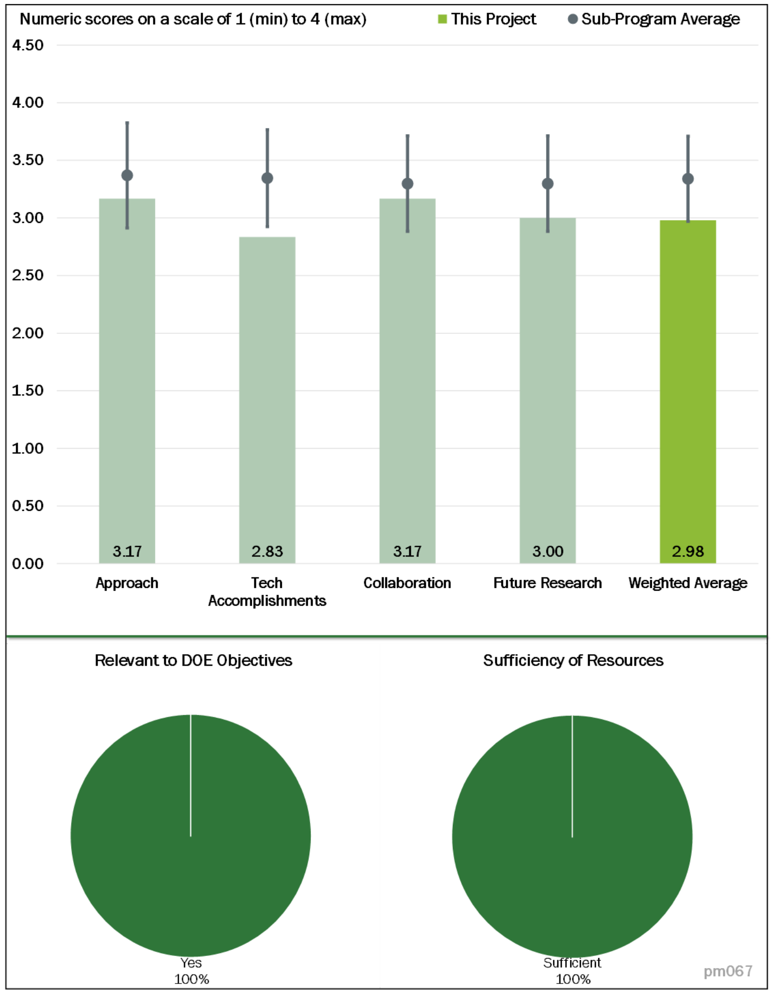

Figure 8-7 - Presentation Number: pm067 Presentation Title: Next-Generation Three-Way Catalysts for Future, Highly Efficient Gasoline Engines Principal Investigator: Christine Lambert (Ford Motor Co.)

Presenter
Christine Lambert, Ford Motor Co.

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer said that the project is near completion and significant progress bears out the excellent approach taken.

Reviewer 2:
The reviewer commented that this project plan has been well-designed and executed in a systematic manner in cooperation with multiple partners who brought in their own unique capabilities. The performance evaluations were done under realistic simulated exhaust conditions after catalyst aging under well-accepted temperature and air-fuel ratio conditions for stoichiometric gasoline engines.

Although the catalyst aging protocol used in this study includes some lean high-temperature exposure, it would have been more assuring if the promising rhodium-based candidate catalysts had been aged under more lean-biased conditions (i.e., at leaner air-fuel ratios and/or for longer periods of lean time) before performance testing. A reason for this view is that TWCs for future "stoichiometric" gasoline engines will likely be exposed to high-temperature lean operations, such as deceleration, fuel cuts, and stop-starts more frequently for improved fuel efficiency.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer noted that the findings of this project may have important implications for alternative and next-generation three-way catalyst formulations, prompting serious consideration of rhodium as a major active component for three-way catalysts. It is rather surprising and interesting to see how much rhodium (at

relatively low loading) can do in the catalytic control of the three major pollutants in exhaust (especially hydrocarbon conversion) at low temperatures.

Reviewer 2:

The reviewer stated that the project made good progress toward the goal of 150°C activity but did not hit the full target.

Reviewer 3:

The reviewer said that there was good progress toward reaching the 150°C light-off goal, but there is still a ways to go to actually reach the goal.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that collaboration with other institutions is generally good, but can be improved. It is good that Johnson Matthey has been involved to guide manufacturing feasibility and cost estimates of the new catalyst preparation and formulation concepts investigated in the project.

Reviewer 2:

The reviewer found that the team covered all key scales, from microscopic to full-scale devices using different team members: universities to commercial catalyst companies.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the project is near completion, but it shows very good final steps of evaluation and consideration for commercialization.

Reviewer 2:

The reviewer stated that this project is very near the official ending date of September 30, 2017. It would have been nice to have feedback and guidance from Johnson Matthey regarding manufacturability and costs associated with possible large-scale production during the remainder of the project period.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer noted that advanced gasoline engines are potential petroleum savers in many markets and rely on cost-effective TWC aftertreatment.

Reviewer 2:

The reviewer stated that improved TWCs have a very broad application across the whole of the automotive space, and will directly impact vehicle efficiency.

Reviewer 3:

The reviewer asserted that this project addresses itself to an important problem of developing TWCs with improved LT activity, which is a critical enabler for next-generation fuel-efficient vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that with about four months remaining, the project status is approximately 90% complete and has completed downselecting promising candidate catalyst formulations.

Presentation Number: pm068
Presentation Title: Sustained Low-Temperature NO_x Reduction (SLTNR)
Principal Investigator: Yuhui Zha (Cummins)

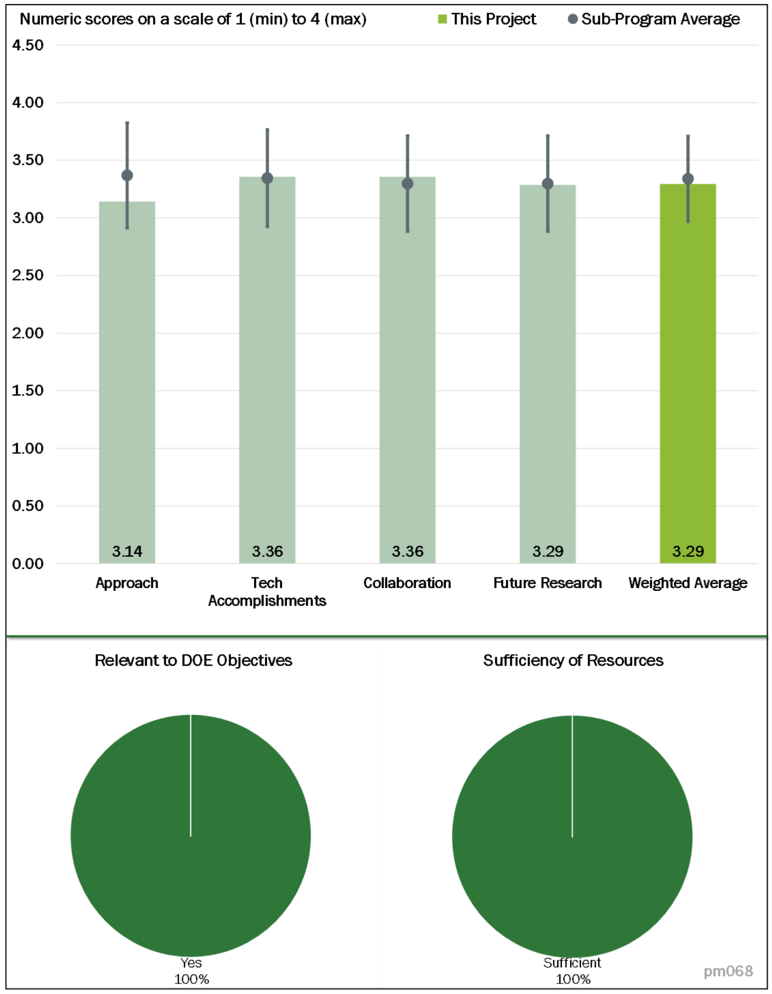

Figure 8-8 - Presentation Number: pm068 Presentation Title: Sustained Low-Temperature NOx Reduction (SLTNR) Principal Investigator: Yuhui Zha (Cummins)

Presenter

Yuhui Zha, Cummins

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the approach of identifying a suitable catalyst, delivering nitrogen dioxide (NO_2) and getting LT urea was successful. It was not easy and all the issues seem to have been addressed and evaluated.

Reviewer 2:

The reviewer said that the project approach was appropriate.

Reviewer 3:

The reviewer mentioned that the approach is sound and addresses both LT catalysis and LT urea delivery, which makes the research comprehensive and believable.

Reviewer 4:

The reviewer asserted that there is a strong approach to this project, with excellent focus on current, near-term, and long-term issues. There is very good collaboration among Cummins, PNNL and Johnson Matthey, all of which had clear roles. It would have been nice to see a university partner included as well.

Reviewer 5:

The reviewer found the approach to be is good, but a monster system shown in Slide 16 is a major concern because of cost and packaging issues.

Reviewer 6:

The reviewer found the approach to be satisfactory—and it could have been good to very good—but there seems to be a key gap in the catalyst materials story. Laboratory testing of sustained low-temperature NO_x reduction (SLTNR) A and B powders at 150°C and 175°C showed promise. However, it was somewhat surprising to not see any study of the conversion efficiency of powders A and B after aging at higher temperatures representative of the broader duty cycle. Such an aging study, as a key metric of materials quality and stability, would have substantially elevated confidence in the potential for success of this approach. The importance of addressing this temperature stability issue should have at least been acknowledged in the presentation as many catalyst materials perform much differently after initial higher temperature exposure or after extended time at higher temperatures. If such work is not in progress yet—and the reviewer suspected that it is knowing the quality of this team—the reviewer strongly recommended that step prior to engine testing.

Testing at various NO_x fractions was performed, which was appropriate. But, it might be helpful for next year's reviewers (not all of whom will have a significant background in aftertreatment systems) to see the anticipated range of actual NO_x levels for engine operation.

As a minor administrative note, the structure of Slide 9 is extremely frustrating for a reviewer as the text is incredibly small!

The diesel emission fluid (DEF) vaporizer study was curious. It was encouraging to see off-the-shelf items being used, although it was somewhat difficult to imagine such a system being re-designed for deployment for a million plus miles on road. The fact that the system degraded in a few days was of concern, but the ability to regenerate provides optimism.

The risk assessment, as presented, was not particularly effective for a reviewer to analyze. The overall approach was good, but there were some curious gaps.

Reviewer 7:

The reviewer stated that barriers as presented did not match Propulsion Materials area barriers.

The sustainability of a high NO_2 strategy should be included. Catalysts that generate NO_2 also tend to generate more nitrous oxide (N_2O) and also oxidize sulfur. This could have long-term effects on both the catalyst system durability and the greenhouse gas emission of the system.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer exclaimed that they project team did it. The reviewer was pleased that the team hit the goal on an engine dynamometer, and the long-term feasibility looks okay. The reviewer remarked well done, and looked forward to the vaporizer results.

Reviewer 2:

The reviewer commented that the results with NH_3 to achieve the project goal were excellent, as was the vaporizer that was developed to be used with DEF.

Reviewer 3:

The reviewer noted that the urea vaporizer is very interesting. This could be a viable way to use existing DEF infrastructure with a new dosing system capable at lower temperatures.

Reviewer 4:

The reviewer mentioned that the researchers have met the goal of delivering urea at LT through the design of a novel vaporizer and used this to enable a LT SCR to reduce NO_x emissions by 90%.

Reviewer 5:

The reviewer said there had been excellent progress toward project completion.

Reviewer 6:

The reviewer remarked that the results look good, but the system is too complicated. It is hard to imagine which vehicle can have a room to install such a complicated system, as shown in Slide 16, not mentioning the cost.

Reviewer 7:

The reviewer observed that the goals for this project are difficult so it is encouraging to see the reported progress. However, the long-term stability of multiple systems still seems questionable or unknown in year 3 of the study, which is of particular concern in HD engines with very long service lifetimes. Thus, more emphasis on the impact and challenges of time and temperature would give a much clearer picture of the potential of the approaches selected.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer asserted that the collaboration obviously worked. Catalyzer, OEM, and PNNL are a winning team. In fact, the team is delivering more than expected.

Reviewer 2:

The reviewer opined that the close relationships among Cummins, Johnson Matthey, and PNNL are apparent.

Reviewer 3:

The reviewer said it seemed appropriate.

Reviewer 4:

The reviewer observed that having a national laboratory and a catalyst supplier as partners are really helpful.

Reviewer 5:

The reviewer stated that the three-way collaboration appears to be effective although the specific contributions of Johnson Matthey to date were not quite clear.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the project will close with not only meeting objectives, but with additional deliverables. As all the future work is bonus, the reviewer said "outstanding."

Reviewer 2:

The reviewer asserted that more work on sulfur effects (catalyst poisoning, sulfate emissions, and effect on the downstream SCR catalyst) needs to be included. There is also a need to measure N_2O under more operating conditions.

Reviewer 3:

The reviewer found the work to be well documented and suggested that the team consider a comparison of NH_3 SCR at these low temperatures versus DEF vaporizer at these low temperatures.

Reviewer 4:

The reviewer stated that the proposed research is to finish out the project by evaluating the durability of the LT catalysis system.

Reviewer 5:
The reviewer remarked that there is still a lot of work to do for a commercially viable project.

Reviewer 6:
According to the reviewer, realizing the packaging is an issue is a good start for the future work, but the reviewer was not sure how it can reduce the system size significantly.

Reviewer 7:
The reviewer stated that the project is in its final year and moving toward an engine test, which is very encouraging. However, it seemed that a number of essential materials durability and stability issues (including longer-term durability of a regeneration cycle in the pre-turbo diesel oxidation catalyst) remain and at a reduced funding level for year 3 as compared to the previous year. It is of concern to see that temperature stability, hydrocarbon effects, and sulfur effects have not yet been examined for the key SCR materials. If there are issues, there will be little time to redesign materials prior to assembly and testing of the engine.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer stated that the ability to significantly improve lower-temperature NO_x reduction in a HD engine will be of enormous value in enabling higher efficiency engine concepts that result in lower exhaust temperatures.

Reviewer 2:
The reviewer pointed out that reducing urban, low-load NO_x costs fuel for thermal management and this approach saves most of loss.

Reviewer 3:
The reviewer stated that the project supports aftertreatment of more efficient diesel engines with lower exhaust temperatures.

Reviewer 4:
The reviewer said yes. Improving NO_x conversion efficiency by means of an SCR catalyst has a direct link to improved fuel efficiency.

Reviewer 5:
According to the reviewer, the more efficient the diesel engine is, the lower the exhaust temperature is. Because the engine cannot be sold without its meeting emissions regulations, the LT catalyst is needed to reduce petroleum use.

Reviewer 6:
The reviewer noted that achieving 150°C light-off temperature is part of DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the program goals were met ahead of time, with resources to spare for bonus work. The reviewer proposed that the team use the remaining funding for this work.

Reviewer 2:
The reviewer commented that the 50-50 cost share with Cummins indicates resources are sufficient for the scope as defined.

Reviewer 3:
The reviewer said yes.

Reviewer 4:
The reviewer reported that the team has what it needs.

Acronyms and Abbreviations

AlCuEx	Aluminum copper alloy
CGI450	compacted graphite iron 450
°C	Celsius
CFD	Computational fluid dynamics
CRADA	Cooperative research and development agreement
DEF	Diesel emission fluid
$DeSO_x$	de-sulfur oxide
DOE	U.S. Department of Energy
FCA	Fiat Chrysler Automobiles
FEM	Finite element modeling
GM	General Motors
HD	Heavy-duty
ICE	Internal combustion engine
ICME	Integrated Computational Materials Engineering
L	Liter
LD	Light-duty
LNC	Lean NO_x catalyst
LT	Low temperature
LT SCR	Low-temperature selective catalytic reduction
MYPP	Multi-Year Program Plan
N_2O	Nitrous Oxide
NH_3	Ammonia
NO_x	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NSC	NO_x storage catalyst
OBD	On-board diagnostics
OEM	Original equipment manufacturer

ORNL	Oak Ridge National Laboratory
PI	Principal investigator
PNNL	Pacific Northwest National Laboratory
RT	Room temperature
SCR	Selective catalytic reduction
SLTNR	Sustained low-temperature NO_x reduction
TWC	Three-way catalyst
VTO	Vehicle Technologies Office

9. Technology Integration

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The Technology Integration (TI) subprogram supports adoption of advanced vehicle technologies, primarily through online tools, user guides, and implementation of the regulatory State and Alternative Fuel Provider Program (S&AFP). The Alternative Fuels Data Center (AFDC) provides technically-accurate, objective, and relevant information about the costs and benefits of alternative fuels in motor vehicles. The DOE-U.S. Environmental Protection Agency (EPA) Fuel Economy Guide provides fuel economy estimates to help car buyers choose the most fuel-efficient vehicle for their needs. Through the S&AFP, DOE works with certain state government and alternative fuel provider fleets to acquire alternative fuel vehicles (AFVs) as part of their annual light-duty vehicle acquisitions. TI projects reviewed at the 2017 Annual Merit Review (AMR) included those co-funded as Alternative Fuel Vehicle Community Partners projects whose focus was to accelerate widespread introduction and adoption of commercially available advanced vehicle technologies to reduce U.S. dependence on petroleum, increase local fuel diversification, and catalyze adoption of clean transportation technologies.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2017 AMR. Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, goals, and objectives adequately covered?

Question 2: Were projects and activities adequately balanced to address both vehicle and fueling/charging infrastructure deployment needs?

Question 3: Were important vehicle deployment issues, barriers, and challenges identified?

Question 4: Are plans and strategies identified for addressing issues, barriers, and challenges?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program areas engaged appropriate government/industry/community partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio of vehicle deployment activities for this area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas or emerging vehicle technologies/market trends that this deployment program should explore to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: ti000 Presentation Title: Technology Integration Overview
Principal Investigator: Linda Bluestein (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, goals, and objectives adequately covered?

Reviewer 1:
The reviewer stated that the presenter did a very good job outlining the VTO Technology Integration (TI) program area and the three activity areas within it. The budget and funding levels for outreach, deployment, and analysis activities were clearly covered. The main strategies of the program were amply communicated, as were critical success factors for pursuing these strategies.

Reviewer 2:
The reviewer remarked that the presentation of the TI Program Overview did a very good job of describing what TI consists of and provided an excellent discussion of its strategy which is to facilitate and accelerate market transformation towards alternative fuels.

Reviewer 3:
The reviewer said that the presentation gave an excellent description of the program and the associated strategy, goals, and objectives.

Reviewer 4:
The reviewer noted that the program area and objectives were adequately covered. Although the time was short and there was a lot of material to cover, the presentation was well organized and described all the major activities. This included activities of Clean Cities to deploy alternative fuel vehicle and refueling infrastructure and build local expertise and support, student competitions (EcoCAR 3) and information dissemination via fueleconomy.gov and the AFDC. Assistance to fleets with federal alternative fuel requirements was also noted.

Reviewer 5:
The reviewer commented that the TI program area was adequately covered during the presentation. The program helps to facilitate and accelerate market transformation with visible examples, objective data, tools, and key lessons learned that benefit future users.

Question 2: Were projects and activities adequately balanced to address both vehicle and fueling/charging infrastructure deployment needs?

Reviewer 1:
The reviewer stated that the projects and activities presented were fairly well-balanced in terms of addressing both vehicle and fueling infrastructure needs. The presenter emphasized the program's broad technical scope that is focused on light-duty (LD), medium-duty, and heavy-duty (HD) vehicles, six Energy Policy Act-approved alternative fuels, as well as energy efficient mobility systems and technologies (involving both vehicles and road system infrastructure). The reviewer also noted that data and information tools were also well-balanced in addressing both vehicles (fueleconomy.gov) and infrastructure (Alternative Fueling Station Locator).

Reviewer 2:
The reviewer remarked that through the projects in this area, both vehicle and fueling/charging infrastructure are balanced.

Reviewer 3:
The reviewer noted that it appears the projects are balanced between alternative fuel and electric vehicle refueling infrastructure needs.

Reviewer 4:

The reviewer said that the projects and activities were adequately balance. The Clean Cities and related work covers both fueling/charging and vehicle deployment and was given substantial coverage. Likewise, the outstanding products and activities of the fueleconomy.gov and AFDC were also adequately described. Although the student vehicle design competition is not a large share of the budget, it has an enormous impact on university students interested in automotive engineering and sustainable transportation and well deserves the attention it was given.

Reviewer 5:

The reviewer stated that the projects, activities and tools/resources appear to be adequately balanced to address both vehicle and fueling/charging infrastructure deployment needs. Some projects/activities were focused on vehicle deployment, such as the Aggregated Purchasing and Plug-in Electric Vehicle (PEV) showcase projects, while others activities/tools such as the AFDC Alternative Fueling Station Locator are focused on infrastructure development. The reviewer concluded that it is important that both sides of the equation have the necessary resources to continue to develop markets.

Question 3: Were important vehicle deployment issues, barriers, and challenges identified?

Reviewer 1:

The reviewer noted that barriers and challenges were clearly described and addressed.

Reviewer 2:

The reviewer commented that several vehicle deployment issues, barriers, and challenges were discussed. For example, the aggregated purchasing project seeks to overcome the additional incremental cost of AFVs by pooling of purchase orders, which could allow for greater buying power of this large group versus a single fleet/entity. Additionally, the projects/activities associated with first responders and permitting officials help these officials become more comfortable with alternative fuel technologies and in turn can help to ease (instead of impede) local adoption.

Reviewer 3:

The reviewer asserted that the Clean Cities program leverages local resources to do much of this work via events like ride and drive (increasing knowledge of alternative vehicles and fuels), training programs for first responders (building human capital), and much more. The program helps coordinate the supply of technical expertise and advice provided by the national laboratories and, as important as any of its activities, it seeks out and collaborates with interested local private and government fleets to deploy AFVs and infrastructure (helping solve the chicken or egg problem). This reviewer reported that the program works with local regulatory agencies to help improve and adapt codes as well as standards and permitting (building institutional infrastructure). The TI program has also facilitated cooperation among AFV purchasers to increase scale economies for suppliers and confer some bargaining power on fleets purchasing AFV (reducing initial costs).

The reviewer further commented that the importance of non-monetary barriers to transitioning to a low greenhouse gas (GHG) transportation system is generally under-appreciated. This reviewer explained that research has shown that the costs of subsidies and mandates can be reduced by implementing a comprehensive strategy that addresses human and institutional barriers as well as financial barriers. The benefits of such programs are difficult to measure in dollars, although it is possible to do. If done well, this reviewer opined that the benefits are generally so large compared with the costs that they may seem difficult to believe. The benefits are real, nonetheless.

Reviewer 4:

The reviewer said that vehicle deployment issues/barriers/challenges were identified through inference, but not covered in great detail. The presentation focused more on program activities, rather than detailed discussion on technical vehicle deployment issues.

Reviewer 5:

The reviewer noted that the barriers and challenges did not seem to be explicitly covered during the discussion.

Question 4: Are plans and strategies identified for addressing issues, barriers, and challenges?

Reviewer 1:

The reviewer stated that the presenter/presentation identified numerous strategies, tactics, and activities being undertaken to advance vehicle and infrastructure deployment.

Reviewer 2:

The reviewer commented that the overall deployment program including new efforts of Living Labs, technical assistance to help fleets and infrastructure providers, and continuing the strong Clean Cities effort helps to address the issues and challenges in this program area.

Reviewer 3:

The reviewer noted that within the funding constraints of the program, a well-balanced strategy was identified to address barriers and challenges associated with alternative fuel and electricity infrastructure needs.

Reviewer 4:

The reviewer remarked that the plans and strategies were identified. This was clearly explained in the presentation and much of the strategy has been described via answers to other questions. This reviewer commented that Clean Cities addresses all of the non-monetary barriers to AFV transition and leverages local resources while simultaneously building local expertise and knowledge. Student competitions address education and inspiration of the automotive engineers of the future. Information programs increase consumer awareness and knowledge and provide technical expertise to fleets and local governments. The reviewer indicated that overcoming non-monetary barriers to the sustainable energy transition is an enormous and enormously important task. This reviewer further opined that TI could do significantly more with a larger budget.

Reviewer 5:

The reviewer said that the Technical and Problem-Solving Assistance activity is an important use of resources to assist local fleets and stakeholders on overcoming issues, barriers and challenges. Under this activity, the program captures lessons learned and best practices, organizes technical forums and user groups, addresses unforeseen permitting and safety issues, identifies chronic vehicle or infrastructure field problems as well as assisting in incident investigations. All are important strategies to address and overcome barriers.

Question 5: Was progress clearly documented and tracked for various deployment activities and technology focus areas?

Reviewer 1:

The reviewer said that program area progress was well covered by the presenter/presentation. Progress was outlined broadly in terms of total petroleum displaced, vehicles deployed, and share of fuels dispensed. Precise metrics were also provided for use of digital resources (e.g., AFDC tools and data downloads, fueleconomy.gov access, etc.).

Reviewer 2:

The reviewer noted that the 2016 results and progress of the data information and AFDC Alternative Fueling Station Locator, data trends, data impact, Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool, and fuel economy information was presented very clearly and effectively.

Reviewer 3:

The reviewer said the presentation provided an historical, present day, and future look at infrastructure support provided by the program.

Reviewer 4:

The reviewer commented that progress in all areas was described and quantified, as appropriate. The reviewer chose to focus on fueleconomy.gov and the AFDC. Fueleconomy.gov is a highly successful website that provides information about new and used vehicle fuel economy (and a lot more) to tens of millions of users each year. The website is in the top 1% of government websites (including Medicare and Social Security, and a lot more great websites of importance to U.S. citizens). The reviewer relayed an anecdote where a luncheon talk in Nashville, Tennessee was given two weeks ago. The reviewer asked how many in the audience had used the website fueleconomy.gov. Roughly half the audience raised their hands. The AFDC is an enormously valuable resource for AFV owners and users, automobile manufacturers and for the internet community. The Station Locator app and data are not only widely used by individuals but are made available to other web developers and are intensively used. The AFDC gets no direct credit for that but the impact is huge when an entity like Google takes the data and purveys it to millions of its users. This also illustrates the spirit of these programs, which is service to the U.S. public first and foremost.

Reviewer 5:

The reviewer noted that the major program metric is the goal of saving 2.5 billion gallons of petroleum per year by 2020. The Deployment Program Metric slide shows that the program appears to be on track to meet this goal.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer stated that the projects in this technology area are very important for helping advance VTO's work. These projects serve to validate research and assumptions of earlier-stage VTO work, and transfer VTO technologies to the marketplace. The projects help expose the public to new vehicle and fuel technologies, which is critical for moving them from laboratory to practical use, deployment, and societal adoption.

Reviewer 2:

The reviewer said the projects in this area show how reduction in petroleum use through the use of alternative fuels is being accomplished and therefore is addressing the broad problem that VTO is trying to solve.

Reviewer 3:

The reviewer remarked that the projects were addressing the broad problems and barriers. The projects in this program provide a platform for newly developed technologies, developed by VTO, to be demonstrated in a comfortable well supported venue. The "early adopters" are provided support during first trial demonstration activities.

Reviewer 4:

The reviewer commented that the projects were "definitely" addressing the broad barriers. While VTO technology R&D attempts to reduce costs and improve the performance of vehicle and fuel technologies, TI works on overcoming the non-financial barriers to making that transition happen. These barriers are large and important and addressing them can greatly reduce the cost of transition.

Reviewer 5:

The reviewer commented that VTO supports R&D and deployment of efficient and sustainable transportation technologies that will improve energy efficiency, fuel economy, and enable America to use less petroleum. These technologies, which include advanced batteries and electric drive systems, lightweight materials, advanced combustion engines, alternative fuels, as well as energy efficient mobility systems. The TI activities support the deployment of the majority of these technologies.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer said that the program area is well-developed, managed, and effective, and provides substantial benefit to VTO/DOE.

Reviewer 2:
The reviewer affirmed that the TI program area is very well managed and definitely supports VTO's overall objectives.

Reviewer 3:
The reviewer said the program appears to be focused, well managed, and effective in its support of VTO technology development activities.

Reviewer 4:
The reviewer referred to the program as an "expert program," that is, it has been in existence and its staff have personally accumulated sufficient experience to be experts in what they do. The program staff know their customers, they know their subject matter, they have built networks, and they know how to get things done. The reviewer asserted that the program needs a larger budget, given the challenges being addressed, but what the program is able to do with the resources they have is very effective.

Reviewer 5:
The reviewer noted that the TI program area appears to be focused, well-managed, and effective in addressing VTO's deployment needs.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer commented that Clean Cities stands out as an excellent example of leveraging local resources and working cooperatively with local authorities and individuals to achieve a common goal. DOE should protect and enhance this effort. This reviewer asserted that Fueleconomy.gov is a winner as the tens of millions of user sessions it hosts each year attest. The website is the only comprehensive source of fuel economy information for the great majority of car buyers who purchase used vehicles. The reviewer further explained that the website contains a lot more than just fuel economy; it is the authoritative source of information in the United States on driving and maintenance tips to maximize fuel economy, for example. It is the largest source of data on in-use, real world fuel economy, and more.

The reviewer stated that the AFDC is also a winner. The Station Locator alone is widely used but is also a basic data source for commercial app developers who provide AFV users with information about where to refuel. The website is also so much more, asserted this reviewer, who highlighted authoritative information about AFVs and fuels; comprehensive information about federal, state, and local incentives; and significantly more. This information is used in studies and published in peer-reviewed journals as well as in the popular media.

The reviewer further commented on the student competitions. The reviewer has met with participants from several universities who have participated and are motivated by EcoCAR 3. The reviewer opined that this has to be the best investment of all.

Reviewer 2:

The reviewer stated that a key strength of the TI program continues to be the vast numbers of Clean Cities Coalitions (CCCs) that exist across the country. This project provides an extreme amount of information and data and helps get the word out regarding alternative fuels to local areas.

Reviewer 3:

The reviewer noted that the strength of this activity is that it provides an opportunity for early adopters to move into an area of higher risk with assurance that they will be provided support in their activities.

Reviewer 4:

The reviewer said that CCC offers several key strengths, including robust public/private partnerships, a deeply extensive stakeholder network, strong knowledge sharing/transfer among stakeholders, transportation technology deployment, among others. The AFDC has key strengths in terms of tool offerings, industry-standard data and information (particularly on refueling stations), impressive traffic/user base, and ease of access.

Reviewer 5:

The reviewer stated that the strengths associated with the TI program area appear to be tools and resources developed by the national laboratories, such as the AFDC, the fueleconomy.gov website, and the AFLEET tool. Weaknesses in this area stem from the lack of funding for hardware, such as vehicles and fueling infrastructure, which were an important feature of the program for many years.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer stated that several projects under the program are particularly innovative. Examples include the AFLEET tool, technical assistance in the form of a "Technologists in Cities" expert, EcoCAR 3, Energy-Efficient Mobility Systems (EEMS) Living Lab projects, and others.

Reviewer 2:

The reviewer noted that the Clean Cities project has proven over the years to be an extremely innovative way to promote the use of alternative fuels and to provide information to the public.

Reviewer 3:

The reviewer said that projects did represent novel and/or innovative ways to approach the barriers, through cost share requirements and community-based partnerships are also formulated to address barriers.

Reviewer 4:

The reviewer noted that innovation was present. The AFDC and fueleconomy.gov websites are constantly finding new ways to reach the public, from web services to new mobile apps. Clean Cities is inherently a problem-solving organization. EcoCAR 3 is all about stimulating university students to come up with new ideas and new designs for AFVs (and working with our auto companies in the process). The reviewer would like to see TI do more basic research on the barriers to energy transition and energy efficiency and how best to overcome them. The budget should be increased and basic social science, economic, and governance research should become an important part of their effort.

Reviewer 5:

The reviewer commented that projects, such as the Aggregated Purchasing, represent an innovative way to help address cost barriers with AFVs.

Question 10: Has the program area engaged appropriate government/industry/community partners?

Reviewer 1:
The reviewer commented that the program area is solidly built on strong public/private partnerships through the CCCs, major fleet and industry partners, other federal agencies, states, and communities, academia, non-profits, and others. External partnerships are the bedrock of this VTO program area.

Reviewer 2:
The reviewer remarked that the TI program continues to have excellent collaboration with community partners, industry, and government. The nearly 100 CCCs is an excellent example of public-private partnerships.

Reviewer 3:
The reviewer said that the program area has engaged appropriate partners. CCCs engage at the state and local levels forming partnerships with governments and industry.

Reviewer 4:
The reviewer said that the program area has "absolutely" engaged partners. This engagement is well documented in the presentation. Partnering with governments, industry, and communities is the fundamental TI strategy.

Reviewer 5:
The reviewer noted that the program has been able to engage with a broad network of government/industry/community partners through its focus on community based public-private partnerships with the CCC network as well as engaging with directly with national fleets with the National Clean Fleets Partnership.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer said the program area has been collaborating with partners effectively to deploy alternative fuel and advanced technology vehicles and infrastructure, primarily through the Clean Cities program. The results of this long-sustained collaboration are evident through substantial petroleum reduction volumes and vehicle and infrastructure deployments. The new EEMS activity is where the program is in an earlier stage of developing new stakeholders and partnerships. The program should make focused efforts to actively develop and grow relationships with new EEMS partners, and expand relationships with existing partners (i.e., U.S. Department of Transportation [DOT], state DOTs, etc.).

Reviewer 2:
The reviewer stated that the program is very effective in the way it coordinates with stakeholders associated with the program.

Reviewer 3:
The reviewer noted that the Clean Cities program continuously assesses the collaboration efforts of the coalitions to ensure that they remain focused on real time issues.

Reviewer 4:
The reviewer stated that the program is collaborating with partners effectively.

Reviewer 5:
The reviewer remarked that, based on the results of continued increase in petroleum displacement, it appears the program is effectively leveraging/collaborating with their partners and stakeholders.

Question 12: Are there any gaps in the portfolio of vehicle deployment activities for this area?

Reviewer 1:

While no gaps were identified, the reviewer noted that the addition of the Living Lab and Aggregated Purchasing projects should prove to be very useful to the program area.

Reviewer 2:

The reviewer stated that more could always be done. However, within funding constraints, the program area is delivering on the realistic goals set by the program.

Reviewer 3:

The reviewer said that TI should do more to help deploy hydrogen refueling infrastructure. TI should be a key member of H2USA, bringing the Clean Cities infrastructure and approach to helping plan and deploy hydrogen infrastructure. While the program is already working on this, the scale of effort should be greatly increased and plans should be developed to assist not only California and the states that have opted in to zero emission vehicle (ZEV) mandates, but also other states with an interest in transitioning to clean transportation.

The reviewer further commented that the national laboratories and universities have now developed valuable databases and analytical tools that could be adapted to assist states and local governments in planning charging and hydrogen refueling infrastructure deployment. This is happening to some extent but on a small and embryonic scale. This reviewer suggested that TI could lead an effort to develop and enhance existing tools to ensure that they meet state and local needs to efficiently and effectively plan and coordinate refueling infrastructure deployment.

Finally, the transition to low-GHG energy is an enormous and enormously important challenge. The reviewer recommended that additional resources should be devoted to addressing the non-financial transition barriers.

Reviewer 4:

The reviewer remarked that, pending availability, specific funding for hardware, such as vehicles and fueling infrastructure could be added to the portfolio.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

The reviewer commented that all of the necessary topics are being addressed appropriately.

Reviewer 2:

The reviewer noted that within funding constraints, the program focusses on targeted topics that are of most importance.

Reviewer 3:

The reviewer stated that all topic areas were adequately addressed.

Reviewer 4:

The reviewer said the program area needs to be more closely tied to economic development benefits and opportunities. Because all of the alternative fuels under the program involve domestic supply chains and mostly domestic jobs (that cannot be shipped overseas), clear economic benefits stem from the development and growth of these supply chains. Perhaps a new metric, tracking monetary benefits, could be added alongside the standard petroleum displacement metric.

The reviewer further noted that training activities should also be tied to economic development with deep-dive analysis on workforce development benefits, job placement, and earnings. EcoCAR 3 needs to be better tied to

U.S. original equipment manufacturer (OEM) competitiveness (related analysis and messaging could be crafted in conjunction with OEMs).

Reviewer 5:
The reviewer reiterated that deploying hydrogen refueling infrastructure should become a central focus of the Clean Cities program. This will take time and resources, of course. Also, basic research is needed to better understand the barriers to energy efficiency and transition to alternative energy.

Question 14: Are there other areas or emerging vehicle technologies/market trends that this deployment program should explore to meet overall programmatic goals?

Reviewer 1:
The reviewer stated that the new EEMS area captures most of the emerging vehicle technologies that this program area should be most concerned with. Although, technology and practices are changing rapidly in this space, which VTO will need to closely monitor.

Reviewer 2:
The reviewer said it seemed that the portfolio of projects in the TI area adequately address the programmatic goals.

Reviewer 3:
The reviewer referenced the “Systems and Modeling for Accelerated Research in Transportation (SMART) Mobility” concept and would appreciate seeing more of this overlay built into the future activities.

Reviewer 4:
The reviewer noted that research to date has shown that if connected and automated vehicles (CAVs) are to have a beneficial impact on petroleum use and GHG emissions, two things must happen: travelers must be willing to share vehicles; and even more importantly, travelers must be willing to share rides. At this point, it is not at all clear how to nudge the transformation to CAVs in these directions. This will require research and will require coordination with and the active participation of state, local, and other federal authorities. This appears to be a good fit with TI’s mission and expertise.

Reviewer 5:
The reviewer commented that the new focus on EEMS related deployment activities should allow the Clean Cities network to stay relevant in the rapidly evolving connected and autonomous vehicle area.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer stated that the challenges in this program area are addressed very well.

Reviewer 2:
The reviewer noted that the Clean Cities approach has and continues to be a work in progress which continuously makes strategy adjustments to meet VTO objectives.

Reviewer 3:
The reviewer suggested revisiting opportunities to collaborate with Google on AFDC data. Leveraging private partner technology and market exposure would be a good thing. The reviewer also remarked that MotorWeek is an outstanding partner. It would be neat to work with them on producing new video content on EEMS technologies.

Reviewer 4:
The reviewer reiterated prior comments on the need for basic research on the nature of transition barriers and ways to overcome them, like the risk aversion of the majority of consumers, the value of fuel and recharging availability to vehicle purchasers and owners and so on. Also, tools for planning infrastructure deployment such as those developed at National Renewable Energy Laboratory and University of California-Irvine but other places as well could be adapted to serve the needs of state and local authorities.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer noted that the program area as it stands now is quite effective and comprehensive.

Reviewer 2:
The reviewer would like to see a push towards the utilization of neighborhood electric vehicles.

Reviewer 3:
The reviewer reiterated that the size of the problem requires more resources.

Reviewer 4:
The reviewer suggested establishing SMART Mobility training for Clean Cities coordinators with delivery by "Technologist in Chief" experts. The reviewer also suggested developing a partnership with the Bioenergy Technologies Office on renewable natural gas and renewable diesel. Areas for collaboration include data sharing, education, demonstrations, project development, and market development. The reviewer further stated a desire to continue to champion Clean Cities coordinators as having the proper skillset and local knowledge needed to demonstrate, test, and deploy new transportation technologies, which will increasingly include EEMS-based technologies, connected vehicles (CVs), autonomous vehicles, and CAVs.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 9-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page #	Objectives	Approach	Accomplishments	Collaboration	Market Impact	Weighted Avg.
ti071	Midwest D.R.I.V.E.S.	Sam Spofforth (Clean Fuels Ohio)	9-15	3.50	3.40	3.30	3.50	3.30	**3.38**
ti072	Penske Truck Leasing Alternative Fuel Vehicle (AFV) Demonstration and Enhanced Driver Experience Project	Dean Stapleton Penske Truck Leasing Co.)	9-20	3.30	3.30	2.50	3.10	2.90	**2.92**
ti073	Southeast Alternative Fuels Demonstration Initiative (SADI)	Andrea Eilers (Triangle J Council of Governments)	9-25	3.30	3.20	2.70	3.20	2.70	**2.97**
ti074	Filling Critical Gaps Through Innovative Cradle-To-Grave Training	Pamela Burns (North Central Texas Council of Governments)	9-30	3.40	3.30	3.30	3.60	3.20	**3.34**
ti075	Creating an Alternative Fuel Training Network for Florida	Colleen Kettles (U. of Central Florida)	9-35	3.40	3.50	3.40	3.40	3.30	**3.41**
ti076	Increasing Nationwide ZEV Adoption—Enhanced Joint Procurement Process for Public Fleets	Jasna Tomic, (CALSTART)	9-40	3.40	3.30	3.30	3.50	3.00	**3.31**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page #	Objectives	Approach	Accomplishments	Collaboration	Market Impact	Weighted Avg.
ti077	Aggregated Alternative Technology Alliance	Leslie Wollack (NARC)	9-45	3.50	3.25	3.50	3.38	3.50	**3.44**
Overall Average				**3.40**	**3.32**	**3.13**	**3.38**	**3.12**	**3.25**

Presentation Number: ti071
Presentation Title: Midwest D.R.I.V.E.S.
Principal Investigator: Sam Spofforth (Clean Fuels Ohio)

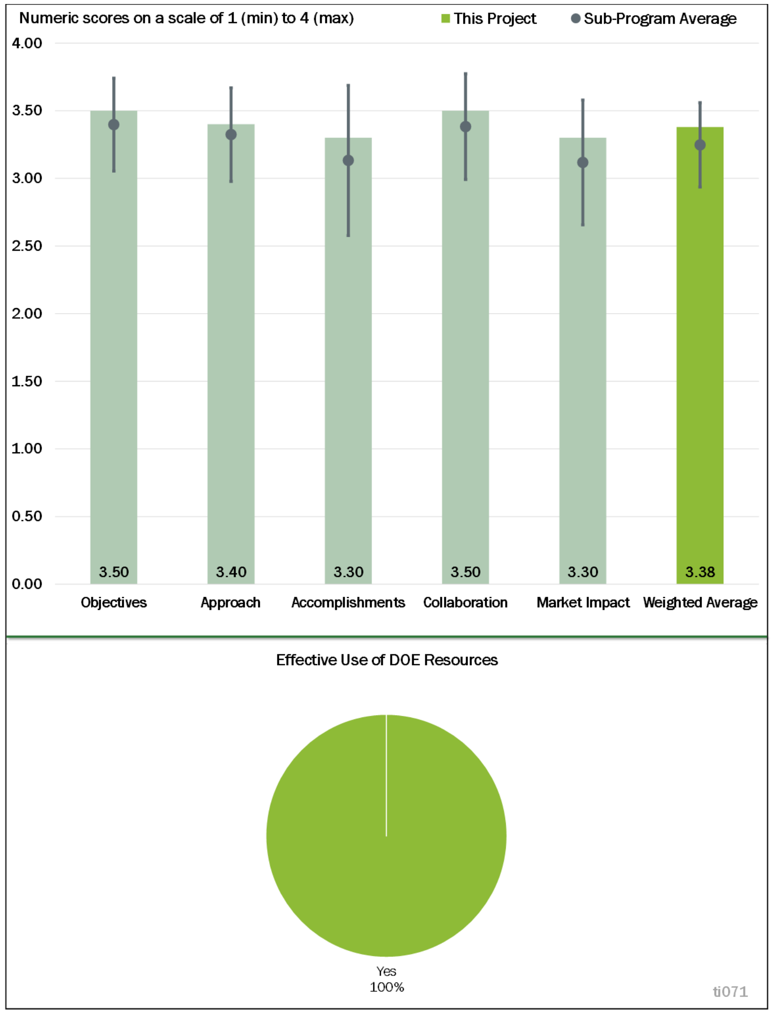

Figure 9-1 - Presentation Number: ti071 Presentation Title: Midwest D.R.I.V.E.S. Principal Investigator: Sam Spofforth (Clean Fuels Ohio)

Presenter

Matt Stephens-Rich, Clean Fuels Ohio

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:

This reviewer commented that the project's objectives are strongly geared towards reducing market barriers (a primary VTO deployment strategy). These objectives include demonstrating, evaluating, and promoting alternative fuel and advanced vehicle technology systems and vehicles; data capture and dissemination; and reducing consumer reluctance to purchase new vehicle technologies.

Reviewer 2:

The reviewer stated that this project is highly responsive to the VTO objectives. The use of data to understand fleet activities is well thought out and offers fleets verifiable information about what fuels are options for them. The data will also help create a business case and educate decision makers who may be reluctant to purchase new technologies. The multiple state execution has the potential to connect activities among the states. The reviewer noted that the multi-pronged approach of in-person visits, webinars, and social media means the message has the potential to be seen multiple times which in turn makes it familiar and less intimidating to end users.

Reviewer 3:

The reviewer remarked that the project's objectives all help to address Goal 1 in the Strategic Plan: to demonstrate and evaluate alternative fuel and fuel efficiency systems to provide data to end users to promote alternative fuels; and to help reduce consumer reluctance to purchase new technologies.

Reviewer 4:

This reviewer stated that the project directly addressed the barrier of fleet operators' lack of familiarity with AFV technologies by providing them with the opportunity to put AFVs to use in their actual operations. It also made telematics available as a part of the demonstration, which can be very useful to those not already making use of it as a way to monitor energy use and fuel costs and factors that affect them.

Reviewer 5:

This reviewer commented that the project objective and overview slides describe the project's specific objectives as well as how the project supports DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 Office of Energy Efficiency and Renewable Energy (EERE) Strategic Plan. The reviewer concluded that project objectives appear to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer appreciated that the project's approach was straightforward and was aimed at maximizing the number of AFV fleet demonstrations and user exposures possible. The three-week demonstration periods provided an appropriate length of time for fleets to experience and assess AFV technologies. The reviewer also stated that the multiple-fuel, multiple-platform focused approach was very good. Despite some data logger technical issues, the data collected for each fleet demonstration and accompanying case studies are a particularly useful part of the approach.

Reviewer 2:

The reviewer stated that this project's multi-partner approach brings significant expertise to the project. The three-week demonstration period ensures sufficient time to capture data, build a relationship with the fleet, overcome objections, and educate both drivers and managers. The goal to produce profiles and video success stories will allow the project have life and impact into the future. Partners are capable of robust fleet analysis because of their diverse skills. This project is sharing lessons with the Triangle Fleet Demonstration program, which the reviewer believed is something DOE should try to do more often among similar active projects. These coalitions have built skills in evaluating data and creating case studies for fleets.

Reviewer 3:

The reviewer stated that the project's approach of program development and set up, program implementation and data analysis, outreach, and education supports the deployment of petroleum reduction strategies. The use of data loggers installed on demonstration vehicles is an excellent approach to allow the project to compare routes and driver performance on alternative vehicles compared to conventional vehicles.

Reviewer 4:

The reviewer stated that the project implemented a well-thought out and structured effort to identify candidate fleets, make contact with them, and provide information and technical advice and access to vehicles. Data loggers were used to ensure that accurate information on the performance of AFVs would be available to the fleet operators. The project was coordinated with the regional CCCs.

Reviewer 5:

This reviewer remarked that the project approach section provided a generally effective methodology to accomplishing the project objectives. Adequate detail was provided on the approach slide with regards to the planned tasks and activities.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:
This reviewer appreciated the YouTube (MotorWeek) video. The demonstrations have included each vehicle technology at least once. The significant number of technologies available is a strength because it gives fleets more broad choices. The projects span a wide breadth from vehicles to mowers and LD to HD. Overall, the reviewer believed this project incorporated an excellent demonstration of the breadth and depth of technologies available.

Reviewer 2:
The reviewer stated that significant progress has been made towards achieving the project goals. Activities associated with the fleet vehicle demonstrations and development of case studies are well underway. The MotorWeek video is an excellent tool to describe the program and its value to potential participants. All initiatives and activities appear to be on track for successful completion. The reviewer has identified no concerns.

Reviewer 3:
This reviewer commented that accomplishing 65 vehicle demonstrations is a reasonable achievement, especially because gasoline prices dropped and were relatively low during the period of the demonstration. This actually dampened interest in natural gas and propane vehicles, in particular. The fact that the battery electric vehicle was most popular reflects the economics of natural gas and propane use at this time. The fuels are still economical but not nearly as advantageous as when gas prices were in the vicinity of $4/gallon. Still, these demonstrations raise awareness of the technologies and their performance with direct usage. The reviewer noted that research has shown this to be the most effective way to increase knowledge and acceptance of novel technologies.

Reviewer 4:
The reviewer pointed out several specific accomplishments. The project has conducted 65 fleet demonstrations to date, exceeding the number originally envisioned (50). MotorWeek (TV broadcast) and YouTube video provided very good exposure for this project. However, the degree that contracting and liability issues impacted the ability for fleet demonstration placements was not clear to the reviewer.

Reviewer 5:
As the reviewer previously commented, the project’s accomplishment of 40 completed vehicle demonstrations helps move the project toward meeting DOE goals, including 12,000 miles driven by vehicle demonstrations and case studies generated for each fleet. The reviewer suggested that it would have been useful if an outline of the report to be prepared on the data collected had been provided.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
This reviewer remarked that commitment by some OEM partners proved fleeting (an unclear number of vehicle partners withdrew from the project). Despite this, the principal investigator (PI), who was also the Chief Financial Officer, has otherwise maintained consistent project participation among project partners.

Reviewer 2:
The reviewer commented that excellent collaboration among partners has been demonstrated. Lessons learned from this project can likely help future demonstration projects immensely. DOE should consider a guidance document for future demonstration projects.

Reviewer 3:
This reviewer commented that there is very good collaboration and coordination between the CCCs and the other partners identified in the project.

Reviewer 4:
The reviewer said that the combination of all regional CCCs, the National Truck Equipment Association (NTEA) to help make connections with fleets, FleetCarma, and others is an outstanding team. The CCCs have local knowledge and contacts. NTEA knows the technologies and the fleet operators and FleetCarma works with them as well and has excellent technology.

Reviewer 5:
The reviewer viewed the collaboration as an effective project team assembled to carry out this project. Industry and CCC partners were involved, which provide an appropriate mix of expertise among team members. Collaboration and communication among project partners appears to be appropriate for the project of this scope.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:
The reviewer appreciated the good project integration with Smart Columbus and electric vehicle (EV) deployment efforts (i.e., Vulcan). The reviewer also pointed out that four fleets that have purchased vehicles as a result of the program (possibly two additional fleet demonstrations will convert to vehicle purchases).

Reviewer 2:
The reviewer pointed out that numerous fleets who demonstrated vehicles indicated in the video that the demonstration will lead them to purchase more vehicles. This is an excellent example of how such an approach quickly grows markets, particularly for LD vehicles and/or fleets. This translates to excellent potential for market expansion and significant petroleum displacement.

Reviewer 3:
The reviewer highlighted that the project has shown an opportunity exists for AFVs and some entities have adopted AFVs due to the work performed during the Midwest DRIVES demonstrations.

Reviewer 4:
The reviewer pointed out that while 65 vehicle demonstrations may seem like a small number for this region, the fact that the demonstrations lasted for 3 weeks gave the operators a chance to extensively experience the technologies and their performance in actual service. The direct experience of the participating fleets not only changed their understanding of AFVs but allowed them to speak with authority to their peers, multiplying the effects of the demonstrations.

Reviewer 5:
The reviewer remarked that the project had good potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence/emissions through educating fleets on real-world performance of various alternative fuels and fuel-efficient technologies through this multi-state AFV demonstration. The reviewer, however, noted that during the oral presentation, it was not clear if the project team had determined exactly how many of the demonstrations had resulted in sales. It is important to

determine that the activities being carried out and data collected are valuable and will result in increased vehicle awareness/sales.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:
The reviewer stated that when involving a major purchase decision, the best thing to do is expose the potential adopter/buyer to the product/technology. The reviewer commented that this project did that in a very practical and meaningful way, giving fleets an indispensable chance to test current AFV and advanced technology vehicles on an extended basis; some that the private sector cannot typically support on its own.

Reviewer 2:
The reviewer said that the partnerships and wise placement of vehicles made this an excellent investment for DOE. Significant matching funds bolster how this type of project can remove barriers and increase markets.

Reviewer 3:
The reviewer stated that the use of DOE funding to allow prospective fleet customers the opportunity to test drive AFVs for an extended period, carrying out the mission of their operations, was critically important to demonstrate the emission and cost benefits of these vehicles.

Reviewer 4:
The reviewer stated that this project was a good use of funds and it would be appropriate to fund similar projects in the future.

Reviewer 5:
This reviewer commented that DOE should definitely fund similar efforts in the future. Natural gas remains an important alternative to petroleum with potentially attractive applications in HD vehicles that can produce co-benefits of reduced air pollution and greenhouse gas emissions, when renewable natural gas is used. The reviewer suggested that in future projects, even greater emphasis should be given to electric drive vehicles (PEVs and fuel cell electric vehicles) because the technologies are less well understood and face even greater market barriers. This is especially true of hydrogen fuel cell vehicles. Although many are working on this problem, the reviewer remarked that DOE and Clean Cities have a special capability that could make important contributions.

Presentation Number: ti072
Presentation Title: Penske Truck Leasing Alternative Fuel Vehicle (AFV) Demonstration and Enhanced Driver Experience Project
Principal Investigator: Dean Stapleton (Penske Truck Leasing Co.)

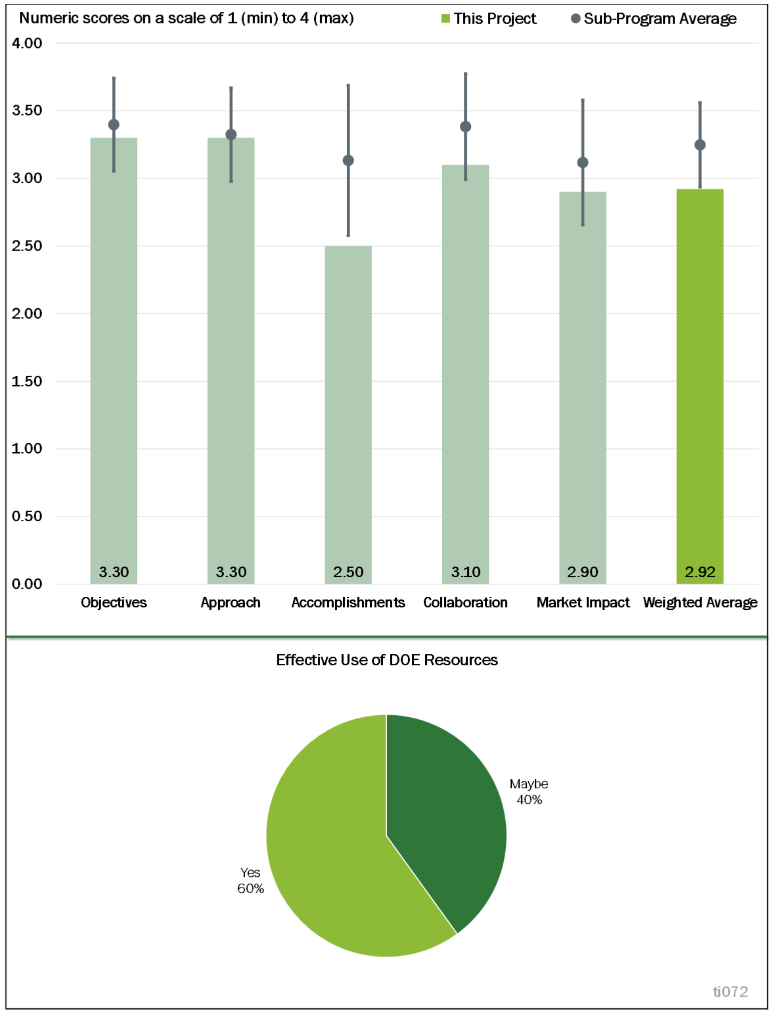

Figure 9-2 - Presentation Number: ti072 Presentation Title: Penske Truck Leasing Alternative Fuel Vehicle (AFV) Demonstration and Enhanced Driver Experience Project Principal Investigator: Dean Stapleton (Penske Truck Leasing Co.)

Presenter
Dean Stapleton, Penske Truck Leasing Co.

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:
The reviewer stated that the project directly supports VTO objectives by reducing reliance on petroleum through the deployment of dedicated AFVs. The vehicles that Penske is deploying are generally high fuel use, low fuel economy vehicles so there is good potential for large impact on fuel use. The reviewer also mentioned that the survey information from the project will provide additional end-user barriers that need to be addressed. Penske is actively reaching users that may not have considered alternative fuels in the past because they lease vehicles instead of purchasing. Therefore, there is good potential to displace petroleum in a different segment of the market.

Reviewer 2:
The reviewer commented that the project’s main objectives support VTO’s deployment strategy to reduce market barriers for AFV deployment. These objectives include exposing truck fleet operators who utilize long-term leases for diesel-fueled fleets to AFV operations and ultimately increasing AFV deployments among participating fleets.

Reviewer 3:
The objectives identified in the project to increase AFV deployments with fleets that use long-term leases, and to increase AFV penetration in different geographic areas definitely supports the DOE objectives of reducing reliance on petroleum. In addition, the reviewer said that the work in this project would also help to address the barriers that are in the EERE Strategic Plan.

Reviewer 4:

The reviewer noted that the project objective and overview slides describe the project's specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer stated that the project objectives appear to be generally effective.

Reviewer 5:

The reviewer said that this project focused on developing new markets for compressed natural gas (CNG) tractors by allowing potential leasers/purchasers to "try before they buy." The reviewer, however, noted that the timing of the project was unfortunate. Gasoline prices dropped sharply just before it began, erasing most of the economic advantage of CNG. Given the much higher capital cost of CNG trucks, this greatly limited the impact of the project on actual acceptance of CNG trucks. Penske offered a relatively low lease price to compensate for the higher initial cost but the lower gas prices still "crushed interest" in the CNG trucks.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project was well designed. It focused on states where acceptance of CNG trucks was low, seeking to increase interest throughout the demonstration. Good relationships were developed with the local CCC who helped identify candidate fleets. Appropriate data and methods were used to identify promising candidates. Appropriate promotional materials were developed. The reviewer further noted that truck fleet operators are very conservative due to the highly competitive business they are in. High costs or unreliable performance cannot be tolerated. This project's approach of allowing operators to experience CNG vehicles in service is a proven method of increasing knowledge and acceptance of AFVs.

Reviewer 2:

The reviewer noted that the approach of this project provided for the development of an AFV marketing plan for fleets, technical support for AFV demonstrations, fleet education about in-use AFV benefits, and progress measured in fleet acceptance of AFV, all of which support the deployment of petroleum reduction technologies.

Reviewer 3:

The reviewer said that the project approach section provided a generally effective methodology to accomplishing the project objectives. The reviewer also said that adequate detail was provided on the Approach and Milestone slides with regards to the planned tasks and activities.

Reviewer 4:

The reviewer remarked that it was not entirely clear why the three targeted regions were chosen. Pre-analysis on potential interest and fleet demand for AFV truck demonstrations was not well-explained by the presenter. It seemed that the market assessment activity should have begun prior to the project award. The reviewer further noted that the project approach provided for up to a 30-90-day demonstration period, which was generous.

Reviewer 5:

The reviewer stated that the project approach used sales staff and Clean Cities partners to identify fleets. The use of a fleet database to identify and refine prospects was also a well-designed approach. The reviewer noted that this multi-pronged approach allows for broader reach. The project switched messaging from price to sustainability when the project team realized it would resonate more with the audience. The reviewer stated that it was short-sighted of Penske to propose propane vehicles for demonstrations when they had none available and their only option was to determine availability after a customer expressed interest. To now simply resign themselves to the lack of interest was disappointing. To the reviewer, it appeared there was poor planning on the part of Penske related to travel time to get vehicles to customers. Conversely, the element of the project that provided cost analysis in addition to the vehicle demonstration ensures that the fleets understand the vehicle operation as well as the potential return on investment (ROI) for their circumstances.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:
The reviewer commented that Penske has achieved good progress and has been nimble in addressing needed change. The marketing effort is refined and focused yet uses multiple channels. Penske has posted useful information and tools on a website which will reach customers outside their defined demographic.

Reviewer 2:
The reviewer noted that the accomplishments to date have been satisfactory. With identifying new opportunities to place vehicles and having a one-year extension, the reviewer stated that the expected outcomes identified for the project should be realized at the end of the program.

Reviewer 3:
The reviewer stated that, although the project was well designed and executed, the low diesel and gasoline prices were almost certainly responsible for reducing its impacts. Still, there was important learning by participants (e.g., about the range limitations of CNG trucks and how to adapt and about the actual price of propane when purchased in bulk).

Reviewer 4:
The reviewer remarked that slow progress has been made towards achieving the project goals. When the project was conceived, the market for CNG HD trucks was experiencing significant activity and/or interest. Unfortunately, when the price of diesel dropped significantly, the interest in fleets getting into CNG vehicles greatly decreased, which has resulted in the little interest in fleets participating in a CNG vehicle demonstration, especially in the target markets which were selected due to the fact that they appeared to be “up and coming” markets for CNG (as opposed to mature markets in California, which may have had sustained interest). Activities are being undertaken to reach new potential customers; however, the results to date have been minimal.

Reviewer 5:
The reviewer noted that, to date, no fleets have demonstrated an interest in either liquefied petroleum gas (LPG) or hybrid electric vehicle trucks. These constitute two of the three fuels or vehicle platforms included under the project’s program. It seemed to the reviewer that not enough pre-market research was conducted prior to the project application or award. The reviewer further noted that fleet data baseline analysis was not complete even though it was the first task. While the project was targeting 60-80 demonstrations, only a handful of demonstrations have occurred. The reviewer stated that, on the positive side, produced marketing and driver instruction materials and video content were all very well done.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer said that Penske assembled a well informed and diverse team to approach potential fleets. Partners are working to their strengths and bringing lessons and suggestions back to the project appropriately for measuring success and course correction.

Reviewer 2:
The reviewer commented that the project interaction with the Clean Cities has been very good and has provided an excellent resource to help move the project forward.

Reviewer 3:
The reviewer noted that the coordination with CCCs was appropriate and worked well.

Reviewer 4:
The reviewer commented that an effective project team was assembled to carry out this project, with industry and CCC partners involved, which provided an appropriate mix of expertise among team members. Collaboration and communication among project partners appeared to the reviewer to be appropriate for the project of this scope.

Reviewer 5:
The reviewer said that the CCCs within each pilot area have defined outreach responsibilities. However, it was not clear to the reviewer if they were fully engaged given the lack of executed vehicle demonstrations.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:
The reviewer commented that, through this project, Penske has found other locations to begin talking about using AFV rentals and will be offering pricing assistance to offer vehicles more comparable to diesels. These actions have a positive impact on the AFV market.

Reviewer 2:
The reviewer said that this project ran into two difficult barriers: low gasoline and diesel prices everywhere; and lack of CNG refueling infrastructure in Baton Rouge, Louisiana. It was not designed to overcome these barriers.

The reviewer noted that, nonetheless, it did increase knowledge and capability at Penske about how to market CNG trucks. With growing interest in sustainability this may serve the company's efforts to market AFVs in the future.

Reviewer 3:
The reviewer noted that deployed demonstration trucks had no labeling identifying them as clean or AFVs. Further, it was difficult to assess a strong market impact, given the lack of executed vehicle demonstrations to date.

Reviewer 4:
The reviewer stated that the limited number of vehicles and willing clients has limited their success. The lack of successful deployment of the propane vehicles demonstrates that low diesel prices continue to impact fleet decisions. The reviewer noted that Penske's commitment to continuing to acquire and lease AFVs is clear. The reviewer observed that, because marketing changed to a sustainability message, this indicated their ability to understand the market and be successful long term.

Reviewer 5:
The reviewer stated that the project had an adequate potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence and emissions through educating fleets on real-world performance of various alternative fuels and fuel-efficient technologies through this multiple-state AFV demonstration. The reviewer commented that unfortunately not enough fleets have participated in the vehicle demonstrations to affect the local target markets.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:
The reviewer stated that companies are cognizant of their public image and understand that sustainability is an important message. The Penske project helps companies consider their options without making a large up-front investment and to learn lessons about how alternative fuels can work for them. The reviewer further stated that sustainability is going to be increasingly important to companies and projects similar to this are well suited to decrease risk and increase long-term change.

Reviewer 2:
The reviewer commented that working with a private entity, such as Penske, was a very good approach to help advance the use of AFVs. As the presenter stated, Penske is already very active in California and this project helped to broaden their experience in the United States. Working with other private companies could also have a positive impact on AFV and infrastructure expansion.

Reviewer 3:
The reviewer remarked that while the project's objectives have strong merit, it seemed that the target pilot regions were not well-chosen. The project is providing some important lessons learned, but DOE funding for this kind of truck rental demonstration effort should be much better targeted to regions with demonstrated interest, based on pre-application market analysis. Ideally, fleet partners should be identified and signed-on prior to award of a project like this.

Reviewer 4:
The reviewer noted that, when gasoline and diesel prices were high, promoting CNG trucks seemed like an obvious winner. However, oil prices are volatile and the project was unlucky in that regard. It is not clear, however, that continuing this particular type of demonstration for CNG trucks would accomplish more than what has already been accomplished.

Reviewer 5:
The reviewer stated that the use of DOE funding to allow prospective fleet customers the opportunity to test drive AFVs for an extended period, carrying out the mission of their operations, is critically important to demonstrate the emission and cost benefits of these vehicles. The reviewer further noted that, unfortunately HD AFV market conditions have dampened the potential success of this approach.

Presentation Number: ti073
Presentation Title: Southeast Alternative Fuels Demonstration Initiative (SADI)
Principal Investigator: Andrea Eilers (Triangle J Council of Governments)

Presenter

Andrea Eilers, Triangle J Council of Governments

Reviewer Sample Size

A total of five reviewers evaluated this project.

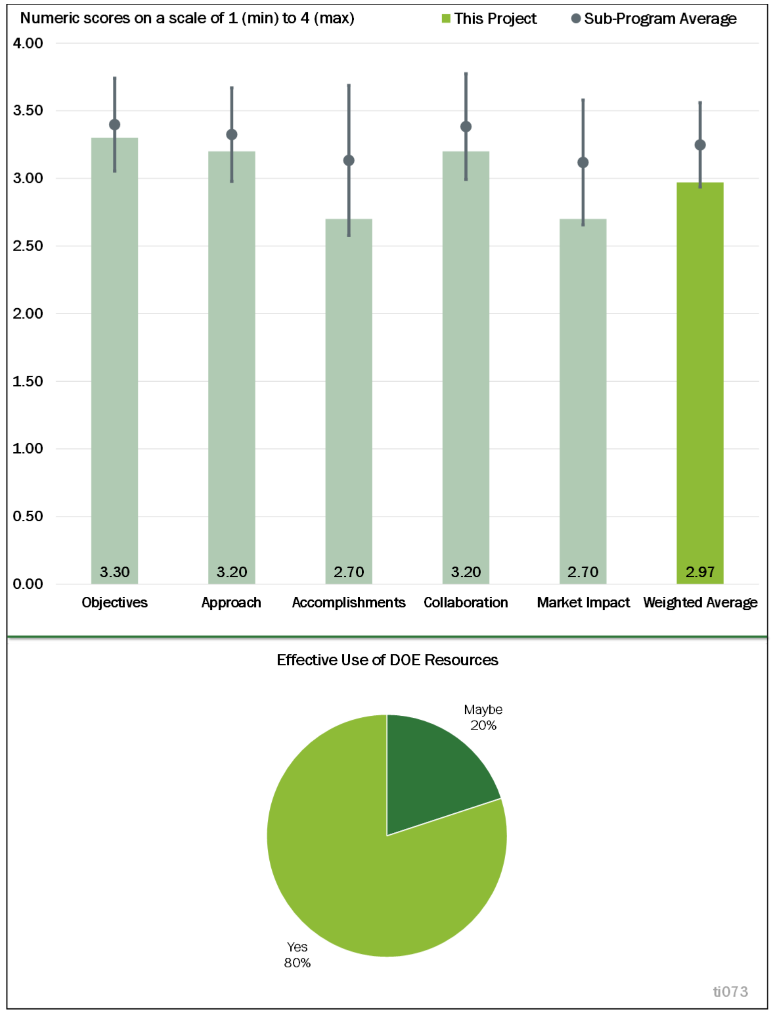

Figure 9-3 - Presentation Number: ti073 Presentation Title: Southeast Alternative Fuels Demonstration Initiative (SADI) Principal Investigator: Andrea Eilers (Triangle J Council of Governments)

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:

The reviewer stated that the project's objectives were strongly set towards reducing market barriers (a primary VTO deployment strategy). These objectives include providing end-users and fleets with AFV demonstration opportunities, along with alternative fuels technical expertise and procurement expertise.

Reviewer 2:

The reviewer said that this project addressed barriers to adoption by enabling fleets to test technology before adopting. "Wading into" technology has proven to be a successful approach.

Reviewer 3:

The reviewer stated that the project's objective supports the DOE goals of reducing the reliance on petroleum by replacing conventional fuel vehicles with alternative fuels.

Reviewer 4:

The reviewer commented that the project objectives were fully consistent with reducing reliance on petroleum fuels by overcoming the lack of awareness and acceptance of AFVs.

Reviewer 5:

The reviewer noted that the project objective and overview slides describe the project's specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. The reviewer further stated that the project addresses several of the goals and deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer commented that the project objectives appeared to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that part of the approach used survey feedback so the project can make course corrections, add information to its outreach, and modify messages. The reviewer noted that this was an excellent process and design for ensuring success through the period of performance and that lessons are integrated as new demonstrations are placed. The reviewer suggested that a "lessons-learned" document about how the project team placed liability for insurance on partners and not the coalitions might be useful.

Reviewer 2:

The reviewer commented that the approach as outlined by the presenter seemed to be adequate.

Reviewer 3:

The reviewer remarked that the project approach section provided a generally effective methodology to accomplishing the project objectives. The reviewer stated that adequate detail was provided on the Approach and Milestone slides with regards to the planned tasks and activities.

Reviewer 4:

The reviewer noted that driver training, vehicle usage data collection, and driver feedback surveys were strong parts of the project's approach. The reviewer also highlighted several difficulties with the project. The presenter indicated that it was difficult to get commitments from school bus OEMs (CNG, LPG) to commit buses to be a part of the project for the full duration (one year). Also, there were supposed to be many Nissan LEAF demonstrations; however, none were demonstrated because Nissan would not commit to the project. On both counts, this indicates to the reviewer that OEMs should be firmly committed partners at the time of project application. The reviewer also notes that the CNG street sweeper has not been a popular demonstration vehicle, largely because it is a large vehicle that requires a commercial driver's license. This detail should have been known in advance.

Reviewer 5:

The reviewer said that involving AFV technology providers as partners and working collaboratively with other CCCs is a reasonable approach. Inclusion of telematics was a good idea but unfortunately had to be abandoned. If redundancy was a problem (fleets already used telematics), the reviewer noted that its use could have been limited to those fleets not already using it. Tracking of outcomes does not appear to be a strong point. The reviewer commented that success was apparently measured by number of demonstrations. While that is a useful metric, outcomes such as adoption of AFVs is more informative.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:

The reviewer stated that 229 demos in 3 states have taken place which displaces a significant amount of fuel and gets technology into the hands of new users.

Reviewer 2:

The reviewer remarked that vehicle demonstrations have been nicely distributed among the three target states. However, the number of demonstrations conducted to date (229) falls well short of the intended goal (900).

Further, the reviewer commented that though 229 vehicle demonstrations have been conducted, just 100 surveys have been completed (less than half of demonstration drivers have submitted surveys).

Reviewer 3:

The reviewer stated that the project enabled 229 drivers to test AFVs, which is a reasonable number but measures of the length of the demonstrations and their impacts on awareness and acceptance were not presented. One hundred surveys were completed but what was learned from the surveys was not explained. The fact that propane was the most popular AFV is understandable to the reviewer because of its cost advantage and similarities to gasoline and diesel fuel. However, propane has been a popular alternative fuel for many years and is probably the best understood of all the AFVs.

Reviewer 4:

The reviewer stated that it was unfortunate that the project did not continue the use of telematics to help with collecting data during the vehicles operations. In addition, the reviewer commented that the project should have made it a requirement for users to answer the survey questions so that at least some data on miles driven could have been reported.

Reviewer 5:

The reviewer said that satisfactory progress has been made towards achieving the project goals. Activities associated with the fleet vehicle demonstrations and data collection are underway. Issues related to the discontinued use of telematics, and the dropping out of several of the technology providers (including the elimination of any school bus demonstrations) have slowed the original scope of the project as replacement partners have been incorporated. While 229 individual drives or demonstrations have occurred to date, the reviewer noted that the presentation did not document the original or revised number that the project is currently working towards at completion.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

The reviewer noted that the project has a significant number of both education partners (coalitions) and technology partners. The partnerships enable a broader set of users (fleets) to potentially participate. The reviewer commented that routing coordination among partners helped ensure clear communications and further assisted them in reaching the project goals.

Reviewer 2:

The reviewer said that the project had a very good group of education and technology partners participating in the project.

Reviewer 3:

The reviewer stated that cooperation among the CCCs was good and that the participation of technology providers was reasonable. The reviewer stated that there were some disappointments, however, for example, CNG and propane school buses did not participate. The reviewer commented that the inclusion of the hydraulic hybrid was encouraging and it will be interesting to see the results of that demonstration because the technology is generally unfamiliar.

Reviewer 4:

The reviewer noted that an effective project team was assembled to carry out this project with industry and CCC partners involved. This provided an appropriate mix of expertise among team members. Collaboration and communication among project partners appears to be appropriate for the project of this scope, according to the reviewer.

Reviewer 5:

The reviewer stated that the project's confirmed and/or committed partners have been strong assets to the team. The reviewer noted that LPG (non-school bus) vehicle demonstrations were particularly successful as a result of strong commitment from Alliance AutoGas. However, the reviewer pointed out that the project has lacked some key vehicle and/or OEM partners needed for project success.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:

The reviewer stated that it was not yet clear how much adoption would result from the demonstrations. The PI indicated that several discussions are underway. The reviewer noted that the project should have more follow up with users about ROI or total cost of ownership to help with adoption and understand why a fleet would or would not purchase vehicles after the demonstration.

Reviewer 2:

The reviewer stated that the number of demonstrations was reasonable. Because the project is still underway it is somewhat premature to assess its impacts, however. The reviewer noted that the inclusion of eco-driving training is likely to have benefits to participants that apply to all types of vehicles.

Reviewer 3:

The reviewer commented that the project had an adequate potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence/emissions through educating fleets on real-world performance of various alternative fuels and fuel-efficient technologies through this multiple-state AFV demonstration. During the oral presentation, it was reported that 100 surveys had been returned to date; however, it was not clear if the project team had determined exactly how many of the demonstrations had resulted in sales. The reviewer noted that it is important to determine that the activities being carried out and data collected is valuable and will result in increased vehicle awareness and/or sales.

Reviewer 4:

The reviewer said it was not clear how the project has contributed to reduced petroleum dependence because the project did not provide any data regarding how the vehicles were used.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:

The reviewer said that adoption of new technology requires buy-in from multiple levels. The reviewer remarked that this project was doing an excellent job of addressing driver hesitation and of demonstrating to fleet managers how the technology can work for them. It is a good low-risk first-step for fleets who have not tried alternative fuels. Historically, we know that hands-on experience allows users to become familiar and comfortable with a technology and helps overcome the perceived risk factor.

Reviewer 2:

The reviewer stated that the project constituted a good use of DOE funding. To even better leverage funding and maximize benefit for AFV demonstration projects, the reviewer noted that OEM technology partners should be firmly committed to the project prior to award. Also, as many demonstration participants and/or fleets should be identified and committed to the project as possible at the time of application.

Reviewer 3:
The reviewer commented that the use of DOE funding to allow prospective fleet customers the opportunity to test drive alternative fuel vehicles for an extended period, carrying out the mission of their operations, is critically important to demonstrate the emission and cost benefits of these vehicles.

Reviewer 4:
The reviewer noted that efforts like this that put AFVs in the hands of potential owners and operators are a proven method of increasing awareness and acceptance and should be continued. CCCs play an important role in this process by providing information and technical assistance as well. The reviewer suggested increasing the emphasis on electric drive vehicles while continuing to promote the other AFVs.

Reviewer 5:
The reviewer commented that similar efforts could be funded by DOE but there should be a requirement that data needs to be collected in order to provide some kind of information back to DOE regarding how the AFVs were used.

Presentation Number: ti074
Presentation Title: Filling Critical Gaps Through Innovative Cradle-To-Grave Training
Principal Investigator: Pamela Burns (North Central Texas Council of Governments)

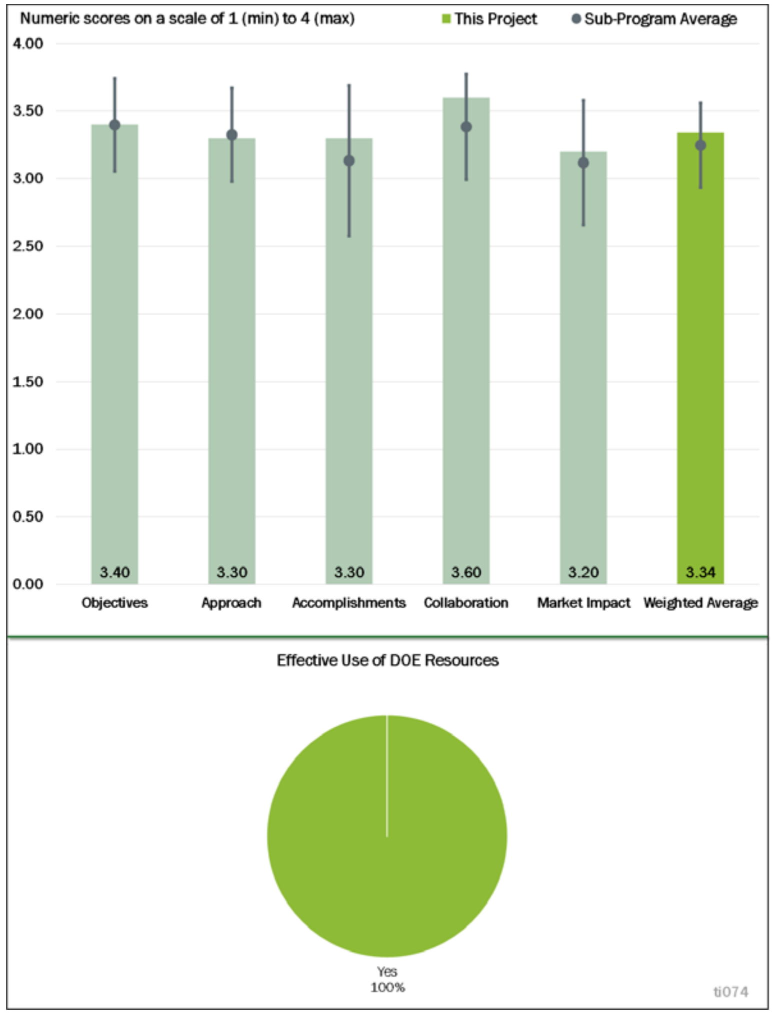

Figure 9-4 - Presentation Number: ti074 Presentation Title: Filling Critical Gaps Through Innovative Cradle-To-Grave Training Principal Investigator: Pamela Burns (North Central Texas Council of Governments)

Presenter

Pamela Burns, North Central Texas Council of Governments

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:

The reviewer stated that the project's objectives are to provide training on alternative fuels and AFVs to mechanics and/or technicians, first responders, public safety officials, and other critical service providers across a large multiple-state region. The reviewer commented that these objectives strongly support VTO's barrier reduction strategy to help prepare and certify sustainable transportation professionals.

Reviewer 2:

The reviewer remarked that the project objectives serve to reduce market barriers by training local officials and technicians which in turn has the potential to reduce barriers to infrastructure development and vehicle adoption. The project addresses numerous audiences and capitalizes on an efficient project budget by using materials that were previously developed through a DOE project and vetted by subject matter experts.

Reviewer 3:

The reviewer commented that the project objectives (enhancing and providing training on alternative fuels and vehicles to first responders and others) definitely supports the VTO objectives and addresses the barriers of lack of technical expertise and consumer reluctance to AFVs.

Reviewer 4:

The reviewer stated that there are institutional as well as market barriers to AFVs. By training first responders (and some mechanics) to be capable of dealing with AFVs in their normal work, the reviewer noted that this project helps to overcome one of the institutional barriers. This indirectly but importantly contributes to the goals.

Reviewer 5:

The reviewer noted that the project objective and overview slides describe the project's specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer remarked that the project objectives appear to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer stated that the project is well integrated with other efforts through the use of established curriculum. The project expands access to training by placing it in vocational and community colleges which helps with long-term use of the curricula in course offerings. The reviewer noted that offering free classes to first responders and public safety official was an excellent method to drive up attendance at trainings. By using existing firefighter instructors and the Freeway Incident management classes, the project team has engaged trusted sources to teach the curriculum.

Reviewer 2:

The reviewer stated that the approach of leveraging existing curriculum and developing "train-the-trainer" information to deliver additional classes after this project is over was very good and supported the reduction of petroleum use.

Reviewer 3:

The reviewer commented that the project approach section provided an effective methodology to accomplishing the project objectives. Significant detail was provided on the Approach slide regarding the planned tasks and activities.

Reviewer 4:

The reviewer noted that the project approach substantively leveraged existing training curriculum funded by other DOE projects (e.g., CNG Station Safety Training for Fire Marshalls and Code Inspectors). The project approach smartly targets pre-existing and captive audiences (e.g., Freeway Incident Management (FIM) classes/attendees). The reviewer said that the project team had some difficulty efficiently engaging with first responder and FIM audiences. This may have been alleviated by using a modified approach to ensure better scheduling, coordination, and training deployment.

Reviewer 5:

The reviewer noted that training first responders and mechanics to be capable of dealing with AFVs facilitated their deployment indirectly. A justification given is that it increases the confidence of potential AFV owners. The reviewer stated that this seemed reasonable but also seemed rather indirect in that the public is not likely to be aware of the training unless it is well publicized. More directly, the reviewer believed that this effort will instill confidence in those who make codes and regulations or control the zoning and approvals for AFV refueling stations and AFVs. This was given little attention in the presentation.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:
The reviewer noted that as of April 1, 2017, 17 classes have been held with over 250 attendees. The project schedule appears to be on track.

Reviewer 2:
The reviewer stated that the number of classes, attendees, and organizations reached was significant. The training across state lines has good potential to ensure consistent response in the event of an emergency. The project has reached technicians and first responders but also placed the curriculum in colleges. The reviewer gave high marks for the pictures in the presentation which show the hands-on experience that attendees receive.

Reviewer 3:
The reviewer stated that the accomplishments identified in the project of 17 total classes with 251 attendees has been very good. The project is on track to complete the remaining milestones by the end of the project in August, which will help to continue to address the identified barriers.

Reviewer 4:
The reviewer noted that between 20 and 65 persons were trained in each of the 6 locations for a total of 251, which represents a reasonable accomplishment given the demands on the time of the trainees. According to the reviewer, it apparently proved to be more difficult than expected to get the training incorporated into the official training requirements for first responders. That is difficult to achieve but it is good to know that the project team is still working on that in order for their project to have a lasting impact.

Reviewer 5:
The reviewer stated that good progress has been made towards achieving the project goals. Activities associated with developing and providing training to alternative fuels and AFVs to reach mechanics and technicians, first responders, public safety officials, and other critical service providers are well underway. All initiatives and activities appear to be on track for successful completion. The reviewer concluded that no concerns have been identified.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer stated that the project demonstrated strong coordination between the PI organization, training organizations (National Alternative Fuels Training Consortium (NAFTC) and Tulsa Area Clean Cities/FS Circle), and partner CCCs. The reviewer also suggested that stronger partnerships with organizations hosting target audiences would be beneficial to the project.

Reviewer 2:
The reviewer commented that roles for each of the partners were well defined and subsequently utilize the strength of each partner. The project successfully involved a significant number of local governments and universities. Local coalitions were very valuable as boots-on-the-ground for finding local audiences and managing each training to ensure success and understand local needs and potential future uses of training.

Reviewer 3:
The reviewer said that the project has an excellent set of collaborators including technical colleges and universities, vehicle providers, local governments, and CCCs. The team has shown very good coordination between training partners, host facilities, and CCCs, which has led to a successful project.

Reviewer 4:
The reviewer commented that project team collaboration and coordination was a particularly strong point of the project. The NAFTC was the best choice for conducting the classes. A solid group of six CCCs cooperated to accomplish the project. The reviewer also noted that seven technological institutes, colleges, and universities were involved as well as seven local governmental agencies and vehicle providers.

Reviewer 5:
The reviewer remarked that an effective project team was assembled to carry out this project, with industry and CCC partners involved, which provided an appropriate mix of expertise among team members. Collaboration and communication among project partners appeared to be appropriate for the project of this scope.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:
The reviewer stated that the project will develop a Future Action Plan to guide continued work and provide for replicability. The project included an effort to sign-up local partner organizations as NAFTC members.

Reviewer 2:
The reviewer noted that the project has trained a significant number of technicians, first responders, and service providers who can more effectively execute their roles and train others. As each of these groups moves among their community they will help reach broader audiences and reduce barriers to market penetration.

Reviewer 3:
The reviewer commented that the project will have good market impact because one of the outcomes will be to work with instructors that have attended the training to implement their own trainings in the future after the project is completed.

Reviewer 4:
The reviewer said that the project had good potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence/emissions through educating mechanics/technicians, first responders, public safety officials, and other critical service providers on various alternative fuels and AFVs. The presentation provided several potential activities and/or strategies that could sustain this training beyond the performance period and how it could be replicated to other coalitions.

Reviewer 5:
The reviewer commented that it is very difficult to measure the market impact of a project such as this. Nonetheless, it is clear that training first responders and mechanics will contribute to market expansion. Like the other training projects, this one asserts that the training will increase consumer confidence in AFVs. Yet little was said about how the public would be made aware of the training or what efforts were undertaken to publicize it.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:

The reviewer noted that technical training to key audiences is a critical need for growing and sustaining the AFV market; DOE funds should continue to support these types of projects. As stated by the reviewer, gaining upfront commitments from target audiences (prior to award) would enhance the effectiveness of future training projects.

Reviewer 2:

The reviewer stated that long-term successful deployment of vehicles and infrastructure requires a depth of training and education to multiple audiences in addition to vehicles being placed; and this project helps achieve that. Technicians must be well educated and familiar with technology, communities must be confident that their first responders are equipped to understand new technologies and how to best respond in an emergency, and fire marshals and code officials need accurate information to ensure infrastructure is compliant and safe. The reviewer remarked that this project does all these things which will help with future deployments and will build a field of smart technicians to support those deployments.

Reviewer 3:

The reviewer said that the project has been a good use of resources and there continues to be a need to educate first responders and others about alternative fuels and vehicles. The reviewer further said that it would be a good use of resources to have others projects similar to this one in other areas of the country.

Reviewer 4:

The reviewer noted that training of this type is valuable in its own right for public safety, may influence those regulating alternative fuels and could increase public confidence in AFVs. The reviewer also commented that success depends on whether the team is able to get AFV training incorporated into required first responder training.

Reviewer 5:

The reviewer stated that the use of DOE funding to develop and deliver training for mechanics and technicians, first responders, public safety officials, and other critical service providers is critically important and necessary. Once the training programs are incorporated into state fire training centers and technical colleges, the reviewer affirms that this will result in an increase the number of key professionals trained on AFVs to support and sustain alternative fuels market development.

Presentation Number: ti075
Presentation Title: Creating an Alternative Fuel Training Network for Florida
Principal Investigator: Colleen Kettles (University of Central Florida)

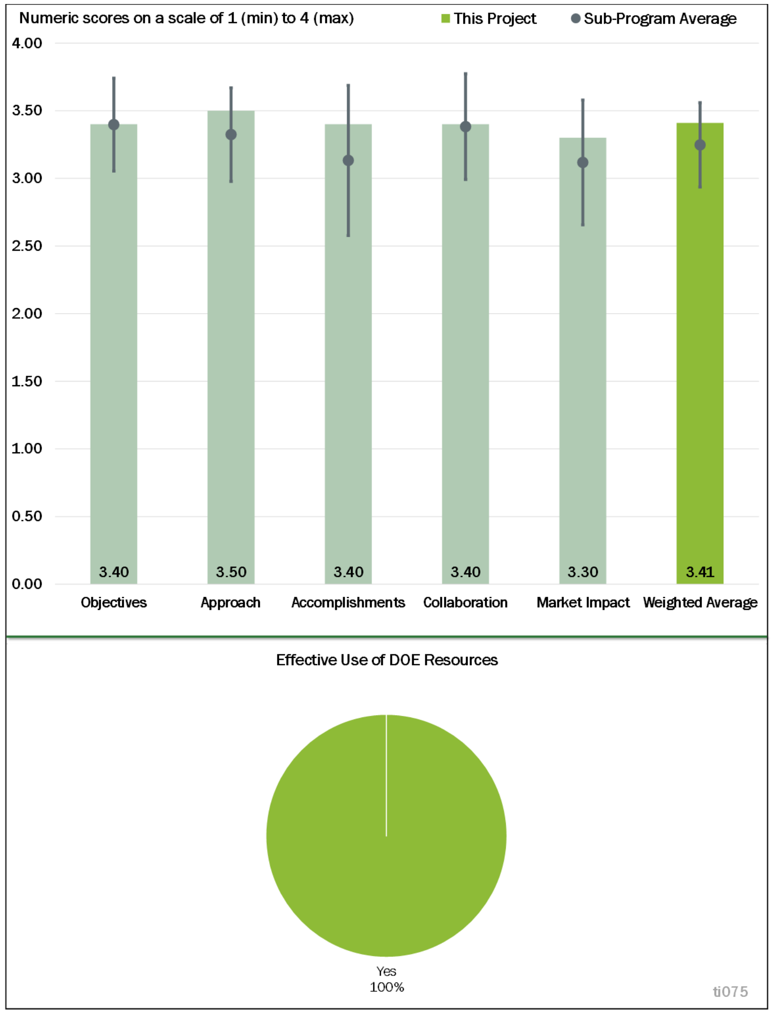

Figure 9-5 - Presentation Number: ti075 Presentation Title: Creating an Alternative Fuel Training Network for Florida Principal Investigator: Colleen Kettles (University of Central Florida)

Presenter
Colleen Kettles, University of Central Florida

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:
The reviewer stated that the project's objectives are to establish an AFV training network in Florida that provides technical and safety training on alternative fuels and AFVs to first responders, public safety officials, and educational instructors. These objectives strongly support VTO's barrier reduction strategy to help prepare and certify sustainable transportation professionals.

Reviewer 2:
The reviewer noted that this project uses high-impact safety related training to increase acceptance of AFVs. The project further establishes training networks in Florida which will educate workforces now and in the future. This project also integrates first responder training into Florida State Fire Marshall approved curriculum.

Reviewer 3:
The reviewer noted that the project supports the VTO deployment goals and addresses the barriers of lack of technical experience with new fuels and vehicles as well as consumer reluctance to purchase new technologies through the objectives of providing best practices, data, and informational materials to end users and communities regarding alternative fuels and vehicles. In addition, the project's objective to establish alternative fuel training networks for emergency responders and safety officials will help address the barriers.

Reviewer 4:
The reviewer commented that safety training for first responders helps to create a sustainable market for alternative fuels and vehicles by overcoming institutional barriers, creating confidence in regulators, and, if appropriately publicized, in the public as well.

Reviewer 5:
The reviewer noted that the project objective and overview slides describe the project's specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum-based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer further noted that project objectives appear to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the project approach targets key audiences (fire fighter trainers, fire fighter recruits, and tow operators) for AFV training. The PI has remained flexible in re-arranging activities to ensure trainings coincide well with first responder audience availability (e.g., move trainings when natural disasters or storms hit, avoid scheduling near other conflicting events, etc.) to maximize attendance. The reviewer also stated that the project is working to identify U.S. Department of Labor-sponsored Workforce Board funding opportunities to help individuals pay training tuition.

Reviewer 2:
The reviewer stated that the project approach was well planned and thoughtful. The inclusion of Fire College approvals and engaging Fire Fighter Instructors will give trainings significant impact into the future. The reviewer appreciated this very robust approach. Workforce Board opportunities are an interesting addition to the project, which could be documented for other areas to also use.

Reviewer 3:
The reviewer remarked that the approach identified in the phase 1 and 2 milestones of the project was very good. The activities in the project should support deployment of petroleum reduction technologies and will definitely help to address the barriers identified by the team.

Reviewer 4:
The reviewer said that the project plan is well-conceived. It gives appropriate attention not only to training trainers who can continue the process, but also to getting the approvals that can make the training a standard part of the curriculum for first responders. In addition, the project addressed the need to make the public aware of the training, which would seem to be key to building public confidence in AFVs.

Reviewer 5:
The reviewer noted that the project approach section provides a generally effective methodology to accomplishing the project objectives. The reviewer also commented that adequate detail was provided on the Approach slide regarding planned tasks and activities.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:
The reviewer commented that the accomplishments identified in the project are very effective in meeting the goals of the project and addressing the associated barriers. The accomplishments, including the establishment of an AFV safety training program approved by the Florida State Fire Marshal and the introduction of AFV

safety training to a national tow operator training organization, are examples of major successes of the project that will ultimately allow for more AFV use.

Reviewer 2:

The reviewer noted that only one tow operator “train-the-trainer” session is scheduled. In the reviewer’s eyes, ideally there would be more scheduled for a large state like Florida. A total of 73 instructors have been trained, covering 22 of 67 Florida counties, which the reviewer considers respectable progress with 50% budget expenditure. The overall project goal in terms of number of trainings targeted was not made clear in the presentation.

Reviewer 3:

The reviewer noted that the database of fire department and training institutions provided an excellent baseline from which to work. The approval by Florida State Fire College ensures a well-educated workforce in Florida. The process by which the project team did this should be taught to other states, and additional lessons from those states should be added to a compendium for future use. The reviewer also said that the use of Workforce Board assistance is an excellent addition to the project which should be documented for others to learn from and use similarly. To the reviewer, it was not clear why all project funds would not be used by the end of the project; however, the project has been highly impactful so this is not a significant shortcoming.

Reviewer 4:

The reviewer commented that the project is still ongoing so much of the training has not yet been accomplished. Still, 73 individuals have been trained as instructors and 22 of Florida’s counties have been reached with training. Importantly, the Florida State Fire Marshall has approved the training as has the Fire College Department of Insurance Continuing Education, which are important steps towards making AFV training standard for firefighters.

Reviewer 5:

The reviewer stated that good progress has been made towards achieving the project goals. Activities associated with establishing AFV training networks for the state of Florida that provide safety and technical training on electric drive, CNG, and propane vehicles to current and future emergency first responders, public safety officials, and instructors at educational institutions are well underway. The reviewer further stated that all initiatives and activities appear to be on track for successful completion. Particularly noteworthy is the cooperation and collaboration with the Workforce Development Boards to provide funding for this training. This project may be a good model for other states to replicate. The reviewer concluded that no concerns have been identified in this category.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

The reviewer stated that the project demonstrates significant successful collaboration among coalitions and a broad set of stakeholders. The fact that the project team was able to secure food and vehicle donations is commendable in the reviewer’s eyes and likely led to happier attendees. Their experience with the State Fire Marshall and successfully integrating training into regular training materials is commendable and documenting their experience would be helpful to others.

Reviewer 2:

The reviewer stated that the project lead has identified a very strong group of sub-recipients and project partners which are collaborating on this project. The participation of the fire departments, academies, and food and vehicle donation companies have all helped make the overall project a success. In addition, the work done by the CCCs have also been integral to meeting this project’s objectives.

Reviewer 3:
The reviewer noted that the collaboration includes Florida CCCs, the Florida State Fire College, the NAFTC, and other relevant participants such as Towers, General Motors, and other stakeholders. The reviewer stated that involving the State Fire College early on was a key to successful approval of the curriculum. The reviewer questioned whether there was a way to further involve the media to provide more exposure.

Reviewer 4:
The reviewer said that an effective project team had been assembled to carry out this project, with industry and CCC partners involved. This provided an appropriate mix of expertise among team members. The reviewer further commented that collaboration and communication among project partners appeared to be appropriate for the project of this scope.

Reviewer 5:
The reviewer remarked that the project demonstrates good coordination between the PI organization, the NAFTC, Florida State Fire College, and Florida CCCs. Of further note, the degree of involvement by the North American Towing Academy is not entirely clear. For example, training was "introduced" to them, however, it was unclear to the reviewer if they will do anything with it. Only one tow operator training has been scheduled, presumably through NAFTC. The reviewer commented that the PI has done an excellent job securing donor vehicles for training sessions through a wide host of partner organizations.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:
The reviewer commented that the project seeks to ensure sustained market impact by integrating AFV Safety First Responder Training into Florida State Fire Marshall training curriculum (through the Florida State Fire College regimen). The reviewer further noted the potential accessibility of financial assistance through Florida Workforce Boards to help cover training tuition was encouraging.

Reviewer 2:
The reviewer stated that because the training materials were part of the state curriculum for training and for new fire fighters, the project had broad and deep market impact and long-term sustainability. The reviewer remarked that the presentation demonstrated an understanding of the future work that will further increase the impact of the project. Particularly, the financial assistance the project team has access to through Workforce Boards will be impactful.

Reviewer 3:
The reviewer stated that the project has had a market impact through the training of 73 instructors in 22 counties in Florida. A sustainability plan is being developed to support continued first responder training that will provide a mechanism to move training forward in Florida long after this project is completed.

Reviewer 4:
The reviewer commented that, although the project is not complete, there are two very important indications that it may succeed in planting AFV training firmly within the firefighter training curriculum in Florida: the curriculum has already been approved by the Florida College Department of Insurance for Continuing Education; and 73 trainers have been trained.

Reviewer 5:

The reviewer said the project had good potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence/emissions through creating and implementing high-impact and highly innovative approaches to increase the acceptance and deployment of AFVs through safety related training.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:

The reviewer noted that technical training to key first responder and fire professional audiences is a critical need for growing and sustaining the AFV market. The reviewer remarked that DOE funds should continue to support these types of projects.

Reviewer 2:

The reviewer said that this project represented an excellent use of funds. The database of Fire Marshalls that was developed and the use of Workforce Board funding highly support the expansion of vehicles and infrastructure and should be replicated.

Reviewer 3:

The reviewer stated that the project has been a good use of resources and, because there continues to be a need to educate first responders and others about AFVs, additional projects like this would be appropriate in other parts of the country.

Reviewer 4:

This reviewer noted that the project may establish the pattern for successfully implanting AFV training in state first responder training. If so, it could be replicated elsewhere and lead to spontaneous adoption of AFV training. Ex post evaluation of this project and the Texas training project should focus on developing a template for replication in other states.

Reviewer 5:

The reviewer stated that the use of DOE funding to develop and deliver training for mechanics and technicians, first responders, public safety officials, and other critical service providers was critically important and necessary. Once the training programs are incorporated into state fire training centers and technical colleges, this will result in an increase the number of key professionals trained on AFVs to support and sustain alternative fuels market development.

Presentation Number: ti076
Presentation Title: Increasing Nationwide ZEV Adoption—Enhanced Joint Procurement Process for Public Fleets
Principal Investigator: Jasna Tomic (CALSTART)

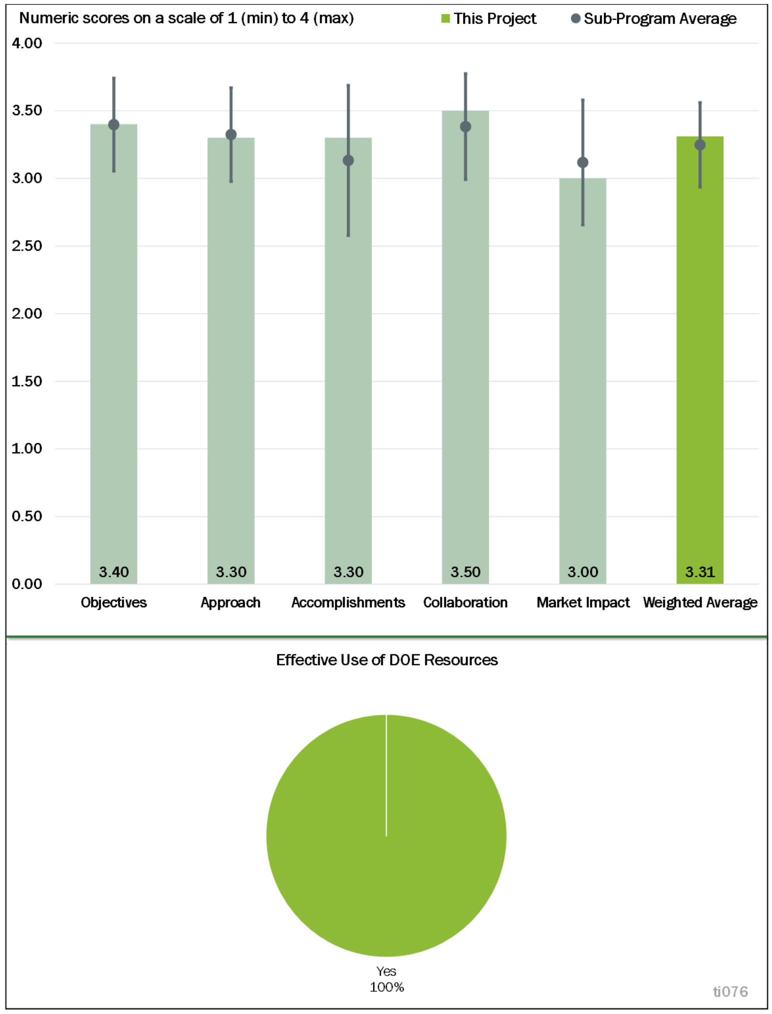

Figure 9-6 – Presentation Number: ti076 Presentation Title: Increasing Nationwide ZEV Adoption—Enhanced Joint Procurement Process for Public Fleets Principal Investigator: Jasna Tomic (CALSTART)

Presenter
Jasna Tomic, CALSTART

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:
The reviewer commented that the project had strong objectives geared towards reducing market barriers (a primary VTO deployment strategy). These objectives focus on developing a replicable procurement model that will secure public fleets' access to a wider range of ZEV models with purchase price reduction and improved access to charging.

Reviewer 2:
The reviewer said that the project strongly supported VTO objectives through a thoughtful approach to group procurements by first identifying potential barriers then developing a replicable model. The project's upfront identification of barriers will allow it to become more successful in both the short and long term. The flexible process will make the procurement process replicable in more places.

Reviewer 3:
The reviewer noted that the project objective to develop a procurement model to help fleets access ZEV models with purchase price reduction and improved access to charging stations will help address the barriers identified and supports the DOE Goal 1 to accelerate the adoption of sustainable transportation technologies.

Reviewer 4:
The reviewer stated that the idea of using buying power and innovative procurement methods to reduce the purchase (or lease) price of ZEVs is an excellent way to increase acquisitions by governments. Joint procurement can also increase the range of choice for states that are not part of the ZEV coalition. Although leasing may seem an obvious way to monetize the federal tax credit, the issue is usually more complicated.

Reviewer 5:

The reviewer said that the project objective and overview slides describe the project's specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum-based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer concluded that the project objectives appear to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer said that the project approach included a logical sequence of tasks. It was well thought out and very thorough.

Reviewer 2:

The reviewer stated that a very robust project approach was evident, which utilized survey information to build models, which were vetted and then updated accordingly. The first six months of the project was outreach-heavy, which ensures that the future work will be impactful. The reviewer noticed that good analysis and course correction opportunities were built into the approach.

Reviewer 3:

The reviewer stated that the approach of the project and associated tasks to complete this activity seemed to be adequate to develop a procurement model for supporting the deployment of petroleum reduction technologies.

Reviewer 4:

The reviewer noted that the project was largely about assembling the right stakeholders and developing a consensus approach that can be adopted, perhaps with variations, by all stakeholders. California is the right choice to lead this effort and has shown that they have the right perspective concerning how to make this work for all the stakeholders. Involving the National Association of Procurement Officials will likely prove to be a key to success.

Reviewer 5:

The reviewer stated that the project approach section provided a generally effective methodology to accomplishing the project objectives. The reviewer further noted that adequate detail was provided on the Approach and Milestone slides regarding the planned tasks and activities.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:

The reviewer noted that the project has accomplished a lot, despite only expending 40% of the budget. The reviewer further said that the Fleet Procurement Analysis Tool looked like a nice tool. The project utilized CCC testers in its development, helping ensure proper functionality.

Reviewer 2:

The reviewer stated that the procurement elements identified by the project team (Slide 11) were important for future projects. The project demonstrated a good understanding of dealerships and how to successfully work with them. The project Analysis Tool is easy to use and includes useful outputs. The reviewer noted that some of the accomplishments information was too quickly presented. The presenter needed to more thoughtfully consider how to present all the required information within the time limit because reviewers cannot intuit needed information from the slides.

Reviewer 3:
The reviewer stated that accomplishments to date included the completed survey and fleet analytical procurement tool. These elements have provided very good background information to allow the project to move to the next steps. The case study of the Alameda County effort to lead a collective purchase of 90 vehicles shows the value of purchasing EVs with multiple public fleets being involved.

Reviewer 4:
The reviewer said that the accomplishments to date are largely planning, organization, and consensus building. In addition, a fleet procurement analysis tool has been developed that should help fleets make better evaluations of ZEVs.

Reviewer 5:
The reviewer stated that good progress has been made towards achieving the project goals. The preliminary activities associated with developing the procurement model are underway; these activities will secure public fleets' access to a wider range of ZEV models. The prepared presentation provides 10 slides with significant detail of project accomplishments to date. Unfortunately, the oral presentation ran out of time before all of these items were covered or discussed. The reviewer concluded that future presentations should ensure that they all material can be covered in the 20-minute time limit.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer commented that the project team is large, but appears to be well coordinated. The reviewer also commented that the project team is strong, and includes numerous leading organizations in AFV deployment. The project convenes a vast number of state vehicle procurement experts and expertise.

Reviewer 2:
The reviewer remarked that the project has multiple strong partners who contributed to the project's success. The reviewer said that the use of partners who are skilled at thoughtfully building models was commendable. Each partner's role was well described (Slide 6).

Reviewer 3:
The reviewer noted that CALSTART has put together an excellent group of collaborators including the Northeast States for Coordinated Air Use Management (NESCAUM), California Department of General Services, Georgetown Climate Center, and nine CCCs. There is very good coordination among the participants in the project through regular meetings and phone calls.

Reviewer 4:
The reviewer said that the project has assembled an outstanding group of participants, including NESCAUM, the Georgetown Climate Center, and nine CCCs. The reviewer pointed out that it was not clear from the presentation materials how involved other state procurement agencies are at this point. Getting them and the National Association of Procurement Officials directly involved is likely to be important to ultimate success.

Reviewer 5:
The reviewer viewed the project as having an effective team assembled to carry out the work, with industry and CCC partners involved, providing an appropriate mix of expertise among team members. Collaboration and communication among project partners appears to be appropriate for the project of this scope.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:
The reviewer noted that the developed purchasing agreement will be open to all state, county, and municipal governments. The procurement model may also be extended to private fleets. The reviewer further commented that the developed procurement model would provide an average vehicle purchase price reduction of approximately 15%, helping to ensure its continued use.

Reviewer 2:
The reviewer stated that the project should have very good market impact because the procurement model being developed can be repeated by other public and private fleets in the future to provide a vehicle purchase price reduction and allow for more AFVs to enter the fleet.

Reviewer 3:
The reviewer commented that if successful in lowering the cost of ZEVs to government agencies through aggregated procurement, this project could substantially increase ZEV sales inside and outside of ZEV states. The resulting market expansion would not only help create economies of scale for manufacturers but would also increase the public's knowledge and familiarity with AFVs.

Reviewer 4:
The reviewer said that the project had an adequate potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence/emissions through educating fleets on real-world performance of various alternative fuels and fuel-efficient technologies through this multiple-state ZEV procurement. The prepared presentation provided adequate detail regarding market impact and sustainability. The reviewer stated that unfortunately, the oral presentation ran out of time before this section of the presentation was covered or discussed. Future presentations should ensure that they all material can be covered in the 20-minute time limit.

Reviewer 5:
The reviewer noted that the overall presentation was not well-rehearsed and/or timed so much of the information on impact and sustainability was not presented or was quickly skipped through. The presenter should more clearly understand that reviewers cannot adequately score information that is inadequately presented. The slide content indicates a reasonable approach to educate fleets and use information to inform the procurement process. The reviewer commented that the slides also appeared to convey that the information gathered so far will contribute to a long-term process that is replicable in other states. It was not clear to the reviewer how the West Coast Electric Fleets specifically contributes to joint procurement processes. The reviewer suggested that the presenter please rehearse so that all information is covered in the future.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:
The reviewer stated that the project constitutes a good use of DOE funding. These kinds of projects help develop AFV and advanced technology vehicle markets and create economies of scale critical to bringing down vehicle cost.

Reviewer 2:
The reviewer noted that providing a procurement mechanism to help with getting AFVs into the marketplace, such as what is being accomplished in this project, was a very good use of funds. Other projects similar to this should be considered in the future to provide additional ideas toward maximizing the economical purchase of AFVs.

Reviewer 3:
The reviewer noted that this project was a good use of DOE funds. However, unless a follow-on is called for, it appears to be a one-off project. If it is truly successful it will help all states.

Reviewer 4:
The reviewer stated that the use of DOE funding to develop a flexible and multiple-state ZEV procurement process is an innovative activity that can, if successful, provide fleets access to a wider range of ZEV models with purchase price reductions.

Reviewer 5:
The reviewer stated that the information presented demonstrates that a replicable process will be created. The project team learned valuable lessons that can be documented for others to use. The reviewer suggested that CALSTART should require presenters to prepare better for the format of the AMR.

Presentation Number: ti077
Presentation Title: Aggregated Alternative Technology Alliance
Principal Investigator: Leslie Wollack (NARC)

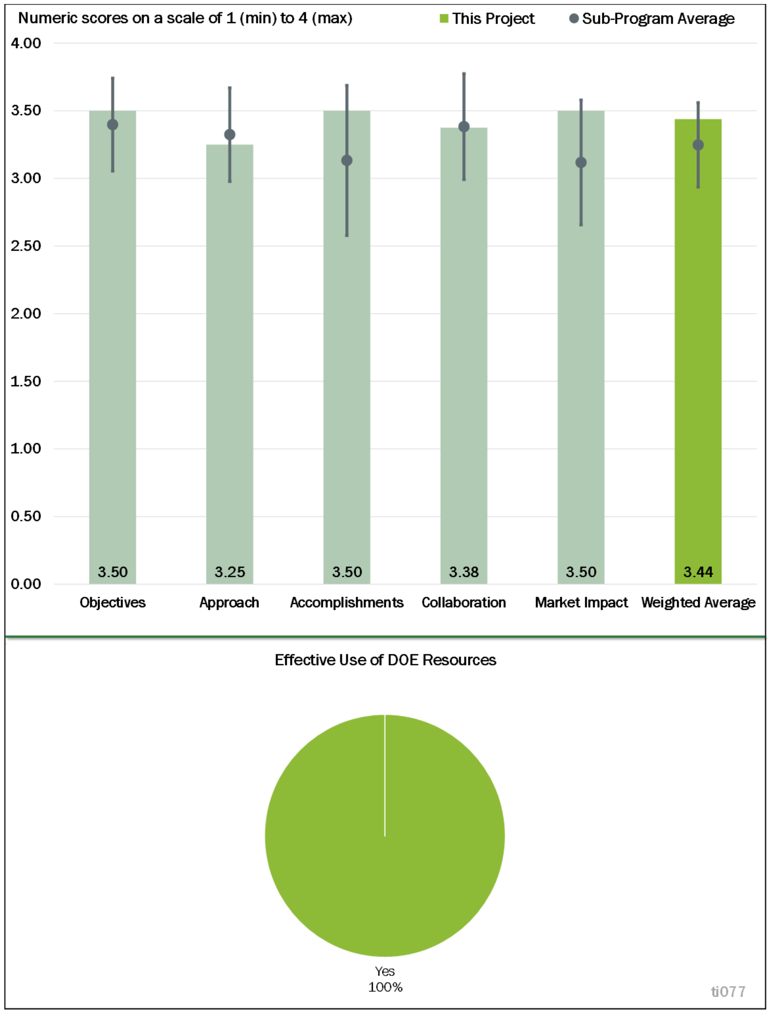

Figure 9-7 - Presentation Number: ti077 Presentation Title: Aggregated Alternative Technology Alliance Principal Investigator: Leslie Wollack (NARC)

Presenter
Phillip Kreycik, Meister Consultants Group

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Project objectives—the degree to which the project objectives support the DOE/VTO objectives of reducing reliance on petroleum based fuels and reducing emissions. This includes the impact the project has on addressing goals and barriers identified in the 2016-2020 EERE Strategic Plan previously listed.

Reviewer 1:
The reviewer stated that the project had strong objectives geared towards reducing market barriers (a primary VTO deployment strategy). These objectives include aggregating regional and national demand for AFVs and refueling and charging infrastructure; reducing cost for private and public fleets using bulk cooperative procurement; establishing best practices guides and procurement templates; implementing regional and national procurements; and developing a web-based toolkit to educate and enable future cooperative procurement initiatives.

Reviewer 2:
The reviewer commented that the project objectives aim to increase the adoption of alternative fuels and vehicles through aggregating demand. The National Association of Regional Councils (NARC) is an ideal agency to gather input on barriers and create a process and/or document that can be used nationally.

Reviewer 3:
The reviewer commented that the project objectives to aggregate regional and national demand for AFVs, reduce the cost of AFVs, develop best practices guides, and implement regional and national procurements are excellent and are very supportive of the DOE Vehicle Technology goals.

Reviewer 4:
The reviewer noted that the project objective and overview slides describe the project’s specific objectives as well as how the project supports the DOE/VTO objectives of reducing reliance on petroleum-based fuels and reducing emissions. The project addresses several of the goals/deployment strategies contained the 2016-2020 EERE Strategic Plan. The reviewer concluded that the project objectives appear to be generally effective.

Question 2: Project approach to supporting deployment of petroleum reduction technologies and practices, alternative fuel vehicles, infrastructure, emissions reductions and related efforts—the degree to which the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer stated that overall, the project approach was logical and well planned, starting with foundational research and business plan development, to a pilot project, to designing a larger initiative of several regional pilots and a national pilot. The project has good leveraging of DOE tools and resources (AFDC Fueling Station Locator, the AFLEET tool, the Vehicle Cost Calculator widget, and CCC publications and guides). The presenter identified some nuanced issues that have come up with efforts to develop regional and national bid initiatives; some of these items (i.e., vendors unwilling to provide deeper discounts at the national level than what is already offered; balancing the need for local service with bulk purchase discount opportunities from distant dealers), could have been anticipated and planned for in the approach.

Reviewer 2:
The reviewer stated that the use of templates and best practices approach will create a replicable process for broader audiences. While existing materials were reviewed it was not clear to the reviewer whether fleets were consulted during the development versus using the templates (Task 2). The reviewer highlighted the excellent use of existing resources and learning from EV Smart Fleets project work. Significant cost share was achieved which means that partners will be "bought into" the project and its results. The reviewer appreciated the thoughtful approach to much of the project including the boot camp curriculum, individual best practices guide for each fuel, and the Gantt chart planning tool which will be very helpful to others.

Reviewer 3:
The reviewer commented that the approach and associated tasks outlined in the project are very good. The creation of procurement and best practices guidebooks and templates will be instrumental in the development of the ultimate design of regional and national procurement initiatives. In addition, the pilot procurement program in Kansas City will also be very useful in helping to design the other procurements planned in the project.

Reviewer 4:
The reviewer stated that the project approach section provided a generally effective methodology to accomplishing the project objectives. Adequate detail was provided on the Approach and Milestone slides regarding planned tasks and activities.

Question 3: Project accomplishments and progress toward overall project and DOE goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project and DOE goals.

Reviewer 1:
The reviewer observed that the Kansas City pilot was successful. It resulted in an 87% increase in year-over-year Nissan LEAF sales during the quarter with more than 100 LEAFs purchased over 45 days. The reviewer said that the project seems to be well on-track. The presenter was not sure how many of the vehicle purchasing fleets were new to AFVs. This would be a good metric for gauging how much the program is growing the market.

Reviewer 2:
The reviewer noted that the PI provided valuable information on individual fleet guides and what each of them contains. The Kansas City pilot was outlined in detail and provided good lessons for the project. The reviewer conveyed that sales training for dealerships was an excellent approach and would increase project success. The increase in sales can be clearly tied to this project. Boot camps for fleets was said to be very effective; even the name infers that everyone is there learning together. The reviewer also stated that the outcome of the Greater

Boston project would be interesting to hear about. The reviewer noted excellent progress toward goals and toward changing market adoption of vehicles.

Reviewer 3:

The reviewer remarked that the project had developed four procurement best practices guidebooks and templates and successfully launched a pilot procurement in the Kansas City area. The Kansas City procurement resulted in more than 100 EVs being purchased through 5 area dealerships. Both of these accomplishments are significant and show good progress toward meeting DOE goals.

Reviewer 4:

The reviewer noted that good progress had been made towards achieving the project goals. Project activities have created replicable procurement best practices and templates. The Kansas City Pilot procurement has been completed and the regional and/or national procurements are moving forward. The prepared presentation provided 10 slides with significant detail of project accomplishments to date. The reviewer concluded that no concerns have been identified.

Question 4: Collaboration and coordination among project team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

The reviewer stated that the project partner roles were well defined and took advantage of each partner's best abilities. The project contained an excellent set of strong partners who bring diverse skills to the project. The reviewer appreciated the very impactful collaboration.

Reviewer 2:

The reviewer noted that this project has put together an excellent group of collaborators including NARC, several regional planning councils, nine CCCs, and several technical experts. All of these groups have coordinated well together which has led to the success of the project.

Reviewer 3:

The reviewer commented that an effective project team was assembled to carry out this project, with industry and CCC partners involved. The project provided an appropriate mix of expertise among team members. Collaboration and communication among project partners appeared to be appropriate for the project of this scope.

Reviewer 4:

The reviewer noted that the project team was large, but appeared to be well coordinated within each pilot region.

Question 5: Market impact and sustainability—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to a sustainable alternative fuel vehicle market, alternative fuel market expansion, and reduced petroleum dependence/emissions in the transportation sector. This would include the potential to reduce barriers to large scale alternative fuel vehicle market penetration, making information about alternative fuels and petroleum reduction opportunities widely available to target audiences, and ability for the project to be replicated in other geographic areas or with other technologies.

Reviewer 1:

The reviewer noted that the project's regional procurement leads have engaged approximately 125 interested fleets with combined purchasing needs of up to 19,000 vehicles over 2-3 years. This is a substantial target market to help drive bulk purchase discounts. The reviewer also commented that the Best Practice guides serve as an on-going reference for existing regional initiatives and new ones. The reviewer said that the national procurement mechanism would remain in place long after the project concludes.

Reviewer 2:

The reviewer noted that already, this project has had market impact by increased sales in Kansas City. The results show high interest from fleets who plan significant procurements over the next 2-3 years. Regional procurement teams can continue to use knowledge from this project, which gives the project life far into the future. The reviewer considered it safe to assume the project is a drop in the bucket and will have far reaching impact as the fleets that participate tell others about their experience. This project has led to significant expansion of EVs on contract lists which makes procurement easier for public fleets. The partnership with National Joint Powers Alliance will have significant future impact. The reviewer also said that great project results were shown.

Reviewer 3:

The reviewer remarked that the project will definitely have an impact on the alternative fuel market. The procurement mechanisms developed in this project will remain in place after this project concludes and the best practices guides developed in this project will allow regions to conduct bulk procurements which will help accelerate getting AFVs into the market place.

Reviewer 4:

The reviewer stated that the project had a good potential to contribute to a sustainable AFV market, alternative fuel market expansion, and reduced petroleum dependence and/or emissions through educating fleets on real-world performance of various alternative fuels and fuel-efficient technologies through this regional and/or national aggregated procurement for propane, electric, and natural gas-powered vehicles and refueling and charging infrastructure.

Question 6: Use of resources—Are DOE funds being used wisely? Should DOE fund similar efforts in the future? If not, what would be a better use of DOE resources to achieve alternative fuel vehicle and infrastructure expansion to support the broader goal of petroleum displacement and emissions reductions?

Reviewer 1:

The reviewer considered the project to constitute a good use of DOE funding. These types of projects help develop AFV and advanced technology vehicle markets and create economies of scale critical to bringing down vehicle cost.

Reviewer 2:

The reviewer viewed this project as being an excellent use of resources. This project will have an impact far into the future. The fleet who participated in the project will very likely tout their success to their peers who will then be more inclined to do the same. The reviewer noted that this is something known from experience, that fleets are more likely to do something if they see someone else was successful doing it. Dealer training experience is worth documenting and repeating to other CCCs.

Reviewer 3:

The reviewer stated that providing a procurement mechanism to help show AFV purchases can be aggregated was a very good use of funds. Other projects similar to this should be considered in the future to continue showing how new and innovative procurement methods can help to reduce the cost of AFVs.

Reviewer 4:

The reviewer said that the use of DOE funding to develop a regional and/or national aggregated procurement process, is an innovative activity that can, if successful, provide fleets access to a wider range of AFV models and fueling equipment with purchase price reductions.

Acronyms and Abbreviations

AFDC	Alternative Fuels Data Center
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation tool
AFV	Alternative fuel vehicle
AMR	Annual Merit Review
CAV	Connected and automated vehicle
CCC	Clean Cities Coalitions
CNG	Compressed natural gas
CV	Connected vehicle
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EEMS	Energy Efficient Mobility Systems
EERE	Office of Energy Efficiency and Renewable Energy
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
FIM	Freeway incident management
GHG	Greenhouse gas
HD	Heavy-sduty
LD	Light-duty
LPG	Liquefied natural gas
NAFTC	National Alternative Fuels Training Consortium
NARC	National Association of Regional Councils
NESCAUM	Northeast States for Coordinated Air Use Management
NTEA	National Truck Equipment Association
OEM	Original equipment manufacturer
PEV	Plug-in electric vehicle
PI	Principal Investigator
R&D	Research and Development

RNG	Renewable natural gas
ROI	Return on investment
SMART	Systems and Modeling for Accelerated Research in Transportation
TI	Technology Integration
VTO	Vehicle Technologies Office
ZEV	Zero-emission vehicle

10. Vehicle Analysis

The Vehicle Technologies Office (VTO) supports early-stage research and development (R&D) to generate knowledge upon which industry can develop and deploy innovative energy technologies for the efficient and secure transportation of people and goods across America. VTO focuses on research that industry either does not have the technical capability to undertake or is too far from market realization to merit sufficient industry focus and critical mass. In addition, VTO leverages the unique capabilities and world-class expertise of the national laboratory system to develop new innovations for significant energy-efficiency improvement. VTO is also uniquely positioned to address early-stage challenges due to its strategic public-private research partnerships with industry (e.g., U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise, prevent duplication, ensure public funding remains focused on the most critical R&D barriers that are the proper role of government, and accelerate progress—at no cost to the Government.

The VTO Analysis (VAN) subprogram supports the planning and execution of technology, economic, and interdisciplinary analyses to inform and prioritize VTO research portfolio planning, including activities such as research target-setting and benefits estimation. VAN supports vehicle data, modeling and simulation, and integrated and applied analysis activities using the unique capabilities, analytical tools, and expertise resident in the U.S. Department of Energy's (DOE) national laboratory system. These activities explore advancements in vehicles and transportation systems and resulting energy impacts to inform early-stage R&D and offer analytical direction for potential and future research investments.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2017 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: van999 Presentation Title: Overview of VTO Analysis Program
Principal Investigator: Rachael Nealer (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer responded yes, it was a great overview.

Reviewer 2:
The reviewer asserted that, overall, the program area and strategy were adequately covered. The pyramid describing the models and tools contributing to the ultimate "integrated analysis" was particularly helpful in revealing the overall strategy behind the stated goals of the vehicle analysis program.

Reviewer 3:
The reviewer was glad to see freight and goods movement as part of this. VTO is expanding to transportation systems, beyond its historic focus of components and vehicles.

Reviewer 4:
The reviewer stated yes, and observed a good overview of material to be reviewed.

Reviewer 5:
The reviewer commented that it was a very good overview of the various programs and activities. It provided a compelling case for more R&D in the transportation sector and established the links between the subprograms.

Reviewer 6:
The reviewer affirmed that the program goals and direction were clearly covered.

Question 2: Is there an appropriate balance between near-, mid-, and long-term research and development?

Reviewer 1:
The reviewer said yes, and highlighted the Systems and Modeling for Accelerated Research in Transportation (SMART) effort as a good way to move existing models into the future to meet emerging information needs.

Reviewer 2:
The reviewer indicated that the scenario analysis of success if all subprograms succeed/fail is a reasonable approach. The reviewer liked the organization of models and tools, and noted that the way these integrate and relate has been mapped to reduce overlap and ensure their complementarity.

Reviewer 3:
The reviewer responded yes, there appears to be a good variety of projects that span near-, mid-, and long-term objectives, although the future work could have been more clearly identified.

Reviewer 4:
The reviewer remarked that the portfolio appears to be well-balanced between near-term and long-term R&D objectives.

Reviewer 5:
The reviewer commented that a good balance was presented. The reviewer expressed interest in seeing more input on the economic or business case that can enable exploitation of the technologies being discussed. It was discussed in several projects that the technology deployment business case has yet to be understood, but examining this was not in the scope of the study. Perhaps more emphasis should be placed on the business case as an enabler for technology deployment and as a pathway for gathering stakeholders and partners.

Reviewer 6:
The reviewer commented that the funded projects span an appropriate range of focus areas. One potential missing area, however, is the development and consumer adoption of more near-term, conventional technologies that would reduce petroleum consumption (e.g., continuously variable transmissions, mild hybrids, etc.). The reviewer noted that incentivizing adoption of these technologies may actually be a more cost-effective strategy for the U.S. Department of Energy (DOE) than investing in some longer-term alternative fuel technologies. The reviewer suggested that at least including them in the analysis tools is warranted to determine whether or not this is the case.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer responded yes, important issues were identified.

Reviewer 2:
The reviewer commented that the key questions presented at the beginning of the presentation were a good sampling of the types of issues facing VTO analysis program.

Reviewer 3:
The reviewer asserted that the program is well motivated by the need for analysis to inform DOE investments and effective means of reducing petroleum consumption.

Reviewer 4:
The reviewer commented that the primary issue is that mobility has the potential to change tremendously in the near future, so the traditional ways of looking at the problem will be inadequate. Implicit to the overall discussion was also that funding uncertainty makes program design and management difficult.

Reviewer 5:
The reviewer noted that data quality and robustness of the various modeling tools expected to be the main challenges. The reviewer encouraged the programs to constantly test and validate the results with real-world data, especially in a rapidly changing transportation landscape.

Reviewer 6:
The reviewer affirmed that important issues were identified, but it was unclear to the reviewer whether “protect human health” includes both safety and emissions/pollution. The reviewer recommended that both safety and environmental risks to human health be considered in the program.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer replied yes, the SMART effort is intended to revise the approach to modeling mobility services.

Reviewer 2:
The reviewer said yes, and explained that the program recognizes that moving from a component and vehicle level program to a system level program will likely lead to challenges, and proposes greater coordination among the projects to meet programmatic goals.

Reviewer 3:
The reviewer affirmed that plans are identified for addressing issues and challenges.

Reviewer 4:
The reviewer responded yes. The program’s pyramid model of developing capabilities in technology and market data, vehicle and market simulations, and overall impacts on energy, the environment, and consumers

is a very useful framework for organizing the funded projects. For future years, the reviewer suggested extending this framework to include a pyramid-type model for strategically planning the specific questions that should be answered by particular case studies using the developed models.

Reviewer 5:

The reviewer commented yes, information was provided on the specific models and tools utilized by the program in order to answer key questions. However, this reviewer pointed out that the specific plans could have been more clearly identified in the presentation.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

The reviewer said yes.

Reviewer 2:

The reviewer responded yes, to the extent this was possible in the context and time allowed.

Reviewer 3:

The reviewer asserted that milestones and progress were described relative to the previous year.

Reviewer 4:

The reviewer replied that the program budget was clearly benchmarked with last year and new outputs of this year were discussed.

Reviewer 5:

The reviewer noted that the presentation included a good sample of new reports and publications.

Reviewer 6:

The reviewer indicated that it was difficult to determine from the presentation if progress was clearly benchmarked against the previous year.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer responded yes, this program contributes important data, models and reports that benefit a variety of stakeholders while also making progress towards solving the fundamental problems identified by the VTO. The projects in this portfolio are filling critical data and research gaps in a world that is quickly moving towards new alternative fuels, vehicles, and technologies.

Reviewer 2:

The reviewer described the projects as well-scoped.

Reviewer 3:

This reviewer said yes.

Reviewer 4:

The reviewer also said yes.

Reviewer 5:

The reviewer replied yes, all the programs fit under the broad umbrella of the VTO with objectives addressing the different challenges and barriers.

Reviewer 6:
The reviewer affirmed that the four sets of models and tools are foundational to the smart mobility program. While the categories of models and type of analysis are clear, the contribution and complementarity of the tools within each category is less clear.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer responded yes, the program is both well-managed and well-structured to meet VTO's needs. It has been successful in developing models, tools, and analyses that represent both individual vehicles and the overall transportation sector and has been responsive to the changes occurring in this rapidly evolving sector.

Reviewer 2:
The reviewer said yes.

Reviewer 3:
This reviewer stated yes.

Reviewer 4:
The reviewer commented that the program area appears to be streamlined and well stewarded with clear objectives for each of the programs.

Reviewer 5:
The reviewer noted that the program does appear to be well-managed and producing valuable outputs relevant to VTO's needs. The determination of the program's portfolio using the pyramid model is a useful framework to strategically fund projects in a diversity of areas relevant to the objectives of the program while also ensuring synergies across projects.

Reviewer 6:
The reviewer replied yes, multiple collaborations and partnerships were discussed. It was not entirely clear to this reviewer, however, how the coordination of so many programs is being reliably carried out—it seems challenging to ensure they are all complementary and synergistic.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer stated that the researchers and tools available to them constitute the key and critical strength of the program as a whole. The broad network with other national laboratories and external participants from academia and industry is another key strength.

The reviewer commented that the program on connected and automated vehicles appears to be particularly relevant. It has access to a suite of tools and leveraging them together could prove to be very beneficial in the study of mobility systems.

Reviewer 2:
The reviewer identified that the key strengths of this program lie in the broad selection of tools that have been developed to simulate the transportation sector with varying levels of granularity. These analyses are providing added value to both VTO and the greater field of transportation research.

Reviewer 3:
The reviewer referenced prior comments.

Reviewer 4:

The reviewer indicated that the program includes a number of strong deployment-oriented projects that consolidate connected and autonomous vehicles (CAVs), electrification, and environmental studies. While broad scope is a strength, not maintaining enough focus could become a weakness.

Reviewer 5:

The reviewer opined that the key strength of this program is that it covers the necessary breadth of modeling mobility services. A key limitation is clearly data—all of these models depend on data, and collecting primary data is expensive and time consuming. Data collection was discussed in side discussions, but it is clear that it is unlikely that the necessary funding will be made available to expand collection efforts.

Reviewer 6:

The reviewer remarked that a strength of the program is developing sophisticated modeling tools to represent a complicated system of consumer and producer behavior and energy and environmental impacts. Vehicle Technologies Analysis (VAN) appears to be focusing their efforts on a valuable set of tools and delivering interesting results with them. This reviewer suggested that one area for improvement is ensuring that the models are transparent, publicly available, and comprehensively documented. Several of the models are not currently publicly available or documented in a way that it is clear how the model inputs are translated to the presented results. The reviewer explained that others (particularly the Market Acceptance of Advanced Automotive Technologies [MA3T]) have produced many publications that very helpfully explain the methodology used by the models, but because the models are quite complicated, even for these models it is not apparent exactly what equations and input parameters are used to generate the results (e.g., a list of all alternative specific constants for every year would be needed to reproduce the MA3T results). The reviewer recommended that VAN work to ensure that the models are publicly available with input files at least by project close.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer responded yes, these projects (particularly some of the newer additions) have adopted innovative methods to investigate challenging and complex systems.

Reviewer 2:

This reviewer believed the projects are deploying new ways to try and tackle the questions and challenges by combining multiple tools and methods.

Reviewer 3:

The reviewer indicated that the projects span a range of innovative approaches to analyzing the systems of interest.

Reviewer 4:

This reviewer said yes.

Reviewer 5:

The reviewer also said yes.

Reviewer 6:

The reviewer asserted that it does seem that new ground is being broken, such as mode shift for freight, which is something that Europe is far ahead of the United States in studying and deploying.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer replied yes, the program area engaged appropriate partners as far as this was discussed.

Reviewer 2:
The reviewer responded yes, the program has engaged a variety of partners and stakeholders from government, the national laboratories, and industry. The addition of Columbus, Ohio (U.S. Department of Transportation (DOT) Smart City winner), as a collaborator could prove particularly useful in the future.

Reviewer 3:
The reviewer responded yes, both internal and external partners. Great to see DOT collaboration, which seems worth strengthening as the emphasis on transportation systems grows for VTO—because co-benefits like safety, energy, environment, and public health will make energy-reducing technology more compelling.

Reviewer 4:
The reviewer stated that all programs appear to have multiple collaborators and partners.

Reviewer 5:
The reviewer replied yes, the program area engaged appropriate partners, but more input from industry stakeholders would be helpful to better understand the technology deployment strategy, and enablers (or barrier removal) associated with same.

Reviewer 6:
The reviewer commented that in general, the program has done a good job of engaging partners in relevant areas. A few projects are missing notable collaborations, particularly with original equipment manufacturers (OEMs) and universities that could help to strengthen their methods and results.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer asserted that the program area is collaborating with partners effectively as far as this was discussed.

Reviewer 2:
This reviewer commented that it appears the program area is collaborating with their partners effectively.

Reviewer 3:
The reviewer replied yes, the program area is collaborating with partners effectively. For example, Urban Science is on the ground in Columbus where the Smart City Challenge activities with Vulcan, Mobileye, etc. are taking place.

Reviewer 4:
The reviewer referenced previous comments.

Reviewer 5:
The reviewer commented that it appears that the projects are collaborating effectively with partners, although it is difficult to tell from a short presentation whether these interactions are meaningful.

Reviewer 6:
The reviewer was unable to assess if the program area is collaborating with partners effectively.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer observed no apparent gaps in this portfolio.

Reviewer 2:
The reviewer stated that there were no gaps identified.

Reviewer 3:
The reviewer commented that the main gap appears to be modeling of emerging mobility services, but this is being addressed.

Reviewer 4:
This reviewer noted that more urban freight and last-mile delivery would be good to address. For example, Federal Highway Administration (FHWA) and Volpe are tackling this in a twinning project with the European Commission, and there is a great deal to learn from European initiatives for urban freight electrification, mode shift, and policy. The 21st Century Truck Partnership project is highway-oriented, not last-mile oriented, so there could be an opportunity here.

Reviewer 5:
The reviewer indicated that no gaps were identified in the portfolio. The reviewer encouraged the researchers to seek validation of their assumptions and quality of the input data throughout the phases of the projects.

Reviewer 6:
This reviewer suggested that it is worth considering whether the evaluation/validation of the developed models should be performed as a separately funded project. Currently, it appears that most validation is done by fitting the model to historical data. However, because these models include many parameters (e.g., the alternative specific constants in ParaChoice and MA3T), this comparison is not a true validation but instead it is simply fitting these model parameters to mimic historic data. This could be addressed by requiring the projects to use hold-out samples to compare their model predictions after all the model parameters are specified. But, it also may be worth considering whether an independent examination or validation test of the models is warranted as an additional project to build confidence in their results.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
The reviewer said none.

Reviewer 2:
This reviewer identified none.

Reviewer 3:
The reviewer had nothing further to add to comments provided previously.

Reviewer 4:
Although not necessarily address this group, this reviewer suggested it would be useful, looking forward, to have a detailed cross-program look at costs for advanced vehicles. Even though this has been done many times, it usually gets to the level of “a motor costs $/kW.” The reality is that things are getting to the point where this is not good enough, and many of the small components like chargers matter. DOE is one of the few organizations that could dig into this.

Reviewer 5:
The reviewer noted that the relatively recent addition of the SMART Mobility program has proven to be both a valuable and necessary change to the VTO analysis portfolio. It would be interesting to see this area expanded further by continuing to add alternative powertrains and fuels to their analyses and to think about future scenarios that move beyond the personal ownership model for vehicles.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
This reviewer identified none.

Reviewer 2:
The reviewer had no further areas to suggest.

Reviewer 3:
This reviewer said none.

Reviewer 4:
The reviewer observed that currently, it appears that the program is focused most on developing modeling capabilities. One area that is currently missing is conducting field experiments or estimation of consumer or producer parameters of interest. These types of studies could serve to address important questions for DOE and inform the parameters used in other projects' models. If the program managers believe that the program could fund teams with the necessary capabilities for conducting these types of studies, expanding the portfolio to include this work would serve as a valuable complement to the other VAN projects.

Reviewer 5:
This reviewer stated that given the limitations in funding, the emphasis will likely be on what to cut, not expand.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer said no.

Reviewer 2:
At this time, the reviewer had no recommendations.

Reviewer 3:
The reviewer had nothing further to add to the comments made in Questions 2, 13, and 14.

Reviewer 4:
The reviewer referenced prior comments.

Reviewer 5:
The reviewer commented that certainly industry involvement can be helpful in this program, however, the reviewer thought that greater emphasis on partnerships with city agencies would be helpful—they are often looking for partners to implement innovative projects, and while they may lack the financial and technical means, they may have the desire and in-kind resources such as street network operations to offer and to demonstrate new vehicle network technologies. Additionally, many cities are committing to aggressive greenhouse gas and emissions reductions, so this program aligns well with these city missions.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer had nothing further to add.

Reviewer 2:
The reviewer offered no further suggestions.

Reviewer 3:
The reviewer said none.

Reviewer 4:
The reviewer suggested more dissemination and awareness of the work with external stakeholders. The reviewer recommended to seek input and vetting of the models by third party to ensure continuous improvements. Also, the reviewer suggested testing the level of interest by tracking the use of the reports and publications by others.

Reviewer 5:
The reviewer commented that it is probably time to downselect vehicle choice models, or at least develop a methodology for determining which approaches are most worthwhile to develop further.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 10-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
van019	ParaChoice Model	Rebecca Levinson (SNL)	10-13	3.50	3.58	3.25	3.17	**3.47**
van020	Applied Analysis of Connected and Automated Vehicles	Tom Stephens (ANL)	10-18	3.50	3.50	2.92	3.00	**3.36**
van021	Transportation Energy Evolution Modeling (TEEM) Program	Zhenhong Lin (ORNL)	10-23	3.50	3.50	3.58	3.33	**3.49**
van022	Connected and Automated Vehicles	Aymeric Rousseau (ANL)	10-28	3.58	3.67	3.42	3.50	**3.59**
van024	Considerations for Corridor and Community DC Fast Charging Complex System Design	James Francfort (INL)	10-32	3.60	3.60	3.00	3.75	**3.54**
van025	Modeling Framework and Results to Inform Charging Infrastructure Investments	Marc Melaina (NREL)	10-36	3.38	3.50	3.38	3.25	**3.42**
Overall Average				**3.52**	**3.56**	**3.26**	**3.28**	**3.48**

Presentation Number: van019
Presentation Title: ParaChoice Model
Principal Investigator: Rebecca Levinson (Sandia National Laboratories)

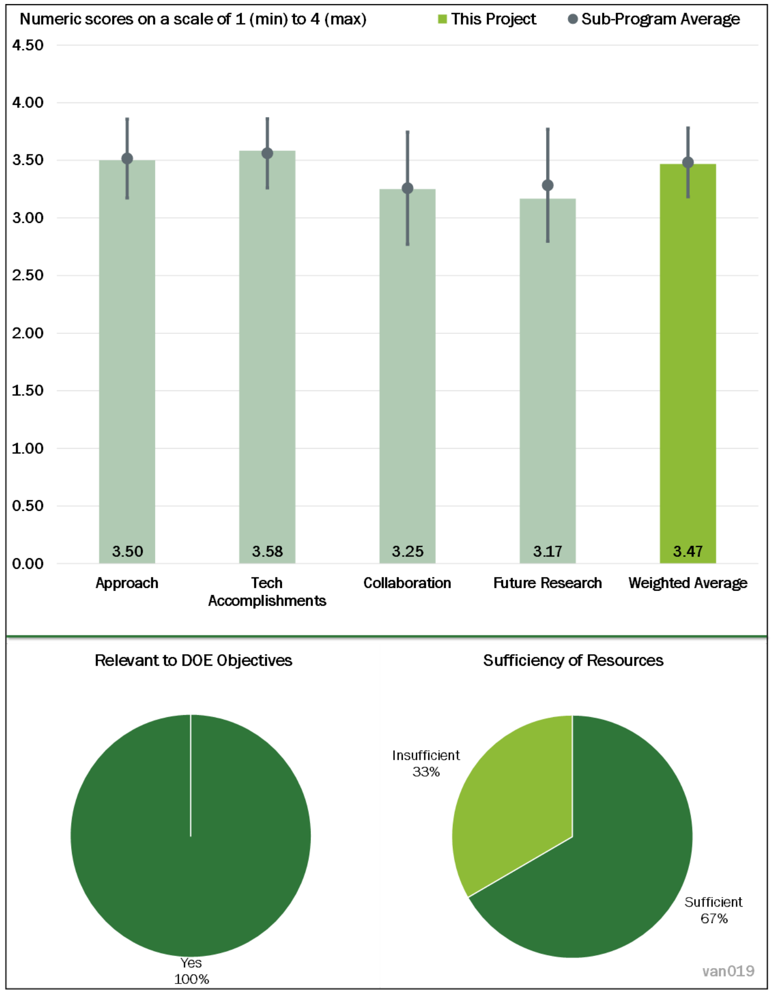

Figure 10-1 - Presentation Number: van019 Presentation Title: ParaChoice Model Principal Investigator: Rebecca Levinson (Sandia National Laboratories)

Presenter

Brandon Heimer, Sandia National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The responder commented that convening stakeholders and getting feedback on the parametric analysis makes sense as the project develops inputs and calibrates the generalized cost function. Inclusion of both one-time and annualized costs and benefits is good given the different incentive landscape in different states. The reviewer noted that the ParaChoice model is distinct from other models in that it explores trade spaces and helps identify tipping points and sensitivities to inputs, for example, how policy decisions will affect the market uptake of different technologies.

Reviewer 2:

The reviewer noted that the project uses a systematic approach to answer the questions that identify key parameters influencing light-duty and heavy-duty vehicle (HDV) choices as related to infrastructure and vehicle technologies.

Reviewer 3:

The reviewer commented that the project has a sensible approach and is well integrated with related projects.

Reviewer 4:

The reviewer commented that the project addresses technical barriers. The reviewer noted that there are business issues that may also be potential barriers and may be significant enough to be worthy of study. One potential business issue to study is under what economic model will the necessary type and number of charging stations be funded and by whom (such as private industry, government, utilities, automotive OEMs). The other business issue the reviewer thought worthy of study is the residual value of batteries and how that value factors into the economic model of electric vehicle (EV) adoption rates.

Reviewer 5:

The reviewer commented that the project is focused on important technical barriers for DOE, particularly issues of alternative fuel vehicle (AFV) infrastructure and the impact of the VTO investments on consumer adoption.

The reviewer had one comment on the details of the model. The reviewer was specifically concerned about the inclusion of several "free" utility parameters (e.g., model availability and alternative specific constants) in the nested logistic regression (logit) model. Including the number of different vehicles in each fuel type category (e.g., by either stock size or model availability) is justified to account for predicting shares of "representative vehicles" of different fuel types (see Daniel McFadden, "Modeling the choice of residential location." Transportation Research Record 673 (1978)); although this paper focuses on choices of residential locations, the methods are relevant and applicable to vehicles as well). However, in this case, there should be an additional term that accounts for the heterogeneity of consumer utility for vehicles within each fuel category. Furthermore, when dealing with future scenarios as this project does, it is difficult for modelers to determine what appropriate values for these terms are in the future and they sometimes become fudge factors for modelers to adjust the predicted scenarios to match their expectations. While the reviewer does not believe this project is making this error, additional documentation explaining what these parameters are, how they are used, and assumed values for them that have been used in the model would be very useful. A further suggestion given by the reviewer is to include a range of these terms in the parameterized scenarios to understand how their variation affects the results.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the project appears to have made excellent progress towards its goals.

Reviewer 2:

The reviewer commented that the project is on track and producing results.

Reviewer 3:

The reviewer commented that the program listed several milestones and decisions points for 2017 and that it is progressing towards meeting their stated objectives.

Reviewer 4:

The reviewer has no concerns about the project in this area.

Reviewer 5:

The reviewer noted that the results viewer tool is now showing the baseline analysis and allows user inspection of adoption outputs out to 2050 and modification of inputs. The reviewer commented that the ability to normalize to total emissions is valuable for quantifying the benefits. The reviewer believed the analysis has shown how range extension and workplace charging accessibility determine predicted petrol reduction, which starts to give actionable information for potential policy interventions. The reviewer suggested bounding information such as the maximum update of an alternative fuel given maximum incentive to provide maximum benefit information.

Reviewer 6:

The reviewer commented that the researchers demonstrated good progress, including the integration of AFVs for the heavy-duty sector and both parametric and scenario level analyses on the impact of charging infrastructure availability for EVs. The reviewer noted that it would be interesting to see the charging analyses expanded further and incorporate higher powered levels of charging (greater than 50 kW) for light-duty and alternative powertrains added for heavy-duty.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project is working with several national laboratories and external partners (OEMs, trade associations), and other government agencies. The reviewer noted that the project appears to have the right level of participation.

Reviewer 2:
The reviewer commented that the project has collaborated with Mike Roeth and North American Council for Freight Efficiency (NAFCE), which is good, given NACFE's grasp on industry pulse. The reviewer noted that the project has also engaged OEMs, the energy industry, and other stakeholders.

Reviewer 3:
The reviewer commented that the project collaborated well with industry stakeholders including an OEM, but noted that the project may want to broaden its engagement with other national laboratories and universities.

Reviewer 4:
The reviewer noted that the project has listed collaborations with OEMs, national laboratories, and trade groups, which appear to provide meaningful input and constructive critiques of the work. The reviewer commented that the project has no university collaborators or technical critiques by academic researchers. The reviewer mentioned that several universities have established programs in electric vehicle charging infrastructure that would be useful to draw on for this work.

Reviewer 5:
The reviewer commented that the project appears to have good linkages to other programs, but noted this type of tool would be more valuable if a very wide range of external parties were able to use it.

Reviewer 6:
The reviewer commented that there should be more partner input to address the issues around funding of recharging stations and battery replacement cost, second life of batteries, etc. The reviewer noted that these economic considerations will have a profound impact on the adoption rate and economic viability of battery electric vehicles (BEVs).

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the projects future work is very pertinent and interesting to a variety of audiences. The reviewer noted that the research into which alternative technologies could gain market penetration in the heavy-duty sector could fill a current research gap. The reviewer encouraged the project to continue to explore how to incorporate challenging parameters into their generalized vehicle costs, especially those related to electric vehicles, such as the willingness to purchase an alternative vehicle, the fact an electric vehicle can be charged in your garage, the impact of the resale value of electric vehicles, etc. Lastly, the reviewer noted that the results viewer which allows public stakeholders to access the projects work is a worthwhile effort that could ultimately spur more collaboration with external researchers.

Reviewer 2:
The reviewer commented that the project appears to have a good plan for future work.

Reviewer 3:

The reviewer commented that the future work included measurable targets and a list of reasonable milestones. The reviewer further noted that there is also a plan to collect real-world data to validate the models and reduce uncertainty.

Reviewer 4:

The reviewer commented that the work plan is good, but noted that there is some suggestion that funding could be inadequate to complete the work plan as outlined.

Reviewer 5:

The reviewer commented that it would be helpful if there was more ability to perform sensitivity analyses to see how much intervention or which type would maximize benefits. The reviewer noted that in the future, including resale value of BEVs and other differently powered vehicles would be an important input for market acceptance given the impact on total cost of ownership. The reviewer also stated that the lack of electric trucks would be good to address in a future version.

Reviewer 6:

The reviewer commented that the planned future work to complete a journal article will help to document the model and receive feedback on results from researchers conducting related studies.

The reviewer noted that the proposed work to study the impact on VTO investments is clearly very well aligned with DOE goals and will be a valuable contribution.

The reviewer commented that future work on HDVs could be valuable, as it is important for DOE goals, and is an often-overlooked area of study. However, the reviewer stated that it was not clear how the current capabilities of the Parachoice model would help to identify promising HDV technologies. The reviewer noted that less choice modeling work has been done for HDVs and there is not much justification for appropriate nested logit parameters for this vehicle class. The reviewer stated that for VTO to be successful in producing meaningful results of HDV future sales scenarios, further work would be needed to estimate choice models for HDVs, either by the project directly or in collaboration with other organizations with experience estimating these models.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that consumer adoption of new vehicle technologies is critical to achieving the goals of increasing energy efficiency and reducing reliance on non-petroleum fuels.

Reviewer 2:

The reviewer commented that understanding how key parameters can impact the integration of AFVs into both the light- and heavy-duty vehicle sectors will aid in DOE’s mission to reduce petroleum usage.

Reviewer 3:

The reviewer commented that by understanding the elements of vehicle choice, lower-consuming choices could be encouraged.

Reviewer 4:

The reviewer commented that the project addresses liquid fuels use through a better understanding of the impacts of infrastructure availability on consumer choices, adoption and market penetration of alternatives transport/mobility technologies.

Reviewer 5:
The reviewer commented that emissions of fleet can be reduced if a system-level model like this is valid and can inform policy interventions or investment choices for charging infrastructure.

Reviewer 6:
The reviewer had no concerns in this area.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the presenter indicated that funding may be insufficient to complete the work plan as outlined. The fiscal year 2017 budget of $350,000 has only been funded up to $194,000 as of March 31, 2017.

Reviewer 2:
The reviewer said that it sounds as though a funding cut may not allow the project to complete the upcoming milestones.

Reviewer 3:
The reviewer commented that the resources and budget appear adequate given the current stage of the program.

Reviewer 4:
The reviewer commented that the budget appears reasonable given the scope of the work.

Reviewer 5:
The reviewer commented that the speaker indicated that funding levels are sufficient to meet current milestones.

Reviewer 6:
The reviewer commented that the funds received for fiscal year 2017 are considerably lower than the budgeted amount, but noted the project seems to be making good progress in spite of the lack of fully transferred funds. The reviewer commented that providing funding to document the model and results in a journal article or other venue where it can receive further technical critiques would be valuable.

Presentation Number: van020
Presentation Title: Applied Analysis of Connected and Automated Vehicles
Principal Investigator: Tom Stephens (Argonne National Laboratory)

Presenter

Tom Stephens, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

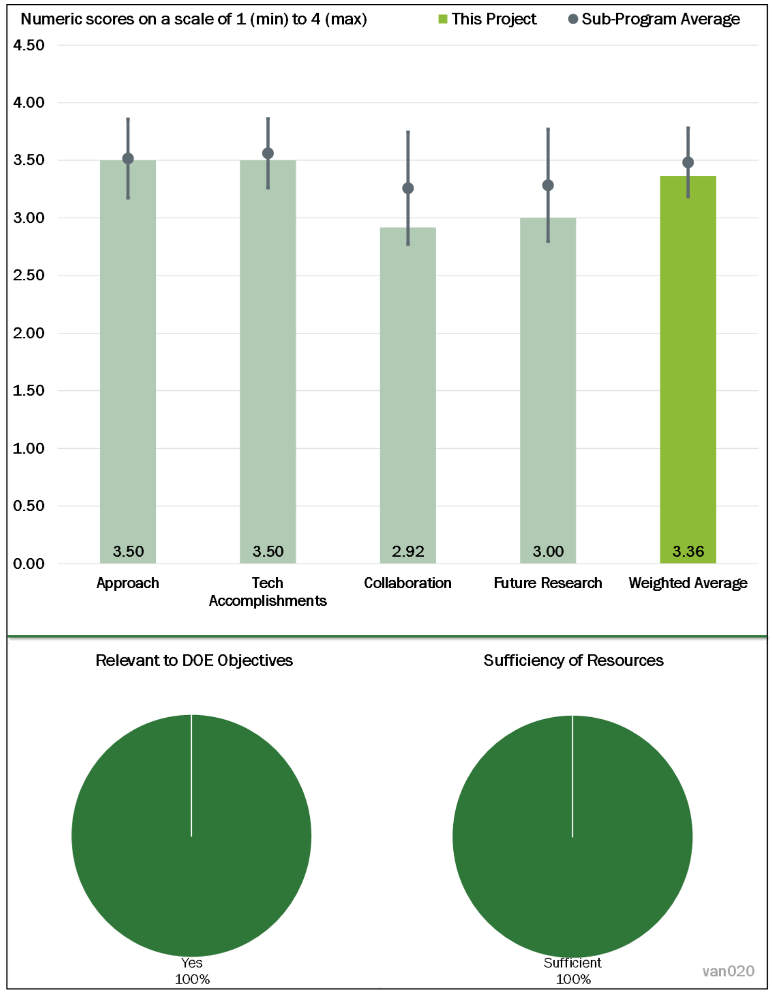

Figure 10-2 – Presentation Number: van020 Presentation Title: Applied Analysis of Connected and Automated Vehicles Principal Investigator: Tom Stephens (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the influence of CAVs on energy use is an important question that is critical to DOE goals. The project's approach to answering the question is sound.

The reviewer further noted that it is very helpful that this project has publicly available documentation of the sources of data and should be commended for this transparency. The reviewer thought it would be helpful in future AMRs, to document these in presentations, or provide a summary, particularly for the range of elasticity of vehicle miles traveled (VMT) demand.

Reviewer 2:

The reviewer commented that the approach appears to be well-designed and appropriate.

Reviewer 3:

The reviewer commented that this analysis aids in filling a gap in our understanding of connected and automated vehicles by synthesizing the current assumptions for CAVs in the literature and establishing an updated framework to estimate their energy impacts. The reviewer noted that the project team built on previous research through identifying the most prominent gaps in information surrounding CAVs, of which there are many, and brainstorming possible analyses to narrow these gaps. The reviewer believed that this gap analysis is an important step towards modeling the full range of implications of CAVs on our transportation system, particularly in regards to the effects on VMT. However, the reviewer noted it would have been helpful for the project to have included alternative fuels and powertrains in the bounding analysis to avoid the need for caveats. The reviewer stated that the issue of caveats will be resolved in future versions of the analysis, per the question and answer session of the presentation. The reviewer noted that while it was understandable that the author wished to separate systems level impacts from vehicle impacts, it would have been useful to have provided one scenario where these impacts were combined.

Reviewer 4:

The reviewer commented that the project is restricting scope to only light-duty, internal combustion engine vehicles with connectivity and automation (CAVs) and will attempt to bound fuel consumption and cost to consumers. The reviewer noted that the demand and efficiency factors considered make sense, although they were not sure if the direction of some of the arrows is qualitatively accurate or knowable, for example, the arrows for underserved and travel demand.

Reviewer 5:

The reviewer commented that the literature review approach is good, and an efficient way to assess a broad range of inputs. The reviewer commented that it was not clear if the literature that was reviewed was complete and covered all of the variables relevant to the assessment of CAV, or if additional literature or studies were needed in order to more fully address any gap areas, such as interaction between CAVs that are shared or not shared vehicles, or CAVs that are BEVs or non-electrified. The reviewer asked if all of these combinations were studied based on available literature.

Reviewer 6:

The reviewer commented that the project started in 2015 and that it appears that the project has run into several hurdles, mostly relative to data availability and quality. The reviewer suggested reassessing the approach and prioritizing the highest value tasks for the remainder of the project.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the project appears to have made excellent progress.

Reviewer 2:

The reviewer commented that the project has made very good progress toward the objectives.

Reviewer 3:

The reviewer commented that this project appears to have made steady progress towards hitting milestones.

Reviewer 4:

The reviewer commented that the early research provided a good insight on the impact automation and connectivity have on energy consumption.

Reviewer 5:

The reviewer commented that data and knowledge gaps were identified, and a detailed matrix of questions were provided to VTO as well as a proposed framework for understanding the uncertainty sensitivity. The reviewer stated that a plan appears to be in place to address these issues.

Reviewer 6:

The reviewer commented that the results should become available next year. The reviewer noted that preliminary results showing bounds of just partial and full automation, but not high-automation or high-automation vehicles, are useful for modeling the relative contributions of different demand and efficiency factors. The reviewer stated that the assumptions for ridesharing should be more robustly analyzed with bounds and a sensitivity analysis. The reviewer further believed that while the scope of the analysis was national, there is value in bounding how much the effects would differ in low-density rural versus high-density urban areas. The reviewer expected bounds would be significantly different in the two environments.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that this project appears to have excellent collaboration, but mostly within DOE. The reviewer stated that it would be good for the project to pursue external collaboration.

Reviewer 2:

The reviewer commented that based upon the presentation, the project has good coordination and collaboration with several of the other national laboratories and more "informal" collaboration with the wider research community, such as universities. The reviewer encouraged the project to gather more formal feedback from external stakeholders in the future.

Reviewer 3:

The reviewer commented that the informal collaborations to date are good, but they could be beneficial to formalize and cross validate technology penetration models. The reviewer provided the example of working with the corporate average fuel economy program and the relationship between the U.S. Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration.

Reviewer 4:

The reviewer commented that the project has collaborations with national laboratories and a university, however noted that there is no apparent input or review from OEMs or other CAV companies. The reviewer stated that the project could benefit from receiving technical critiques from these stakeholders as well as universities and the national laboratories.

Reviewer 5:

The reviewer noted that additional partners may be needed to help address the previously described gaps.

Reviewer 6:

The reviewer commented that the project is 100% internal to DOE and believed it would have been beneficial to involve external experts and stakeholders.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the next steps are reasonably well defined.

Reviewer 2:

The reviewer commented that the proposed future research appears to be well positioned to continue to advance our knowledge and understanding around CAV impacts. The reviewer encouraged the inclusion of heavy-duty CAVs into any future analyses in order to broaden national level estimates of CAVs. The reviewer noted that, when concerning CAV adoption, it is important to consider that these vehicles may be all part of fleets as opposed to consumers purchasing individual vehicles. The reviewer stated that, while this outcome is clearly uncertain, it is necessary to consider the impacts of a variety of futures.

Reviewer 3:

The reviewer commented that the proposed work would help to address DOE goals. The reviewer noted that because the estimates of key parameters, such as long-term VMT elasticity of CAVs, currently span a large range, the modeling capabilities that the project is producing may be most useful in the future once more precise estimates of these parameters are available. The reviewer believed it was critical that the project produce a publicly available version of the model that others could use so that the model can be put to use even after the project is completed.

Reviewer 4:
The reviewer commented that the highest priorities proposed make sense. The reviewer thought that scenarios for future CAV adoption need to be carefully chosen to understand what wedges to pursue further through this and sister projects. The reviewer thought that the heavy-duty area is a known gap in this project that would be good to tackle, given the fact that HDVs are a rapidly growing fraction of fuel consumption among the overall fleet. The reviewer commented that future differentiation of the VMT bounds by geographic location would be a worthwhile goal to be able to both validate the model as CAVs are implemented and to inform possible interventions at a more local or regional level to nudge CAV development in the “utopia” rather than “nightmare” direction.

Reviewer 5:
The reviewer noted that the presentation included a list of tasks and a number of challenges. The reviewer was not sure there will be enough resources (time and budget) to execute all of the tasks and suggested the project team prioritize and focus on the highest value activities.

Reviewer 6:
The reviewer noted that future milestones appear to be vague and far-off, but was confident that they are achievable. The reviewer thought it would be useful to be more specific about what will be done and why it will take the time it will.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that by looking at future energy use, the study should help reduce petroleum use.

Reviewer 2:
The reviewer commented that understanding the potential fuel impacts CAVs may have on our future transportation system can hopefully assist in avoiding undesirable outcomes and reduce petroleum usage.

Reviewer 3:
The reviewer commented that understanding the wedges that can either increase or decrease VMT the most may allow targeted CAVs research and policy in the future.

Reviewer 4:
The reviewer commented that the research is quite relevant to energy consumption and market implications of connected and automated vehicles.

Reviewer 5:
The reviewer commented that understanding the influence of CAVs on VMT and energy use is very important for DOE to accomplish its goals of petroleum displacement.

Reviewer 6:
The reviewer had no concerns about the project in this area.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that funding seems appropriate for the level of effort.

Reviewer 2:
The reviewer commented that the funding should be sufficient to achieve stated goals.

Reviewer 3:
The reviewer commented that resources appear to be in line with scope and timeline.

Reviewer 4:
The reviewer had no concerns about the project in this area.

Reviewer 5:
The reviewer commented that the project scope may be too large for the resources.

Presentation Number: van021
Presentation Title: Transportation Energy Evolution Modeling (TEEM) Program
Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

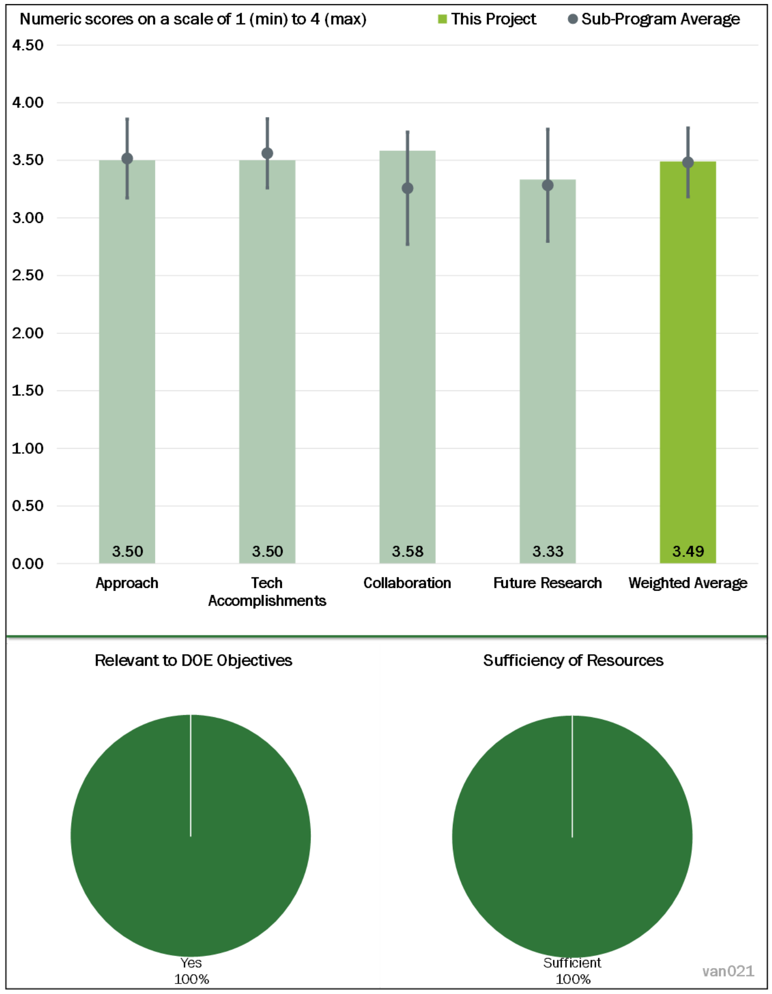

Figure 10-3 - Presentation Number: van021 Presentation Title: Transportation Energy Evolution Modeling (TEEM) Program Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

Presenter

Zhenhong Lin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project approach appears to be well-thought-out and makes incremental improvements to reduce risk.

Reviewer 2:

The reviewer commented that the project employs assumption-impact linkages using system dynamics model based on consumer surveys and other secondary sources, but also original stakeholder input, for example, on the "insurance" value of low-utility features like ability to tow. The reviewer noted that the Transportation Energy Evolution Modeling (TEEM) has multiple activities that could potentially inform one another. The reviewer also remarked that the model has informed other DOE studies, such as the Baseline and Scenario VTO model and any other models within the SMART Mobility program.

Reviewer 3:

The reviewer had no concerns about the project in this area.

Reviewer 4:

The reviewer commented that the project TEEM is linked to several other programs and tools. The reviewer believed the project team provided a good description of the goal and the milestones. Further, this reviewer acknowledged the need for resources.

Reviewer 5:

The reviewer noted that this project employs a comprehensive approach in evaluating market behavior and penetration of both vehicles and technologies via a consumer choice model. The reviewer believed that the overall method seemed coordinated with other VTO efforts and serves as a good complement to other work in the portfolio. The reviewer said that validation and verification of the model was not discussed during the presentation and it was unclear to the reviewer whether this step is occurring or not.

Reviewer 6:

The reviewer commented that the project is focused on understanding producer and consumer behavior, which the reviewer believed is key to achieving DOE's goals. The reviewer found the work to be clearly integrated with related efforts in other agencies and laboratories.

The reviewer was concerned about the determination of future values of a couple "free" utility parameters, specifically, the make and model availability and the alternative specific constants, in the nested logit model. The reviewer believed that including the number of different vehicle alternatives available in each vehicle type category is justified to account for predicting shares of "representative vehicles" of different types (see McFadden, 1978). However, the reviewer believed in this case, there should be an additional term that accounts for the heterogeneity of consumer utility for vehicles within each type category. Furthermore, when dealing with future scenarios as this project does, the reviewer believed that it is difficult for modelers to determine what appropriate values for these terms are in the future and, as a result, they sometimes become fudge factors for modelers to adjust the predicted future scenarios to match their expectations. While the reviewer did not believe this project is making that error, additional documentation explaining exactly how these parameters evolve over future years, and what values have been assumed for them in producing the model results would be very useful.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer commented that the project's progress appears good, including a number of interesting-looking papers.

Reviewer 2:

The reviewer commented that this project has made progress on several fronts, including modeling the synergy between shared and electric and beginning to probe what impacts that could have on the transportation sector. The reviewer also noted that the project had successfully completed other model upgrades, including adding vehicle automation, although less information or results were presented on these upgrades. The reviewer thought the linkage between shared and electric is particularly interesting as it appears few other projects presented as part of this subprogram's portfolio are currently investigating this link.

Reviewer 3:

The reviewer noted that about halfway through the project life, the team achieved several of its goals and have developed and integrated an approach to studying trends and adoption of new transportation technologies.

Reviewer 4:

The reviewer commented that the project is focused on producing a tool and scenario analysis of consumer adoption of vehicle technologies, which is clearly related to DOE goals. The reviewer noted that the project has made good progress so far, particularly in publishing articles that serve to bolster the rigor and transparency of the methods.

Reviewer 5:

The reviewer had no concerns on the project in this area.

Reviewer 6:

The reviewer commented that the new choice structure of the model now includes automation, shared mobility and transit, but does not appear to include non-motorized modes such as walking or riding a bike, as primary transportation choices. The reviewer found the Initial scenarios of no automation versus no automation produced for 2030-2050, showing how automation improvements in fuel efficiency might affect uptake of BEVs, plug-in hybrid electric vehicles (PHEVs), hybrid electric vehicles, and internal combustions (ICs) to be very interesting. The reviewer commented that the assumption should be further examined through consumer segmentation to know what the energy and emissions implications are.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project seems to have great collaboration within and outside of DOE.

Reviewer 2:
The reviewer commented that the project has a very broad set of collaborators, including industry, national laboratories, and universities.

Reviewer 3:
The reviewer commented that the project team has developed a broad collaboration with national laboratories, universities and internal institutions; a very good mix to gain more insights and make the projects models more robust.

Reviewer 4:
The reviewer commented that this project includes ample collaborators across national laboratories, universities, industry, and research organizations.

Reviewer 5:
The reviewer noted that the project identified good collaboration partners, with good variety both technically and geographically. The reviewer commented that there was a good range of stakeholders included, with exception of human powered transportation alternatives, such as bike or walking, which are especially relevant in urban settings. The reviewer further noted that electric bikes may be relevant as well, especially in Asia, but also in mature markets.

Reviewer 6:
The reviewer commented that there was limited stakeholder feedback from industry being solicited to provide certain inputs for the model. The reviewer noted that there were not many other external partners engaged at this point, and suggested growing the collaborator pool.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the project appears to have a good plan for continuing to produce interesting results.

Reviewer 2:
The reviewer had no concerns about the project in this area.

Reviewer 3:
The reviewer commented that the travel time valuation for the TEEM model should probably work with Tom Stephens. The reviewer noted that integrating mobility as a service could be challenging and uncertainty should be bounded, assuming vehicle sharing versus private ownership, as these could potentially affect the bounds by a lot.

Reviewer 4:

The reviewer commented that the presentation explained well the progress to date and next steps. The reviewer recommended that the program team take a broader view about modes transportation and include other possible scenarios such as shared ownership, non-motorized transportation such as bicycles and walking, especially with the observed trend of younger generations living in urban, high-density areas. In addition, the reviewer noted that the resale value of vehicles with alternative technologies is expected to be important factor as well.

Reviewer 5:

The reviewer noted that there was not much information presented on the project's future work plans, although it appears the project is pursuing a range of activities to better resolve the understanding between shared, autonomous and electric. The reviewer commented that this research, plus the completion of the linkage between the MA3T model and TruckChoice, could potentially shed some light on some of the complex questions raised in the development of their overall assumptions. The reviewer commented it would have been interesting to have seen information regarding how the project plans to address the numerous barriers identified throughout the presentation.

Reviewer 6:

The reviewer commented that the proposed work focuses on questions that are important for DOE goals. However, the reviewer was unable to determine whether the project could be able to meaningfully model the synergy between vehicle automation and electrification as proposed when key demand and VMT elasticity parameters governing whether or not there are synergies are not yet well understood. The reviewer further commented that using the range of parameters determined by the VAN020 SMART Mobility project, it is likely that the simulated MA3T results for a particular policy incentive would be swamped by uncertainty in the model input parameters. The reviewer noted that while this was not specifically addressed by the presentation it is possible the project may already have a plan in place to handle such issues.

In conclusion, the reviewer stated that the focus on modeling long-term and short-term consumer mobility decisions could potentially be very useful and is backed up with comparatively more research that the project could draw from.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:

The reviewer commented that this project helps to understand alternative transportation options that will help to reduce petroleum usage.

Reviewer 2:

The reviewer commented that this model assists with both predicting AFV market penetration and understanding the ultimate barriers to their acceptance.

Reviewer 3:

The reviewer commented that an energy transition is required for petroleum displacement, and believed a market dynamics modeling tool and communications can influence this.

Reviewer 4:

The reviewer believed that the outcome of this research would help decisions makers of future R&D efforts as well as policies to address energy consumption and reducing emissions.

Reviewer 5:

The reviewer commented that the project focuses on building tools to understand scenario analysis of producer and consumer behavior that is clearly relevant to DOE goals.

Reviewer 6:
The reviewer had no concerns regarding the project in this area.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that to date the resources appear adequate and have achieved a good deal of work. The reviewer noted the researchers have expressed potential need for more resources in the future, which the reviewer thought should be revaluated as the project progresses.

Reviewer 2:
The reviewer commented that funding appears to be adequate for this scope.

Reviewer 3:
The reviewer had no concerns regarding the project in this area.

Reviewer 4:
The reviewer commented that the funding for this project specifically seems insufficient, but given a number of related efforts that work to develop the same tools it seems sufficient.

Reviewer 5:
The reviewer commented that the funds for this analysis are much higher than most of the other projects in the portfolio but seem reasonable due to the large scope of modeling activities and research.

Reviewer 6:
The reviewer commented that the budgeted funds are higher than other projects, but understood this higher funding level enables the project to produce much more accessible tools and publications that serve to increase the transparency and rigor of the work. The reviewer found this is important as it helps to build confidence in the project outcomes.

Presentation Number: van022
Presentation Title: Connected and Automated Vehicles
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

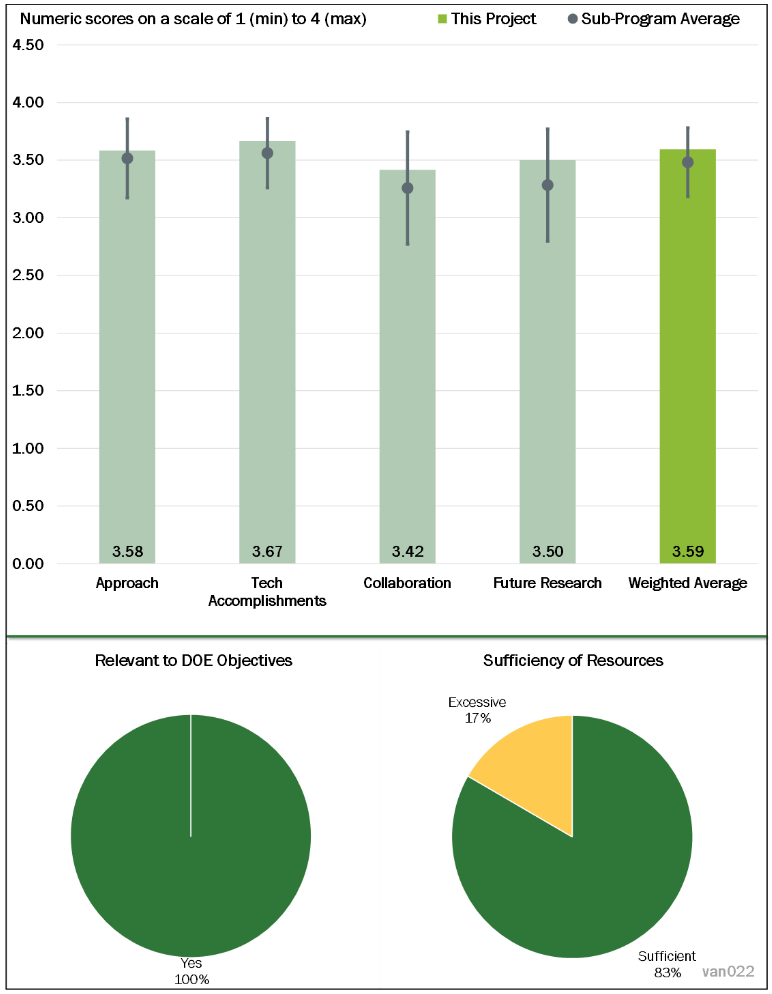

Figure 10-4 – Presentation Number: van022 Presentation Title: Connected and Automated Vehicles Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter
Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:
The reviewer commented that the project appears to be well-designed and feasible.

Reviewer 2:
The reviewer noted that this is an important, scientifically robust project that will serve a variety of stakeholders well, especially as POLARIS is open source. The reviewer thought that the integration of CAVs into this framework is a significant step and adds value.

Reviewer 3:
The reviewer commented that this project started in 2017 and has an ambitious goal of integrating information from various simulation and modeling tools to help understand barriers to market for new technologies. The reviewer believed the approach is sound and if executed well could lead to very useful insights.

Reviewer 4:
The reviewer had no concerns regarding the project in this area.

Reviewer 5:
The reviewer found there to be clear explanation of the four major DOE models, but now the models need to work for a metropolitan area. The reviewer noted that POLARIS will be used to process a range of inputs, be passed to Autonomie, and will output VMT and consumed energy. The reviewer found the largest uncertainty to be the decision modeling of individuals. The reviewer commented that the instead of using location specific agent data, the model is portable to different locations. The reviewer found the model to be closely linked with the TEEM project.

Reviewer 6:
The reviewer commented that the project is clearly relevant to achieving DOE goals in the SMART Pillars.

The reviewer found the general approach sound, but was not sure that the assumption that CAVs will be optimized for maximum energy savings will necessarily be the case. The reviewer noted that it could be useful to explore how much energy consumption changes if CAVs are instead optimized for shortest travel time, or include a scenario to tune the control logic between these two extremes.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that given the early stage in the project, the team has done a good job testing the approach.

Reviewer 2:
The reviewer commented that the project is only 20% complete and there has been significant progress in this short time.

Reviewer 3:
The reviewer commented that project progress looks good.

Reviewer 4:
The reviewer commented that the project has made good progress, significantly improving the model and conducting several interesting analyses that align well with the objectives of the VTO.

Reviewer 5:
The reviewer noted that the efficiency bound of automation at the vehicle level for slope and speed has been modeled, showing up to about 3%-4% savings without vehicle interaction. The reviewer commented that the project has developed a framework for intersections and control theory to maximize energy savings, and applied it to highway vehicle following for several vehicles. The reviewer suggested reviewing a case study for the City of Chicago showing VMT and energy increases as a function of full automated vehicle (AV) automation, which breaks out fleet level from vehicle level energy impacts of AV penetration.

Reviewer 6:
The reviewer commented that the presentation covered the energy impact and the interaction of POLARIS and Autonomie in the context of evolving vehicle powertrain technologies. The reviewer requested to see a more through discussion of the implications of this work on the choices of future powertrain technologies, and those likely to more successfully support the objectives of Energy Efficient Mobility Systems.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project has a wide variety of collaborators from both industry, government, and academia.

Reviewer 2:
The reviewer commented that the presenter mentioned FHWA funding of POLARIS. The reviewer further noted that many collaborations and coordination with government, bother federal and local, and private players appear to be underway, but little detail was provided.

Reviewer 3:
The reviewer commented that the list of partners looked good, although it was not clear what role they had.

Reviewer 4:
The reviewer commented that the project includes extensive group of collaborators across several universities, federal and city agencies. The reviewer noted that some partnership or input from manufacturers could serve to further strengthen the project.

Reviewer 5:
The reviewer commented that more collaboration with industry partners would help in assessing the relevance of the evolving technology choices.

Reviewer 6:
The reviewer commented that a good mix of collaborators including an international institution were associated with the project. The reviewer suggested including OEMs and possibly more international participation, as mobility patterns may be different.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the proposed work, particularly the linkage with the SMART work, looks interesting and logical.

Reviewer 2:
The reviewer commented that the future selected enhancements are interesting, particularly the work proposed for new modes of travel, including transportation network companies (TNCs) and CAVs, and addressing problems that could result from these modes, such as zero occupancy vehicles. Additionally, the ability to scale these analyses to a national level will be very useful, although admittedly challenging. The reviewer noted these changes could narrow some presently existing model gaps and provides a good focus for future work.

Reviewer 3:
The reviewer commented that zero occupancy vehicles make up important unknown that is planned for future work. The reviewer noted that including other modes like transit, bike, TNC will be key, but ultimately the question of whether AVs will be shared or privately owned should be bounded. The reviewer believed that this question could be the single biggest determinant of VMT and energy, because it determines the value of travel time, whether it is marginally high or marginally low.

Reviewer 4:
The reviewer commented that it was stated in the question and answer session of the presentation that future work on other projects will more fully evaluate the relevance to understanding evolving powertrain technologies.

Reviewer 5:
The reviewer commented that this is a new project; the near-term goals are well planned.

Reviewer 6:
The reviewer commented that the proposed work is appropriate for the goals of the project. The reviewer suggested, given the high computational complexity of the model, to quantify uncertainty using scenarios that vary key input parameters rather than running a Monte Carlo analysis that may not be computationally feasible.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that by improving efficiency petroleum use will be reduced.

Reviewer 2:
The reviewer commented that this work allows the evaluation of technologies that fit squarely within VTO's objectives.

Reviewer 3:
The reviewer commented that this project helps calculate scenarios for fleet-level energy impacts of CAVs.

Reviewer 4:
The reviewer commented that the research is very relevant not only to liquid fuels use but to overall energy efficiency and reduction of environmental emissions.

Reviewer 5:
The reviewer commented that the project could produce valuable results on how connected vehicles and cities can reduce petroleum use.

Reviewer 6:
The reviewer has no concerns regarding the project in this area.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the funding level appeared appropriate.

Reviewer 2:
The reviewer commented that the resources for this project seem appropriate given the scope of the tool and the amount of work being accomplished.

Reviewer 3:
The reviewer commented that the resources appear to be aligned with the project scope and milestones.

Reviewer 4:
The reviewer had no concerns regarding the project in this area.

Reviewer 5:
The reviewer commented that the budget and resources appear to be sufficient at this time.

Reviewer 6:
The reviewer commented that the budgeted funding levels are significantly higher than many other projects. The reviewer noted that the project may very well require this level of funding to support high-performance computing capabilities or development of significantly new models compared to the other projects. It was just not completely clear from the presentation what the reasoning was for this significantly higher level of funding.

Presentation Number: van024
Presentation Title: Considerations for Corridor and Community DC Fast Charging Complex System Design
Principal Investigator: James Francfort (Idaho National Laboratory)

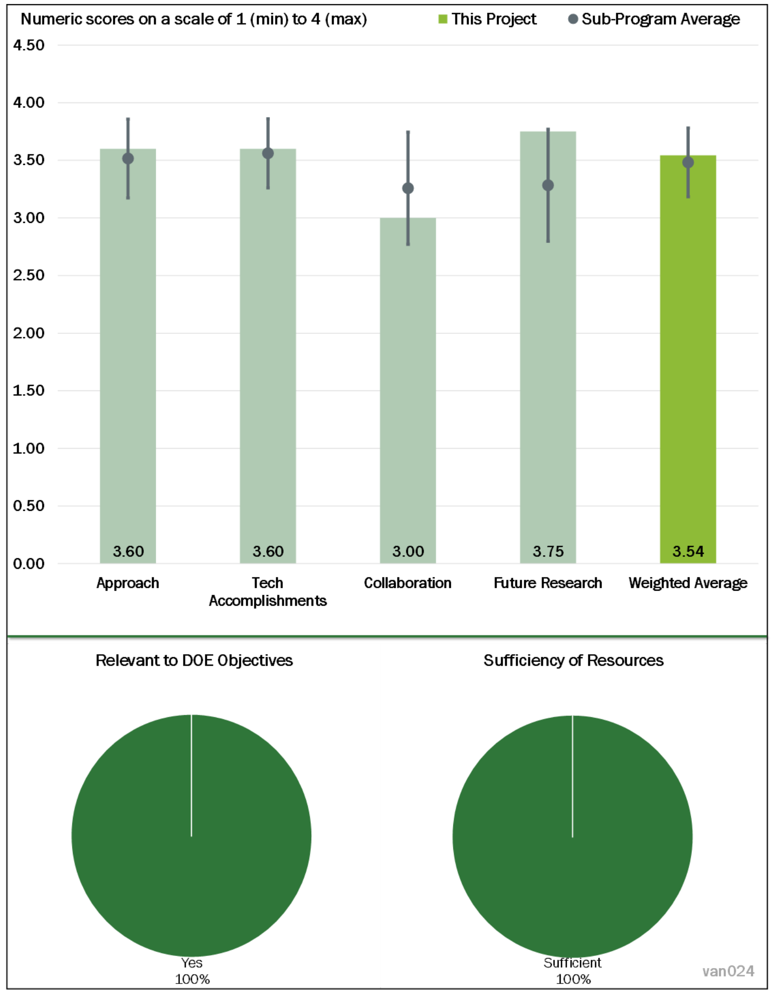

Figure 10-5 – Presentation Number: van024 Presentation Title: Considerations for Corridor and Community DC Fast Charging Complex System Design Principal Investigator: James Francfort (Idaho National Laboratory)

Presenter

John Smart, Idaho National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer commented that the project has an excellent approach.

Reviewer 2:

The reviewer commented that this is an important study with a solid, robust approach. The reviewer noted that the estimates provided in this presentation are useful to a variety of audiences and will be a significant part of the growing discussion regarding high-powered direct-current fast-chargers (DCFC).

Reviewer 3:

The reviewer commented that the project focus is on providing faster charging for EVs. The reviewer noted that the project team has conducted a business case analysis for DCFC infrastructure by reviewing previous projects, including issues and lessons that were learned, and what the design parameters were. The reviewer mentioned that the project team convened working groups for industry and expert input. The reviewer thought that it made sense that this project did not model the parameters, but rather relied on consultation given what was probably a small dataset and a mostly prospective issue.

Reviewer 4:

The reviewer commented that the project was well scoped and executed and contained outputs that produced valuable insights.

Reviewer 5:

The reviewer commented that some gaps may exist in the approach regarding the understanding of the economic model for funding DCFC projects. The reviewer noted that the project mentioned that private funding is often not profitable under current market conditions, but did not present a clear method of addressing this concern.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that the results look great.

Reviewer 2:
The reviewer commented that the project was completed, providing some of the earliest available research on high-powered DCFCs.

Reviewer 3:
The reviewer had no concerns regarding the project in this area.

Reviewer 4:
The reviewer commented that the project was completed and written up. The reviewer noted that recommendations were produced, some highlighted recommendations dealt with onsite energy storage and generation and a phased upgrade strategy. The reviewer further noted that the major cost drivers making existing DCFC projects unfavorable in current market were identified, and concepts for charging complex architecture developed. The reviewer asked why above-ground distribution was not considered to reduce installation costs and if feasible options exist to reduce capital costs. The reviewer found the breakeven analysis is very interesting and suggested it be augmented with ancillary service revenue.

Reviewer 5:
The reviewer noted that the project was successfully completed. The reviewer commented that even though the project produced results that imply it will be difficult to provide EV charging infrastructure with a sustainable business model, the insights are valuable for DOE to be able to move forward on addressing this barrier.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project consulted with industry and the Electric Power Research Institute, which was reasonable given the limited budget and proprietary information involved.

Reviewer 2:
The reviewer commented that it would have been good to have a wider base of contributors. The reviewer acknowledged that this area is competitive, and finding areas to collaborate and coordinate together is difficult.

Reviewer 3:
The reviewer commented that there were not a huge number of collaborators on this project, however, the study was limited in scope and Idaho National Laboratory (INL) is one of the few institutions doing this work currently.

Reviewer 4:
The reviewer commented that the project involved some partners, but did not include collaborations with OEMs, consumer behavior researchers, or other national laboratories or agencies. The reviewer noted that the work could have benefited from input from some of these other groups.

Reviewer 5:
The reviewer commented that the project may benefit from industry partners from the DCFC supply base and PEV OEMs to further explore under what set of conditions funding of public DCFC stations will be viable.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project has ended.

Reviewer 2:
The reviewer noted that the project is complete.

Reviewer 3:
The reviewer noted that although this study is completed, the future work described a follow-on study that is very relevant given the barriers specified in this presentation. The reviewer commented that understanding what a viable business case for DCFC looks like going forward will be necessary for this industry to survive and investigating the components presented in this list, such as demand charges, will be important pieces of the solution.

Reviewer 4:
The reviewer commented that sophisticated optimization would be useful to validate these consultation-based findings, as well as revenue options analysis to help support the ROI of the complexes. The reviewer noted that vehicle-to-grid bidirectional charging might support peak shaving, though at the cost of high turnover.

Reviewer 5:
The reviewer commented that the project may benefit from industry partners from the DCFC supply base and the PEV OEMs to further explore under what set of conditions funding of public DCFC stations will be viable.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer commented that increasing transportation electrification will reduce petroleum usage.

Reviewer 2:
The reviewer commented that this project is incredibly relevant to the ultimate market acceptance of AFVs, and will hopefully aid in addressing what is currently a major roadblock.

Reviewer 3:
The reviewer commented that the project results are valuable for DOE to consider whether EV fast-charging is a viable and cost-effective path forward to reducing petroleum use or whether alternative technology pathways are more preferred.

Reviewer 4:
The reviewer commented that this project supports DOE objectives to the extent that fast-charging is important to petroleum displacement.

Reviewer 5:
The reviewer had no additional concerns regarding the project in this area.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the funding appears to be adequate to complete the project as expected.

Reviewer 2:
The reviewer commented that the project produced meaningful results with a relatively small budget and a very quick timeframe. The reviewer noted that the investigators should be commended for their efforts.

Reviewer 3:
The reviewer commented that the resources seemed sufficient for the project size.

Reviewer 4:
The reviewer commented that the project has been completed.

Reviewer 5:
The reviewer had no concerns regarding the project in this area.

Presentation Number: van025
Presentation Title: Modeling Framework and Results to Inform Charging Infrastructure Investments
Principal Investigator: Marc Melaina (National Renewable Energy Laboratory)

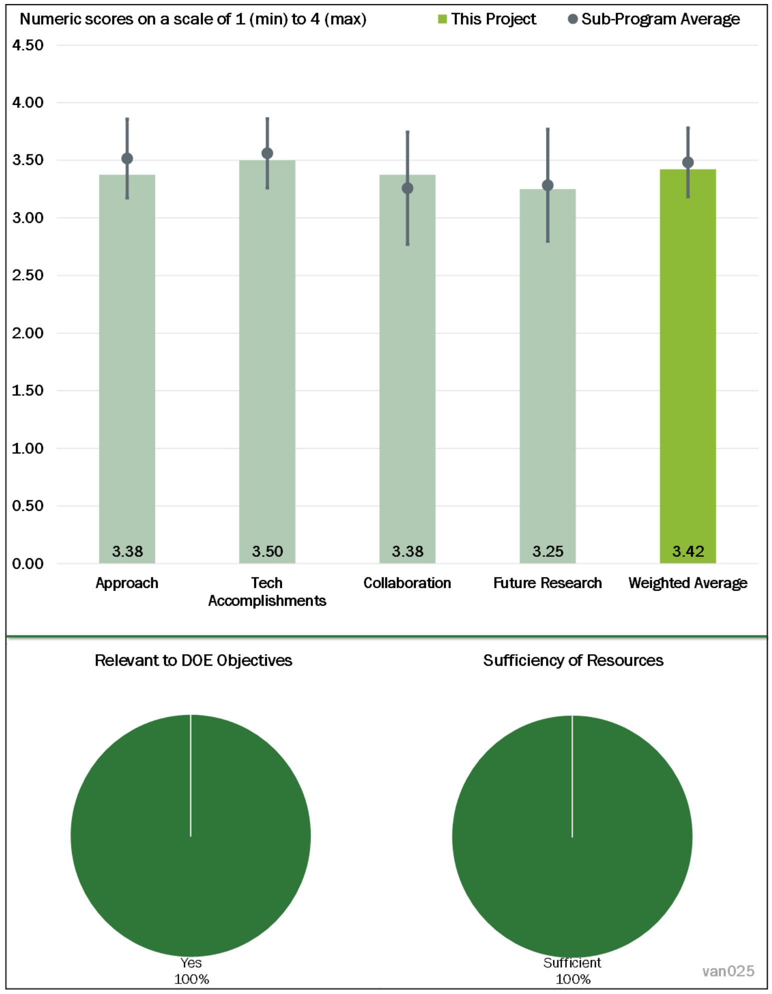

Figure 10-6 - Presentation Number: van025 Presentation Title: Modeling Framework and Results to Inform Charging Infrastructure Investments Principal Investigator: Marc Melaina (National Renewable Energy Laboratory)

Presenter

Marc Melaina, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The review commented that the project's approach looks great.

Reviewer 2:

The reviewer commented that the project included a good range of studies in studying the electric vehicle supply equipment (EVSE) role in supporting PEV growth requirements.

Reviewer 3:

The reviewer commented that this project informs electric vehicle EVSE planning at the state, local and utility level by taking account of uncertainty through scenario analysis for future vehicle fleet and their requirements. The reviewer noted that five separate analyses feed into the research goal of the project, including a Massachusetts-wide EVSE needs planning study.

Reviewer 4:

The reviewer commented that the aim of the project on understanding the role of vehicle technology adoption on increased electric miles is a useful goal that has synergies with other VTO projects. The reviewer noted that because the National Economic Value Assessment of Plug-In Electric Vehicles (NEVA) results rely on optimistic trends for PEV cost and performance, it is difficult to know how meaningful the results are. The reviewer suggested that scenarios of parameters be proposed and carefully reviewed by multiple individuals with expertise in consumer behavior and electric vehicles, perhaps in a workshop format. The reviewer further commented that comparing the model results with other estimates of the private and social benefits of PEVs in published articles and reports would be useful. The reviewer sensed that the project's results are much more optimistic than other estimates. The reviewer suggested including a scenario of non-plug-in hybrids as a comparison to determine whether or not the social benefits of hybrids outweigh the social benefits of PEVs.

Question 2: Technical accomplishments and progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The reviewer commented that progress to date looks excellent.

Reviewer 2:
The reviewer commented that the NEVA basic cost and benefit estimates for national scenarios combined wedges and showed both VMT and fleet displacement by BEVs, PHEVs, etc. The reviewer noted that the Massachusetts analysis, an infrastructure projection tool, mapped out necessary infrastructure to meet state's EV goal by 2025. The reviewer noted that net costs and benefits for national deployment scenarios are nicely captured by stacked bar charts, but should clarify whether the societal benefits are based on tailpipe or lifecycle greenhouse gas emissions. The reviewer commented that the national corridor work also uses scenario-based analysis, which makes sense to bind the costs and benefits. The reviewer wondered how this project interacts with the DOT Alternative Fuels Corridors (AFCs) that were designated very recently.

Reviewer 3:
The reviewer commented that while the project seems mostly on track, it is ending in a few short months and has only completed 75% of the work planned for the full 3 years. The reviewer noted that it would have been helpful to see a timeline of project goals indicating which ones have been completed and the plan for completing the remaining work.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the project had a solid set of partners in industry, states, cities, and other federal agencies. The reviewer was curious what the DOT collaboration is, given DOT's Fixing America's Surface Transportation Act's statutorily required AFC program, which is very relevant to charger investment.

Reviewer 2:
The reviewer commented that there appears to be good collaboration, although it seemed to be an area for improvement.

Reviewer 3:
The reviewer commented that the project includes partners from several federal agencies as well as stakeholders relevant to the Massachusetts and Ohio case studies. The reviewer noted that the project would have benefited from collaboration with OEMs and university researchers, particularly in selecting appropriate input parameters for PEV cost and performance.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that future plans seem to be appropriate and logical.

Reviewer 2:
The reviewer noted that uncertainty around future EV markets will require sensitivity analysis to the model. The reviewer suggested incorporating MA3T as an input and exploring greater DOT coordination as well as collecting data from large charger deployments in New York City.

Reviewer 3:
The reviewer commented that the proposed questions for future work are the right ones to focus on, particularly regarding acquiring market data to understand the relationships between increased EVSE availability and consumer demand for PEVs and electric VMT. The reviewer noted that from the presentation, it was not clear how the project anticipates acquiring these data.

Question 5: Relevance—Does this project support the overall DOE objectives of petroleum displacement?

Reviewer 1:
The reviewer noted that improving infrastructure will increase electrification and reduce petroleum usage.

Reviewer 2:
The reviewer commented that because electrification is largely limited by charging infrastructure, this type of model is a necessary part of the EV chicken and egg solution.

Reviewer 3:
The reviewer commented that the project is relevant to the DOE goal of petroleum displacement, particularly in how it relates to understanding the relationship between PEV availability and electric miles driven.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that funding appears to be sufficient.

Reviewer 2:
The reviewer commented that resources appear adequate and consistent with the project scope.

Reviewer 3:
The reviewer commented that the budgeted funds are appropriate for the scope of the project.

Acronyms and Abbreviations

AFC	Alternative Fuel Corridor
AFV	Alternative fuel vehicle
AMR	Annual Merit Review
ANL	Argonne National Laboratory
AV	Automated vehicle
BEV	Battery electric vehicle
CAV	Connected and automated vehicle
DC	Direct current
DCFC	Direct-current fast charging
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FHWA	Federal Highway Administration
HDV	Heavy-duty vehicle
kW	kilowatt
MA3T	Market Acceptance of Advanced Automotive Technologies
NACFE	North American Council on Freight Efficiency
NEVA	National Economic Value Assessment
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PHEV	Plug-in hybrid electric vehicle
R&D	Research and development
SMART	Systems and Modeling for Accelerated Research in Transportation
TEEM	Transportation Energy Evolution Modeling
TNC	Transportation network company

VAN	Vehicle Analysis
VMT	Vehicle miles traveled

11. Acronyms and Abbreviations

°C	Degrees Celsius
µm	Microns
3D	Three-dimensional
3GAHSSS	Third-Generation Advanced High-Strength Steel
A	Ampere
ABR	Advanced Battery Research
ACC	Automated Cruise Control
ACEC	Advanced Combustion and Emissions Control
ACI	Advanced compression ignition
AEC	Advanced Engine Combustion
AER	All-electric range
AFC	Alternative Fuel Corridor
AFDC	Alternative Fuels Data Center
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation tool
AFM	Atomic force microscopy
AFV	Alternative fuel vehicle
Ag	Silver
Ah	Ampere-hour
Al	Aluminum
Al_2O_3	Aluminum oxide
AlCuEx	Aluminum copper alloy
ALD	Atomic layer deposition
AlF_3	Aluminum fluoride
AlNiCo	Aluminum-nickel-cobalt
AMBER	Advanced Model Based Engineering Resource
AMD	Automated Mobility Districts
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	American Petroleum Institute
APRF	Advanced Powertrain Research Facility
ARL	Army Research Laboratory
A_{rms}	Ampere root mean square
ARPA-E	Advanced Research Projects Agency-Energy
ATP	Advanced Technology Powertrain
ATR	Attenuated total reflectance
AV	Automated vehicle
BEAM	Behavior Energy Autonomy Mobility
BES	Basic Energy Sciences
BET	Battery electric truck
BEV	Battery electric vehicle
BMEP	Brake mean effective pressure

BMR	Battery Materials Research
BMS	Battery management system
BNL	Brookhaven National Laboratory
BOB	Blendstock for oxygenated blending
BOPP	Bi-oriented polypropylene
BSFC	Brake-specific fuel consumption
BTE	Brake thermal efficiency
C	Carbon
CA50	Crank angle position at which 50% of heat is released
CABS	Consortium for Advanced Batteries Simulation
CACC	Cooperative Adaptive Cruise Control
CAE	Computer-aided engineering
CAEBAT	Computer-aided engineering of batteries
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CARB	California Air Resources Board
CAV	Connected and Autonomous Vehicle
CAV	Connected and automated vehicle
CB	Carbon black
CCC	Clean Cities Coalitions
CCD	Critical current density
CDC	Conventional diesel combustion
CDOT	Colorado Department of Transportation
Ce	Cerium
CE	Coulombic efficiency
CEC	California Energy Commission
CEI	cathode electrolyte interfacial
CF	Carbon Fiber
CFD	Computational fluid dynamics
CFRP	Carbon Fiber-Reinforced Polymer
CGI450	compacted graphite iron 450
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression Ignition
CLEERS	Cross-cut Lean Exhaust Emissions Reduction Simulations
cm	Centimeter
CMC	Carboxymethyl cellulose
CN	Combustion noise
CN	Cetane number
CNG	Compressed natural gas
CNT	Carbon nanotubes
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
Co-Ex	Co-extrusion
CPE	Composite polymer electrolytes

CPEC	Close Proximity Electromagnetic Carbonization
CPOX	Catalytic partial oxidation
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
CRF	Combustion Research Facility
Cu	Copper
CuF_2	Copper (II) Fluoride
CuOH	Copper hydroxide
CuZ	Copper sulfanide
CV	Connected Vehicle
CY	Calendar Year
dBA	A-weighted decibels
DC	Direct current
DCFC	Direct-current fast charging
DEC	Diethyl carbonate
DEF	Diesel emission fluid
DEGR	Dedicated exhaust gas recirculation
DEMS	Differential electrochemical mass spectroscopy
$DeSO_x$	de-sulfur oxide
DFC	Detroit Future City
DFT	Density functional theory
DI	Direct injection
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DOE	Design of experiments
DOT	U.S. Department of Transportation
DOT	U.S. Department of Transportation
DP	Dynamic Programming
DPF	Diesel particulate filter
DREaM	Development of Radically Enhanced alnico Magnets
DST	Dynamic stress test
E10	10% ethanol blend with gasoline
E20	20% ethanol blend with gasoline
E30	30% ethanol blend with gasoline
EAVS	Electrically Assisted Variable Speed
EB	Electron beam
ECN	Engine Combustion Network
ED	Electric drive
EDAX	Energy-dispersive X-ray spectroscopy
EDS	Energy dispersive spectroscopy
EDT	Electric Drive Technologies
EDV	Electric drive vehicle
EEMS	Energy-Efficient Mobility Systems
EERE	Office of Energy Efficiency and Renewable Energy

EGR	Exhaust gas recirculation
EM	Electron microscopy
EMA	ElectroMechanical Associates
EMC	Electromagnetic compatibility
EOL	End-of-life
EOS	Equation of state
EPA	U.S. Environmental Protection Agency
EPMA	Electron Probe Micro-Analyzer
EPRI	Electric Power Research Institute
ERC	Engine Research Center
ESS	Energy storage system
Eu	Europium
EV	Electric vehicle
EVSE	Electrical Vehicle Supply Equipment
eWHR	Electric waste heat recovery
FBJ	Friction Bit Joining
FCA	Fiat Chrysler Automobiles
FCEV	Fuel cell electric vehicle
FE	Fuel economy, fuel efficiency
Fe	Iron
FE	Fuel economy
FEA	Finite element analysis
FEC	Fluoroethylene carbonate
FEM	Finite element modeling
FeSi	Ferrosilicon
FHWA	Federal Highway Administration
FIE	Fuel injected engine
FIM	Freeway incident management
FLD	Forming Limit Diagram
FOA	Funding opportunity announcement
FRESCO	Fast and Reliable Engine Simulation Code
FSS	Friction Stir Scribe
FSW	Friction Stir Weld
FTA	Federal Transit Administration
FTIR	Fourier transform infrared
FTP	Federal Test Procedure
FV	Finite volume
FY	Fiscal year
g	Gram
G	Giga
GaN	Gallium nitride
GCI	Gasoline compression ignition
GDCI	Gasoline direct compression ignition
GDI	Gasoline direct injection
GHG	Greenhouse gas

GM	General Motors Corporation
GMU	George Mason University
GPF	Gasoline particulate filter
GPS	Global Positioning System
GPU	Graphics processing unit
GSF	Generic speed form
GTI	Gas Technology Institute
H/D	Hydrogen/Deuterium
H_2O	Water
HA	High active
HATCI	Hyundai American Technical Center, Inc.
HAZ	Heat-Affected Zone
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HCl	Hydrochloric acid
HD	Heavy-duty
HDV	Heavy-Duty Vehicle
HECC	High efficiency clean combustion
HET	Hybrid electric truck
HEV	Hybrid electric vehicle
HIL	Hardware-in-the-loop
HPC	High-performance computing
HPC	High-Performance Computing
HPDC	High-Pressure Die Cast
HP-RTM	High-Pressure Resin Transfer Molding
hr	Hour
HRR	Heat release rate
HRTEM	High-resolution transmission electron microscopy
HVAC	Heating, ventilating, and air conditioning
HXN	Hard X-ray nano-probe
Hz	Hertz
ICE	Internal combustion engine
ICME	Integrated Computational Material Engineering
ID	Ignition delay
IGBT	Insulated-gate bipolar transistors
IL	Ionic liquid
INL	Idaho National Laboratory
IP	Intellectual property
IQT	Ignition quality tester
ITS-JPO	Intelligent Transportation System Joint Program Office
K	Kelvin
KERS	Kinetic recovery system
kg	Kilogram
KH-RT	Kelvin-Helmholtz Rayleigh-Taylor
kW	Kilowatt

kWh	Kilowatt-hour
L	Liter
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle analysis
LCO	Lithium cobalt oxide
LD	Light-duty
LDD	Light-duty diesel
LDV	Light-duty vehicle
LES	Large eddy simulation
LEV	Low-emission vehicle
LFO	Lithium iron oxide
LFP	Lithium iron phosphate
Li	Lithium
Li_3PO_4	Lithium phosphate
LIB	Lithium-ion battery
$LiCoO_2$	Lithium cobalt oxide
LiFSI	Lithium bis(flurosulfonyl)mide
Li-ion	Lithium Ion
$LiPF_6$	Effective electrolyte salt for lithium-ion battery
LiPON	$Li_{2.88}PO_{3.86}N_{0.}14$
Li-S	Lithium-sulfur
LL	Layered-layered
LLNL	Lawrence Livermore National Laboratory
LLS	Layered-layered spinel
LLZO	Lithium lanthanum zironate
LMNO	Lithium manganese nickel oxide
LMO	Lithium manganese oxide
LMR	Lithium manganese rich
LNC	Lean NO_x catalyst
LNMO	Lithium nickel manganese oxide
LNT	Lean NO_x trap
LPG	Liquefied natural gas
LSPI	Low-speed pre-ignition
LT	Low temperature
LT SCR	Low-temperature selective catalytic reduction
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTGC	Low temperature gasoline combustion
LTO	Lithium titanium oxide
m	Meter
M&S	Modeling and simulation
mA	Milliampere
MA3T	Market Acceptance of Advanced Automotive Technologies
MATSim	Multi-Agent Transport Simulation
MD	Molecular dynamics

MDV	Medium-duty vehicle
MERF	Materials Engineering Research Facility
Mg	Magnesium
MIT	Massachusetts Institute of Technology
MLD	Molecular layer deposition
mm	Millimeter
MMFC	Multi-mode fluid controller
Mn	Manganese
Mn	Manganese
MON	Motor octane number
MORPC	Mid-Ohio Regional Planning Commission
MOSFET	Metal–oxide–semiconductor field-effect transistor
MOU	Memorandum of Understanding
MPC	Model-Predictive Control
MPG	Miles per gallon
MRI	Magnetic resonance imaging
ms	Milliseconds
MW	Megawatt
MYPP	Multi-Year Program Plan
N_2O	Nitrous Oxide
N_2O	Nitrous Oxide
NACFE	North American Council on Freight Efficiency
NARC	National Association of Regional Councils
NASA	National Aeronautics and Space Administration
NCA	Battery cathode material (nickel cobalt aluminum oxide)
NCM	Nickel cobalt manganese oxide
NDE	Non-Destructive Evaluation
NEAT	Non-Light Duty Energy and GHG Emissions Accounting Tool
NESCAUM	Northeast States for Coordinated Air Use Management
NETL	National Energy Technology Laboratory
NEVA	National Economic Value Assessment
NH_3	Ammonia
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel
NMC	Nickel manganese cobalt oxide
NMO	Nickel manganese oxide
NMP	N-methylpyrrolidone
NMR	Nuclear magnetic resonance
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NP	nanoparticles
NREL	National Renewable Energy Laboratory
NSC	NO_x storage catalyst
NSLSII	National Synchrotron Light Source II

NTEA	National Truck Equipment Association
NU	Northwestern University
NVO	Negative valve overlap
NYBEST	New York Battery and Energy Storage Technology Consortium
O_2	Oxygen
OAS	Open architecture software
OBD	On-board diagnostics
ODD	Operational Design Domain
OEM	Original equipment manufacturer
OH	Hydroxide
OI	Octane index
OpenFOAM	Open source Field Operation And Manipulation
ORAD	On-Road Automated Driving
ORNL	Oak Ridge National Laboratory
OS	Organosilicon
OSC	Oxygen storage capacity
P	Phosphorus
PAA	Polyacrylic acid
PAG	Polyalkylene glycol
PAN	Polyacrylonitrile
*P*c	Compressed pressure
Pd	Palladium
PDF	Paired distribution function
PEMS	Portable emissions monitoring system
PEV	Plug-in electric vehicle
PGM	Platinum group metals
PHET	Plug-in hybrid electric truck
PHEV	Plug-in hybrid electric vehicle
PHS	Press-Hardening Steels
PI	Principal investigator
PM	Particulate matter
PMI	Particulate matter index
PMP	Pontryagin's Minimum Principle
PN	Particulate number
PNA	Passive NO_x adsorber
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
PPy	Polypyrrole
PRT	Personal Rapid Transit
PSD	Particle size diameter
Pt	Platinum
PTWA	Plasma transfer wire arc
PVDF	Polyvinylidene difluoride
R&D	Research and development
RANS	Reynolds-Averaged Navier Stokes

RCCI	Reactivity controlled compression ignition
RCM	Rapid compression machines
RDE	Real-world driving emissions
Rds(on)	Resistance from drain to source
RE	Rare earth
RF	Radio frequency
RNG	Renewable natural gas
ROI	Return on investment
RON	Research octane number
RPM	Revolutions per minute
RPT	Reference performance test
RT	Room temperature
S	Sulfur
SAE	Society of Automotive Engineers
SBD	Schottky barrier diodes
SBIR	Small Business Inngovation Research
SCC	Stress-Corrosion Cracking
SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SD	Standard deviation
SEI	Solid electrolyte interface
SEMCOG	Southeast Michigan Council of Governments
SHRP2	Second Strategic Highway Research Program
SI	Spark ignition
Si	Silicon
SiC	Silicon carbide
Si-C	Silicon Carbon
SIDI	Spark ignition direct injection
SiO_2	Silicon dioxide
SiO_x	Silicon oxide
SLAC	Stanford Linear Accelerator Center
SLTNR	Sustained low-temperature NO_x reduction
SMART	Specific, measurable, achievable, relevant, and time bound
SMART	Systems and Modeling for Accelerated Research in Transportation
SMD	Sauter mean diameter
SME	Subject matter expert
Sn	Tin
SNL	Sandia National Laboratories
SOA	Semiconductor optical amplifier
SOC	State of charge
SOI	Start of ignition
SPH	Smoothed particle hydrodynamics
SRL	Surface reconstruction layer
$SrTiO_3$	Strontium titanate

SSRL	Stanford Synchrotron Radiation Lightsource
STEM	Scanning transmission electron microscopy—electron energy loss spectroscopy
SULEV	Super ultra-low emission vehicle
SUNY	State University of New York
SUV	Sport Utility Vehicle
SWCNT	Single wall carbon nanotube
SwRI	Southwest Research Institute
SynchRel	Synchronous reluctance
T50	Temperature at which 50% conversion occurs
*T*c	Compressed temperature
TCO	Total cost of ownership
TEA	Technology-Economic Analysis
TEEM	Transportation Energy Evolution Modeling
TEM	Transmission electron microscopy
TEY	Total electron yield
TFM	Thickened flame model
TI	Technology Integration
TIM	Thermal interface material
TM	Transition metal
TMS	Thermal management system
TNC	Transportation Network Company
TRB	Transportation Research Board
TRC	Transportation Research Center
TRL	Technology Readiness Level
TSDC	Transportation Secure Data Center
TUMS	Toolbox for Urban Mobility Simulation
TWB	Tailored-Welded Blanks
TWC	Three-way catalyst
TXM	Transmission X-ray microscopy
U.S.	United States
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy
UC	Ultra-capacitor
UHSS	Ultra-High Strength Steels
UIC	University of Illinois at Chicago
UM	University of Michigan
UPS	United Parcel Service
UQ	Uncertainty quantification
USABC	United States Advanced Battery Consortium
USAMP	United States Automotive Materials Partnership
USCAR	United States Council for Automotive Research
USPS	U.S. Postal Service
UTEMPRA	Unitary thermal energy management for propulsion range augmentation
UV	Ultraviolet
UW	University of Wisconsin
V	Volt

V2G	Vehicle to grid
VAN	Vehicle Analysis
VC	Vinylene carbonate
VCR	Variable compression ratio
VERIFY	Virtual Engine Research Institute and Fuels Initiative
VMT	Vehicle miles traveled
VN	Vanadium nitride
VOF	Volume of fluid
VOPO4	Vanadium phosphate
VOTT	Value of Travel Time
VTO	Vehicle Technologies Office
VVA	Variable valve actuation
VVT	Variable valve timing
W	Watt
WBG	Wide bandgap
WFO	Work-for-others
Wh	Watt hour
Wh/l	Watt hour per liter
WHR	Waste heat recovery
WPT	Wireless power transfer
WTP	Willingness-to-Pay
XANES	X-ray absorption near edge structure
XAS	X-ray absorption spectroscopy
XFC	Extreme fast charging
XPD	X-ray powder diffraction
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
ZECT	Zero emission cargo truck
ZEV	Zero-emission vehicle
Zr	Zirconium
ZrO_2	Zirconium dioxide
µ	Micron

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Appendix A: 2017 Annual Merit Review Attendees

Name	Affiliation
Rene Abarcar	Energetics Incorporated
Luigi Abbate	NOHMs Technologies
Sofyane Abbou	Michigan Tech University
Mohamad Abdul-Hak	Mercedes Benz Research and Development
Tadashi Abe	HySUT
Daniel Abraham	Argonne National Laboratory
Judi Abraham	Alliance Technical Services, Inc.
Salvador Aceves	Lawrence Livermore Lab
Jesse Adams	U.S. Department of Energy
Kev Adjemian	Idaho National Laboratory
Suresh Advani	University of Delaware
Radoslav Adzic	Brookhaven National Laboratory
Kareem Afzal	PDC Machines
Nicos Agathocleous	Hanon Systems
Ajay Agrawal	University of Alabama
Rajesh Ahluwalia	Argonne National Laboratory
Alauddin Ahmed	University of Michigan, Ann Arbor
Imran Ahmed	FedEx Express
Qadeer Ahmed	Center for Automotive Research, The Ohio State University

Name	Affiliation
Shabbir Ahmed	Argonne National Laboratory
Channing Ahn	Caltech
Dongjoon Ahn	LG Chem
Venkat Aitharaju	General Motors
Oyelayo Ajayi	Argonne National Laboratory
Etsuo Akiba	Kyushu University
Abhid Akram	Continental Automotive Systems
Mohamed Alamgir	LG Chem Power
Paul Albertus	ARPA-E
Mark Alexander	EPRI
Shaun Alia	National Renewable Energy Laboratory
Mowafak Al-Jassim	National Renewable Energy Laboratory (NREL)
James Alkire	DOE
Lawrence Allard	Oak Ridge National Laboratory
Eric Allcorn	Sandia National Labs
Jan Allen	U.S. Army Research Laboratory
Mark Allendorf	Sandia
John Allison	University of Michigan
Srikanth Allu	ORNL
Abdullah Alrashidi	University of Miami

Name	Affiliation
Pascal Amar	Volvo Group North America
Glenn Amatucci	Rutgers University
Khalil Amine	Argonne National Laboratory
Ramin Amin-Sanayei	Arkema
Art Anderson	National Renewable Energy Laboratory
David Anderson	U.S. Department of Energy/VTO
Everett Anderson	Proton OnSite
Iver Anderson	Ames Laboratory
Simon Ang	University of Arkansas
Donald Anton	SRNL
Laurenrt Antoni	CEA
Chris Apblett	Sandia National Laboratories
Koorosh Araghi	NASA Johnson Space Center
Shane Ardo	University of California Irvine
Christopher Arges	Louisiana State University
Brett Aristegui	DOE NETL
John Arnold	Miltec UV International
David Arthur	USDOT/Volpe Center
Koichiro Asazawa	Daihatsu Motor
Mirela Atanasiu	FCH2 JU
Plamen Atanassov	University of New Mexico

Name	Affiliation
Lance Atkins	Nissan Technical Center North America
Pradeep Attibele	FCA US LLC
Marc Auger	Arplas USA
Joshua Auld	Argonne National Laboratory
Peter Aurora	Navitas Systems LLC
Tom Autrey	Pacific Northwest National Laboratory
Tom Avedisian	Cornell University
Scott Averitt	Robert Bosch LLC
Michelle Avillanoza	Allegheny Science & Technology
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