U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 Annual Merit Review, Vehicle Technologies Office

Results Report

November 2021

(This Page Intentionally Left Blank)

Table of Contents

(This Page Intentionally Left Blank)

Introduction

The 2021 U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy's (EERE) Vehicle Technologies Office (VTO) Annual Merit Review (AMR) was held June 21-25, 2021, virtually, due to extenuating circumstances resulting from the global coronavirus disease (COVID-19) pandemic. The review encompassed work done by VTO: 273 individual activities were reviewed by 281 reviewers. Exactly 1,152 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 virtual forum for interaction and technology information transfer.

The peer review process followed the guidelines of the Peer Review Guide developed by EERE. Each activity is reviewed every 3 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.

Reviewers provided qualitative and quantitative feedback on VTO projects evaluated during the AMR. Qualitatively, reviewers offered written comments in response to a series of specific project evaluation questions. Quantitatively, reviewers provided numeric assessments for each of the same questions. These scores were organized and analyzed on both a project-level and subprogram-level basis. Tables summarizing the average numeric score for each question, by VTO subprogram portfolio, is presented below.

Table I-1 – Average Project Scores, By VTO Research & Development Subprogram

VTO Subprogram	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Combustion Engines (ACE)	3.34	3.24	3.37	3.22	**3.28**
Battery R&D (BAT)	3.41	3.29	3.32	3.22	**3.32**
Energy Efficient Mobility Systems (EEMS)	3.29	3.22	3.38	3.17	**3.25**
Electrification (ELT)	3.29	3.29	3.28	3.14	**3.27**
Fuel Technologies (FT)	3.36	3.32	3.32	3.27	**3.32**
Materials Technology (MAT)	3.28	3.29	3.22	3.16	**3.26**
Vehicle Analysis (VAN)	3.45	3.42	3.48	3.32	**3.42**

Table I-2 – Average Project Scores, By VTO Technology Integration Subprogram

VTO Subprogram	Objectives	Approach	Accomplish-ments	Collaborations	Future Research	Weighted Average
Technology Integration (TI)	3.51	3.35	3.21	3.43	3.21	**3.32**

Evaluation Criteria—Research & Development Subprograms

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 and well-planned. (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 goals—the degree to which progress has been made and plan is on schedule. (Scoring weight for overall average = 40%)

- 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 3: Collaboration and Coordination Across Project Team. (Scoring weight for overall average = 10%)

- 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 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 state project ended. (Scoring weight for overall average = 10%)

- 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 5: Relevance—Does this project support the overall DOE objectives? Why or why not? (Scoring weight, not included with overall average = 20%)

- Yes
- No.

Question 6: Relevance—Does this project support the overall DOE objectives? Why or why not?

- Excessive
- Sufficient
- Insufficient.

Evaluation Criteria—Technology Integration Subprogram

Reviewers for the Technology Integration (TI) technical session answered questions tailored to TI's 2020 AMR focus on increasing transportation efficiency and fuel diversity. 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 increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (project objectives are sharply focused on supporting DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. The project has a direct and substantial impact upon addressing barriers; difficult to improve project objectives significantly)
- 3.5=Excellent (project objectives are effective and substantially support DOE/VTO objectives; project addresses a significant number of barriers; effectively contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 3.0=Good (project objectives are generally effective and support DOE/VTO objectives, but could be improved; project addresses some barriers; contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 2.5=Satisfactory (project objectives have some weaknesses and support DOE/VTO objectives; project addresses some barriers; project may have some impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 2.0=Fair (project objectives have significant weaknesses and minimally support DOE/VTO objectives; project addresses few barriers; project may have a small impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 1.5=Poor (project objectives are minimally responsive to DOE/VTO objectives; project does not address barriers; project is unlikely to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 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 increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency).

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned 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 objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals. (Scoring weight for overall average = 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 overall average = 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: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring Weight for overall average = 10%).

- 4.0=Outstanding (sharply focused on critical barriers to achieving project objectives; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers to achieving project objectives)
- 3.0=Good (generally effective in overcoming barriers to achieving project objectives)
- 2.5=Satisfactory (has some weaknesses; but needs better focus on overcoming some barriers to achieve project objectives)
- 2.0=Fair (has significant weaknesses)
- 1.5=Poor (minimally responsive)
- 1.0=Unsatisfactory (not responsive to eliminating barriers to achieving project objectives).

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

- 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.

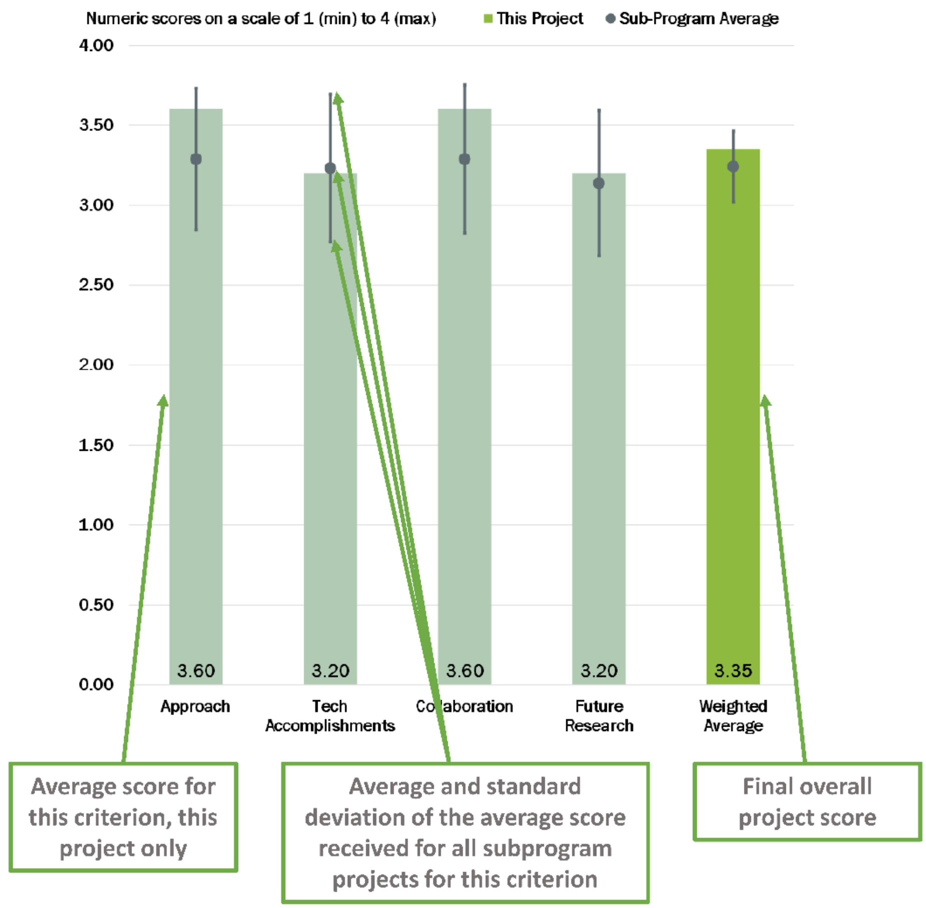


Figure 1. Sample Question 1 through Question 4 score averages, standard deviations, and Overall Weighted Average for an R&D project.

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.

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 2, 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.

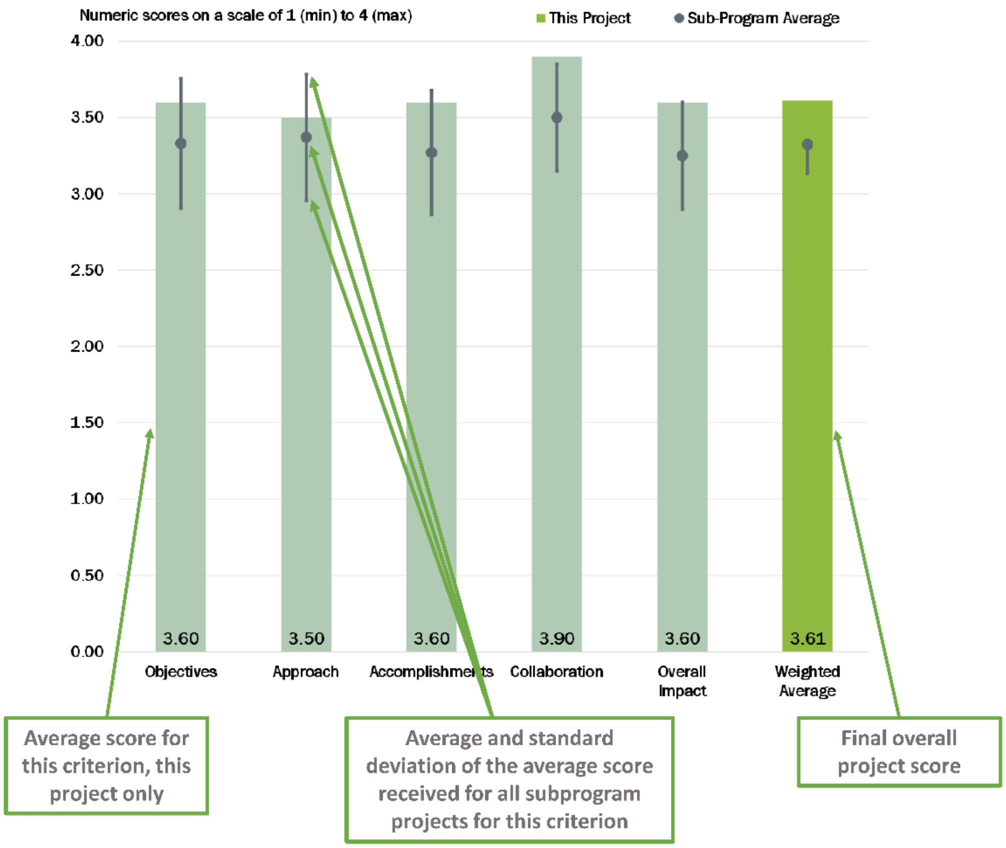


Figure 2. Sample Question 1 through Question 5 score averages, standard deviations, and overall Weighted Average for a TI subprogram project.

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.

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 3, below, provides an example project title.

Presentation Number: van016
Presentation Title: Transportation Data Program
Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

Figure 3. 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 graphs.

(This Page Intentionally Left Blank)

1. Advanced Combustion Engines

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Advanced Combustion Engines (ACE) subprogram supports research and development (R&D) necessary for industry to develop efficient engines that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, to reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively. Internal combustion engines will continue to be an important power source for medium- and heavy-duty onroad trucks and off-road vehicles including construction, agriculture and forestry, and rail and marine, during the next several decades. Increasing their efficiency and reducing GHG and criteria emissions will ensure that the clean energy economy benefits all Americans. Optimization of high efficiency engines and emission control systems, integration of hybrid powertrains, and utilization of renewable fuels has the potential to improve heavy-duty engine efficiency.

The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts.

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
ace015	Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes	Jim Szybist (ORNL)	1-7	3.50	3.40	3.20	3.20	**3.38**
ace022	Joint Development and Coordination of Emissions Control Data and Models (Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination)	Josh Pihl (ORNL)	1-12	3.83	3.33	4.00	3.33	**3.54**
ace023	Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination	Yong Wang (PNNL)	1-16	3.17	3.00	3.33	3.33	**3.13**
ace027	Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)	Feng Gao (PNNL)	1-18	3.60	3.50	3.70	3.20	**3.51**
ace032	Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems	William Partridge (ORNL)	1-22	3.00	3.00	3.00	2.88	**2.98**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace033	Emission Control for Lean Gasoline Engines	Vitaly Prikhodko (ORNL)	1-26	3.50	3.50	3.50	3.17	**3.46**
ace056	Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs)	Yong Wang (PNNL)	1-29	3.00	3.13	3.00	2.88	**3.05**
ace085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-33	3.50	3.33	3.50	3.17	**3.38**
ace100	Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2	Darek Villeneuve (Daimler Trucks North AmerIca)	1-35	3.42	3.33	3.42	3.17	**3.34**
ace101	Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo Trucks North America)	1-40	3.00	2.67	3.00	2.75	**2.80**
ace102	Cummins-Peterbilt SuperTruck 2	Jon Dickson (Cummins-Peterbilt)	1-46	3.58	3.58	3.50	3.50	**3.56**
ace103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck	Russell Zukouski (Navistar)	1-50	3.08	3.08	3.17	3.00	**3.08**
ace118	Advanced Nitrogen Oxide Storage	Janos Szanyi (PNNL)	1-55	2.88	2.75	3.00	3.13	**2.86**
ace119	Advanced Multi-Functional Diesel Particulate Filters (Deer and Company)	Ken Rappe (PNNL)	1-59	3.33	3.17	3.50	3.17	**3.25**
ace124	SuperTruck 2 - PACCAR	Maarten Meijer (PACCAR)	1-62	3.08	3.17	3.17	3.08	**3.14**
ace128	Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles	Michael Harold (University of Houston)	1-67	3.50	3.38	3.25	3.13	**3.36**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace133	Next-Generation Heavy-Duty Powertrains	Scott Curran (ORNL)	1-70	3.50	3.63	4.00	3.33	**3.60**
ace138	Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium	Matthew McNenly (LLNL)	1-74	3.75	3.58	3.83	3.25	**3.61**
ace139	Chemical Kinetic Models for Surrogate Fuels	Scott Wagnon (LLNL)	1-78	3.60	3.40	3.70	3.50	**3.50**
ace140	Accelerated Chemistry and Transport for Engine Simulations	Russell Whitesides (LLNL)	1-83	3.38	3.75	3.38	3.00	**3.52**
ace141	Advanced Ignition Barriers Research	Isaac Ekoto (SNL)	1-86	3.38	3.25	3.38	3.38	**3.31**
ace142	Development and Validation of Predictive Ignition Models	Riccardo Scarcelli (ANL)	1-90	3.50	3.25	3.38	3.25	**3.33**
ace143	Fuel Injection and Spray Research	Chris Powell (ANL)	1-93	3.60	3.40	3.40	3.40	**3.45**
ace144	Spray Wall Interactions	Lyle Pickett (SNL)	1-98	3.80	3.40	3.60	3.50	**3.54**
ace145	Cold Start Modeling and Experiments for Emissions Reduction	K. Dean Edwards (ORNL)	1-102	3.50	3.50	3.38	3.50	**3.48**
ace146	Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes	Muhsin Ameen (ANL)	1-106	3.25	3.38	3.13	3.25	**3.30**
ace147	Mitigation of Abnormal Combustion	Derek Splitter (ORNL)	1-109	3.40	3.30	3.10	3.30	**3.30**
ace153	Chemistry of Cold-Start Emissions and Impact of Emissions Control	Melanie Moses-DeBusk (ORNL)	1-113	3.75	3.50	3.50	3.50	**3.56**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace155	Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications	Qigui Wang (General Motors, LLC)	1-117	3.42	3.42	3.17	3.25	**3.36**
ace156	Next-Generation, High-Efficiency Boosted Engine Development	Michael Shelby (Ford Motor Company)	1-121	3.63	3.38	3.38	3.38	**3.44**
ace158	Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach	Wei Li (General Motors, LLC)	1-125	3.00	2.75	3.25	3.25	**2.94**
ace159	Reduced Cost and Complexity for Off Highway Aftertreatment	Ken Rappe (PNNL)	1-128	2.67	2.67	3.00	2.67	**2.71**
ace160	Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles	Zongxuan Sun (University of Minnesota)	1-131	3.10	3.00	3.40	3.20	**3.10**
ace161	New Approach for Increasing Efficiency of Agricultural Tractors and Implements	Andrea Vacca (Purdue University)	1-136	3.33	3.17	3.33	3.33	**3.25**
ace162	Improved Efficiency of Off-Road Material Handling Equipment through Electrification	Jeremy Worm (MTU)	1-139	2.67	2.17	2.67	2.83	**2.44**
ace163	Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines	Adam Klingbel (Wabtec)	1-142	3.38	3.38	3.50	3.38	**3.39**
ace164	Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines	Sage Kokjohn (University of Wisconsin)	1-146	3.75	3.75	3.50	3.63	**3.70**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ace165	Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics	Gina Magnotti (ANL)	1-151	3.50	3.40	3.60	3.50	**3.46**
ace166	New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine	Fabien Redon (Achates Power, Inc.)	1-156	2.50	2.80	3.30	2.80	**2.79**
ace167	Spray/Flow Interaction in Engines	Roberto Torelli (ANL)	1-161	3.60	3.40	3.50	3.10	**3.43**
ace168	Soot Modeling and Experiments	Julien Manin (SNL)	1-164	3.40	3.40	3.50	3.50	**3.43**
ace169	Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts	Yong Wang (Washington State University)	1-168	3.00	2.75	3.25	3.00	**2.91**
Overall Average				**3.34**	**3.24**	**3.37**	**3.22**	**3.28**

Presentation Number: ace015
Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes
Principal Investigator: Jim Szybist (ORNL)

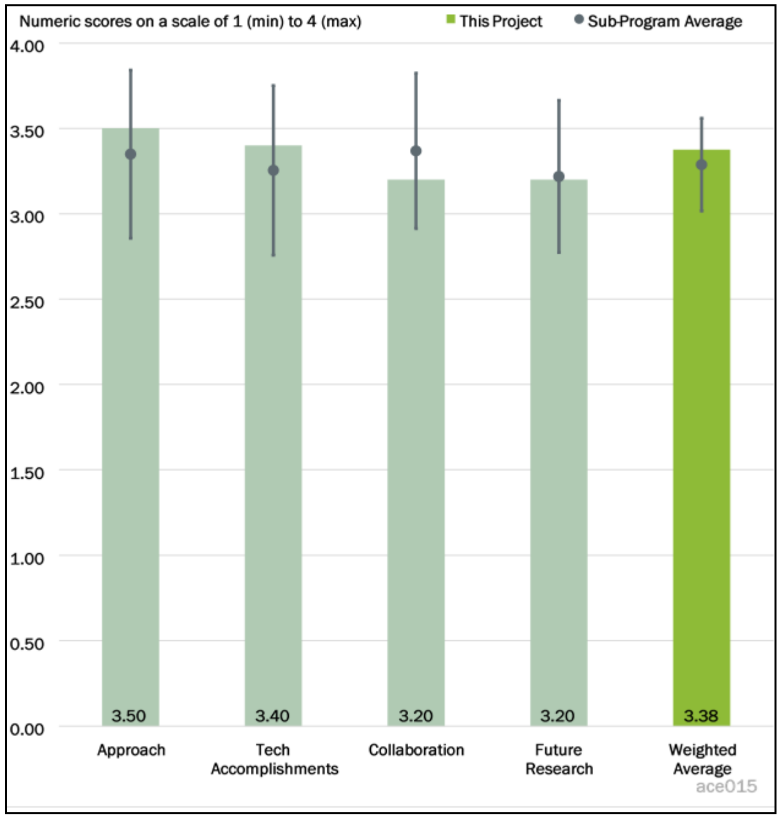


Figure 1-1 - Presentation Number: ace015 Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New High-Dilution Combustion Regimes Principal Investigator: Jim Szybist (ORNL)

Presenter

Jim Szybist, ORNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer said that it is a well-managed project from a technical point of view.

Reviewer 2:

The reviewer stated the approach is very interesting—using one cylinder of a four-cylinder engine to create reformate that allows for improved molar expansion ratio (MER) in the pursuit of higher efficiency and potentially lower oxides of nitrogen (NO_x) emissions. This project is exploring the thermodynamic tradeoff between potentially improved Second Law of Thermodynamics efficiency versus heat transfer and other more conventional efficiency gains. The reviewer also stated the question will be whether the additional hardware and controls costs will be worth the potentially higher efficiency.

Reviewer 3:

The reviewer commented the combined approach using thermodynamics principles, engine experimentation, and modeling together is excellent. The focus on stoichiometric operation makes the very concept relevant for emissions technology.

Reviewer 4:

The reviewer said the work is well designed and well planned for the key objectives identified. However, it is less clear that the key overall barriers to advancement of the reforming concept are being addressed by the specific study elements.

Reviewer 5:

The reviewer commented the insight on MER and efficiency for a project with a modest (relative to other projects) $150,000 budget. The reviewer stated barriers to commercialization remain.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated the MER investigation is useful. The increased MER effect has been known for decades, but seldom reduced to practice. However, it would be disappointing if that were all this project achieved. The reviewer suggested there must be other stoichiometric combustion phenomena that can be investigated.

Reviewer 2:

The reviewer stated the project is on track to the stated goals.

Reviewer 3:

While the Principal Investigator (PI) are not expected to devise the optimal control strategy for this concept, the reviewer indicated it would be nice to discuss the strategy of lowest load operation (where the heavily reformate-dilute combustion actually is lost relative to baseline). The reviewer asked if the dilution system can be easily shut off at those load points or if the reforming catalysts will cool off too much. The reviewer also inquired about the operability temperatures required for the reformate catalysts to operate.

Reviewer 4:

The reviewer reported the 2020 milestone was completed. While the work is on track, the 2021 milestone is an end-of-year milestone, and the meat of the project progress is still to be completed. The reviewer noted the project does not have clear performance indicators, making it hard to judge overall project progress on a development arc.

Reviewer 5:

The reviewer acknowledged that the PI has taken previous comments and incorporated them into the current work. The engine showed the ability to achieve some efficiency gains, as well as an opportunity to reduce the engine-out NO_x using the reformer cylinder. However, the reviewer stated the current configuration is still pretty far from resembling production hardware, particularly in the air-handling system.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented there were good results from collaboration. However, most of the end products of the work seem to be technical papers, rather than any sort of technology transfer to original equipment manufacturers (OEM) or suppliers. The reviewer also stated with the internal combustion (IC) engine under significant threat, it seemed there is insufficient time for the old engine-development model to work, where advances took a decade to see commercialization.

Reviewer 2:

The reviewer stated that adding a partner to assist with the reformer catalyst was an excellent idea. The communication and collaboration between project partners appeared to be effective, which enabled technical progress to be made. The reviewer stated also it would be helpful in the future to potentially have either an OEM or a turbocharger supplier work closely with this project.

Reviewer 3:

The reviewer commented standard collaboration avenues (Advanced Engine Combustion [AEC]) have been supplemented with additional industry (Precision Combustion Inc. [PCI]) and university (Ghent) collaborations.

Reviewer 4:

The reviewer stated there are evident technical collaborations between the project team and researchers from an academic institution through a joint publication and aligned research and catalyst suppliers for catalyst development. The catalyst development scope in the partnership, however, is not as clear. The reviewer also stated these partners were involved in the project since its inception, and limited discussion is focused on catalyst development, making it unclear whether this is an active effort or continued use of catalysts developed early in the project. It is also challenging that so many of the other collaborations noted focus on discussion. While it is encouraging that the project team is actively soliciting feedback on opportunities and barriers, the lack of an OEM partner backing the technology project raises concerns that it is pursuing a technology not likely to see uptake for commercial development.

Reviewer 5:

The reviewer stated there could have been better OEM involvement. Alignment with an OEM for commercialization should be a priority for this and future projects considering the pressures placed on the future relevance of the internal combustion engine (ICE).

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 state project ended.

Reviewer 1:

The reviewer said that plans to combine this technology with flame speed enhancing devices (pre-chambers [PCs], etc.) are an excellent avenue.

Reviewer 2:

The reviewer stated future work looks to address the efficiency tradeoffs that were discovered in the first portions of the work, particularly as pertains to exhaust gas recirculation (EGR). The prosed idea to explore the opportunity for studying any sulfur (S) poisoning of the reformer catalyst is also very sound. The reviewer stated it would be useful to see some more work done on examining how the Second Law efficiency tradeoffs can influence potential engine OEM decision-making regarding incorporating this strategy in a future product. It makes sense to look at low carbon and net-zero carbon fuel possibilities as well.

Reviewer 3:

The reviewer said the future research seems to be more of the same. How does this work relate to other dedicated EGR projects or to other thermo-chemical recuperation systems or projects?

Reviewer 4:

The reviewer said the proposed future work to address the identified “Remaining Barrier 1” focused on the efficiency tradeoffs is well aligned with addressing open questions associated with this technology. Understanding the balance of efficiency tradeoffs is important, as the project team notes, to aligning future development efforts appropriately. The reviewer said the second workstream, focused on the impact of fuel-borne (S on catalyst efficacy, is a lower priority. Recognizing that prior-year reviewers have highlighted this as an area to focus, it does not seem as critical a barrier to adoption of the technology. Given the scale of system complexity compared to a conventional spark ignition (SI) engine, the reviewer stated that delivering sufficient efficiency opportunities to justify the added cost and complexity seems to be the primary barrier, more so than catalyst durability The focus on MER impacts, "Remaining Barrier 3," is interesting from a scientific perspective, but is fundamental focused; it is less clear to the reviewer how this advances the overall program.

The reviewer stated the proposed future work does include a decision point, with respect to the work focus as determined by the work on "Remaining Barrier 1." However, it would be good to see more aggressive decision points or go/no-go milestones incorporated to reflect the overall technology development. The reviewer stated this has been a long-running program, with work extending back well before the current iteration started in the 2019 lab call.

An additional technical direction to consider is whether the reformer process can be used to leverage lower octane fuels at conditions relevant to vehicle drive cycles. The reviewer said it appears high load conditions, where the knock mitigation is most valued, may be limited by air- system capabilities. Reducing the target load range may align the reformer capabilities for improving knock resistance with the engine hardware constraints.

Reviewer 5:
The reviewer stated these are reasonable goals considering project will end in Fiscal Year (FY) 2021.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer said this project directly addresses the improvement of SI engine efficiency and emissions compliance.

Reviewer 2:
The reviewer stated the researchers draw clear correlations between the research areas and U.S. Department of Energy (DOE) identified barriers and objectives.

Reviewer 3:
The reviewer stated advancing the IC engine is still a useful endeavor and asked about low- or zero-carbon fuels, including biofuels and/or hydrogen (H_2).

Reviewer 4:
The reviewer commented the project supports overall DOE objectives of engine efficiency improvements and technologies to advance IC engine development. With the recent shifts in DOE objectives toward development supporting harder-to-electrify sectors, it may not remain well aligned in its current form.

Reviewer 5:
The reviewer stated that, for the project to remain relevant, a strong link to commercialization is needed for this and any future endeavors.

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 this project seems to be proceeding adequately on the allocated budget.

Reviewer 2:
The reviewer stated resources appear sufficient, unless switching to PC work will incur large costs.

Reviewer 3:
The reviewer commented that this is great fundamental research for a modest budget.

Reviewer 4:

The reviewer said the level of work and results are well aligned with the relatively low funding level. That said, the challenge is whether the technology being explored has high potential for a meaningful impact on engine technology evolution, and if there is potential to transition to higher Technology Readiness Level (TRL) commercial development. The reviewer also said if it does, then the project could benefit not only from more resources, but also strong milestones and go/no-go decision points. If the technology does not have the potential, or the OEM interest, then even a low level of funding is excessive, and the project should probably stop. The low funding level allows the research to trundle along without necessarily significant criticism or significant impact.

Reviewer 5:

The reviewer commented the last 2 years provided little more than caretaker funds for this project. It needs more resources if there is to be any substantial progress made toward achieving the goals.

Presentation Number: ace022
Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination)
Principal Investigator: Josh Pihl (ORNL)

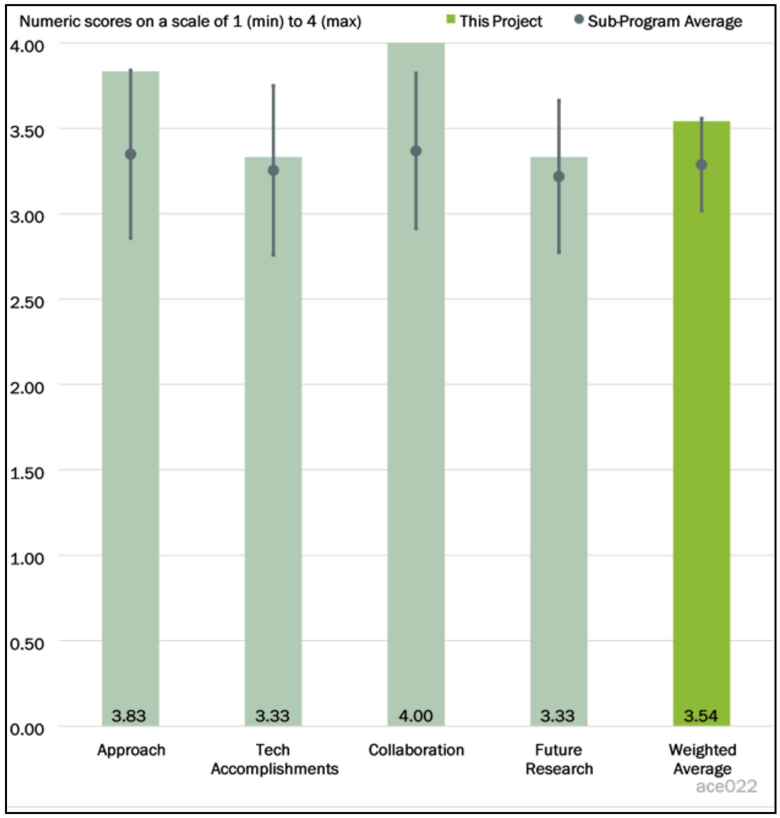


Figure 1-2 - Presentation Number: ace022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS) Analysis and Coordination) Principal Investigator: Josh Pihl (ORNL)

Presenter

Josh Pihl, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS) does a great job of aligning practical experiments with analytical models for critical aftertreatment devices. The annual workshop involves OEMs, suppliers, universities, and national laboratories. The reviewer stated last year's free, virtual format was well done and well received, allowing more participants than usual. The annual survey helps set priorities for the projects. The reviewer stated abandoning polynuclear aromatics (PNA) is the right direction. The hydrocarbon trap (HCT) is very worthy of further investigation and modeling toward future emission standards. The reviewer stated applying the selective catalytic reduction (SCR) model to longer mileages will be helpful for medium-duty (MD) and heavy-duty (HD) diesel.

Reviewer 2:

The reviewer commented that the project team did a great job coordinating the collaboration activities, including the annual CLEERS conference (whether virtual or in person) and the teleconferences. It is good that the project curtailed the work on NO_x traps and increased the research on HC traps. The reviewer commented that CLEERS at Oak Ridge National Laboratory (ORNL) continues to be a good blend of coordination activities and technical research.

Reviewer 3:

The reviewer said wrapping up PNA work is good progress since the industry survey indicated SCR and ammonia oxidation (AMOX) as the topics of interest. The aging effect of SCR is a highly important topic to be focused on.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said progress was made on the Langmuir HC trap model. The SCR NO_x reduction and ammonia (NH_3) storage model was extended to represent longer mileages. Models were used only to predict reactor data. The reviewer said predicting vehicle data is much more difficult.

Reviewer 2:

The reviewer observed a very nice study on the adsorption of different HCs on the uncatalyzed zeolite beta (BEA) formulation using the single-site Langmuir isotherm. Also, there is a very nice fit of the NH_3 storage capacity of the copper (Cu)/aluminosilicate zeolite (SSZ-13) catalyst as a function of the storage temperature, aging temperature, water (H_2O) concentration, and NH_3 concentration using the three-site model. The reviewer gave kudos for investigating the NO_x conversion of the Cu/SSZ-13 catalyst with the pre-adsorbed NH_3 at different temperatures and aging conditions.

Reviewer 3:

The reviewer asserted that excellent progress has been made in the last year, with all the uncertainties that revolved around the pandemic. The virtual CLEERS workshop is a highlight of the accomplishments in 2020. The results related to SCR aging are very promising, especially the drop in low-temperature NH_3 storage with increasing age.

The reviewer inquired if there is any research on nitrous oxide (N_2O) generation pathways from SCR being researched. Since greenhouse gas (GHG) emissions are becoming critical, N_2O pathways from SCR may start becoming critical.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination are where CLEERS delivers on its mission. The reviewer noted that the workshop involved 250 people from industry, academia, and national laboratories. Monthly audios are also well attended. Presentations shared are on very timely topics.

Reviewer 2:

CLEERS is very effective for promoting collaboration among industry researchers on vehicle emission controls. According to the reviewer, the CLEERS conference and monthly teleconferences are excellent forums for the sharing of pre-competitive emissions data from different companies and institutions. The priorities survey also highlights the emission control topics that currently need to be prioritized. CLEERS at ORNL has good collaboration with the University of Virginia, Johnson Matthey, Pacific Northwest National Laboratory (PNNL), the Advanced Combustion and Emissions Control (ACEC) tech team, and the advanced engine crosscut team.

Reviewer 3:

The presentation shows a large collaborative effort between industry, academia, and national laboratories; the reviewer asserted that it would be interesting to group the collaborators according to their contributions.

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 state project ended.

Reviewer 1:

Since the industry may be considering dual SCR with an iron (Fe) zeolite close to the engine and a copper zeolite after the diesel particulate filter (DPF), the reviewer wanted to know whether the SCR-related research would be focused on the Fe zeolite catalyst as well. Also, will the SCR-coated DPF be a topic of research since off-road applications may consider this pathway?

Reviewer 2:

Aged SCR performance at higher mileages is worthy of further investigation. The reviewer encouraged the team to continue using the annual survey to set priorities for the work. The HC trap will be critical for gasoline vehicles to meet Super Ultra-Low Emissions Vehicle (SULEV)20/30. PNA is not durable and there is no business case for palladium (Pd) as a NO_x storage media anyway.

Reviewer 3:

The reviewer indicated that the collaboration and coordination activities should definitely be continued with the annual CLEERS conference and the teleconferences. The HCT work needs to be expanded to include catalyzed HCTs (with Pd and/or platinum [Pt]) so the stored HC species oxidation can be studied. The reviewer also remarked that there is a need to assess methods to introduce oxygen (e.g., with oxygen storage capacity [OSC] and air injection) so the adsorbed HCs can be oxidized on stoichiometric engines where there is no excess oxygen. The effects of different aging conditions (rich, stoichiometric, or lean) on the HCT would be helpful (similar to the work performed on the SCR catalyst for the passive SCR lean-burn project).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented the project supports the overall DOE objectives of developing fundamental simulations for an aftertreatment system that can lower NO_x emissions during low-temperature operation as well as lower carbon dioxide (CO_2) emissions. Lowering fuel consumption will invariably result in lower exhaust thermal energy, and this research project supports the goal of simultaneously lowering tailpipe emissions of NO_x as well as CO_2.

Reviewer 2:

The reviewer said the CLEERS work supports fuel efficiency and energy independence through improved understanding of aftertreatment devices.

Reviewer 3:

The reviewer stated CLEERS conferences and telecoms provide a good forum for sharing technical data with peers from other companies and thereby are helpful for promoting pre-competitive collaboration. Studying emission control technologies that will help fuel-efficient engines go into production while satisfying the appropriate emission standards will help DOE achieve its goal of reducing dependence on foreign oil.

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 there is a wealth of computing and experimental bench testing resources with ORNL as well as their collaborators to conduct this project.

Reviewer 2:

The reviewer stated resources appear to be adequate for now, although there might be a need for more resources for experimental research in order to expand the HCT work to include oxygen addition, HC oxidation, and the effects of aging on the HCT.

Reviewer 3:

The reviewer said current resources appear to be sufficient. Future resources are a question for any area that supports ICEs, although it is believed by many that ICEs will continue for several more decades, and higher efficiency emission controls will be needed more than ever.

Presentation Number: ace023
Presentation Title: Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination
Principal Investigator: Yong Wang (PNNL)

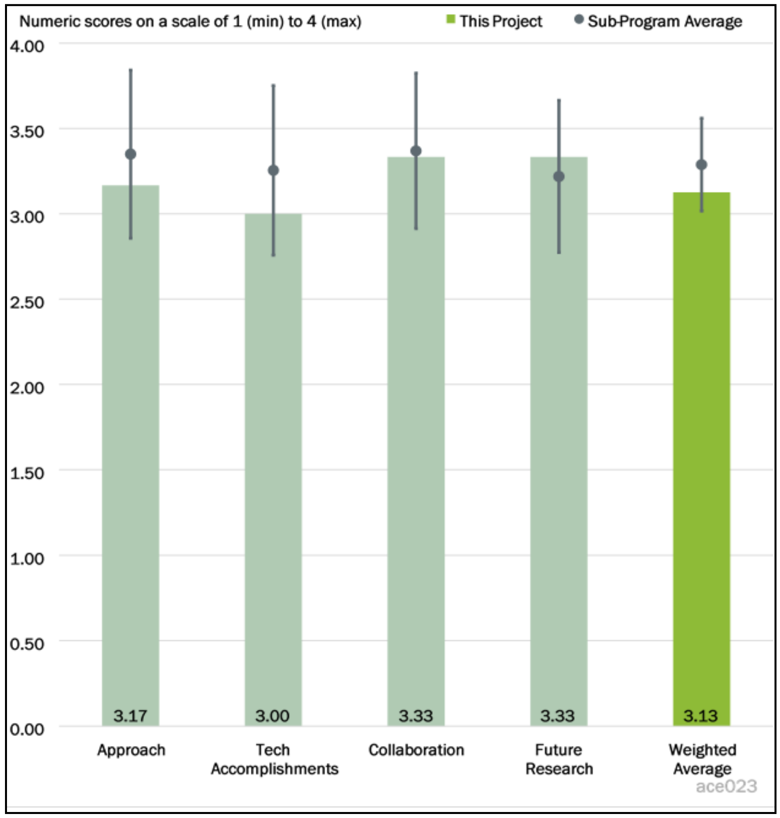


Figure 1-3 - Presentation Number: ace023 Presentation Title: Cross-Cut Lean Exhaust Emissions Reduction Simulations (CLEERS): Fundamentals and Coordination Principal Investigator: Yong Wang (PNNL)

Presenter

Yong Wang, PNNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

PNNL made good use of its expertise in fundamental science to study and develop emission control catalysts. The work on single-atom catalysts with Cu could be beneficial for reducing platinum group metals (PGM) loadings in catalytic converters. The reviewer observed that developing new tools such as electron paramagnetic resonance (EPR) spectroscopy for examining aged SCR catalysts can be useful for understanding the deactivation of current catalysts and hopefully will lead to catalysts with improved thermal durability to meet the increased mileage requirements.

Reviewer 2:

The reviewer stated the approach to address industry priorities is excellent, since ultimately this fundamental work should cater toward the greater goal of developing cleaner exhaust systems in production vehicles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted good work on using EPR for characterizing the aged SCR catalysts and an interesting study on the effects of S poisoning and desulfation on the single-atom Cu/cerium (Ce) catalyst under lean conditions. Nice job on adding manganese (Mn)-cerium (Ce) to the SCR catalyst to increase the NO_2 formation, thereby improving the low-temperature activity of the catalyst.

Reviewer 2:

The research team accomplished many of their key milestones and addressed many of the comments from previous year reviews, according to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

PNNL demonstrated good collaboration with General Motors (GM), the University of New Mexico, and Washington State University on the single-atom catalysts. The reviewer noted that PNNL also collaborates with ORNL on the annual CLEERS conference.

Reviewer 2:

The reviewer said collaboration with the industry helped the overall progress 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer asserted that there were several needs to assess and investigate: single-atom catalysts (SAC) Cu catalysts for stoichiometric applications; promising catalysts at higher temperatures (e.g., 900°C and 950°C) for engines operating at stoichiometry; and S-poisoning and desulfations on the MnCe-modified SCR catalyst because Mn is difficult to disulfate and S is known to inhibit the low-temperature activity of SCR catalysts.

Reviewer 2:

The focus on SCR-filters was very interesting to the reviewer, and it is good to see the project team has proposed this idea for future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said PNNL is developing catalysts for low-temperature operation, which will be needed to meet the Tier 3 Bin 3 emission standards with future fuel-efficient engines that generate lower exhaust temperatures. The project team is also working on catalyst technologies (e.g., SAC Cu) that can reduce PGM use, which is critical given today's market prices for Pd and rhodium (Rh).

Reviewer 2:

Understanding the chemical kinetics and the failure mechanisms of modern aftertreatment systems are highly critical, according to the reviewer. This best practice supports the overall DOE objective of lowering energy consumption from transportation while lowering tailpipe 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 commented that PNNL and its industry collaborators have sufficient resources to complete current and future milestones.

Reviewer 2:

Resources appeared to be sufficient to the reviewer for the current workload.

Presentation Number: ace027
Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA)
Principal Investigator: Feng Gao (PNNL)

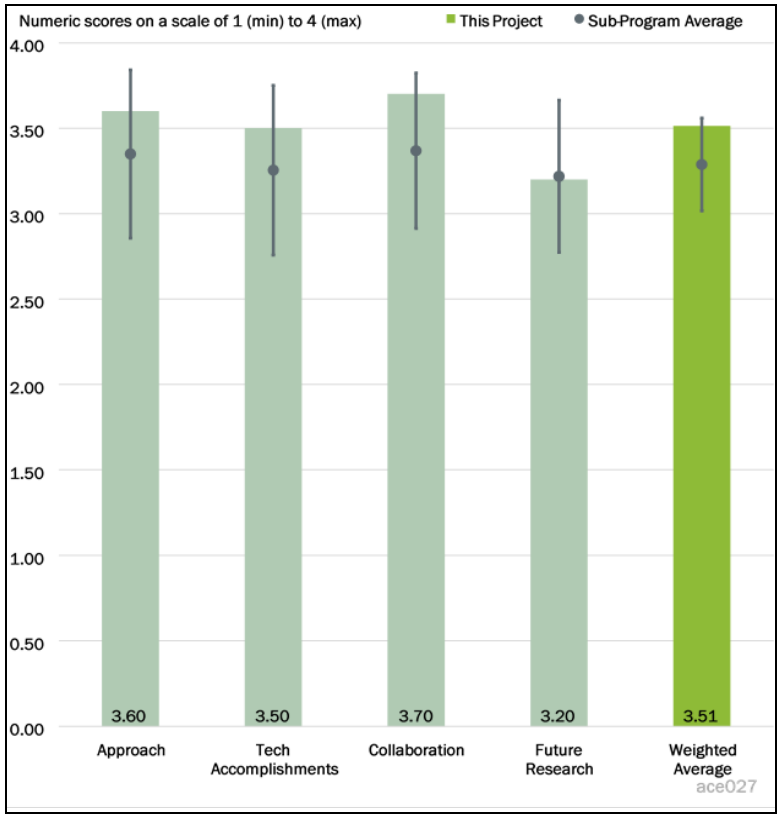


Figure 1-4 - Presentation Number: ace027 Presentation Title: Fundamental Understanding of Copper-Zeolite Selective Catalytic Reduction (SCR) Catalyst Aging Mechanism (Cummins CRADA) Principal Investigator: Feng Gao (PNNL)

Presenter

Feng Gao, PNNL

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said this is a methodical approach with four key milestones (two of which have been completed). It leverages PNNL's core competencies developed as part of CLEERS research and Cummins' lab- and field-aging specimen characterization to generate models that describe the SCR performance degradation.

Reviewer 2:

The approach to this work is sound and makes good use of PNNL's strength in catalyst characterization and tool development. The reviewer hoped that, by determining the mechanism for increased aging in field-age versus lab-aged samples, a technique for mitigating this increase can be developed.

Reviewer 3:

This reviewer commented that the set of tools selected turned out to be very appropriate for identifying the difference in aging field-aged and lab-aged samples.

Reviewer 4:

SCR catalyst aging directly affects the NO_x conversions in use, and the state of Cu active species is a critical issue that needs to be understood. Therefore, it made sense to the reviewer to use various characterization tools to probe the nature and state of the Cu species, including the effect of the poison species (sulfur or others). In addition, zeolite structure and acidity may also affect the catalyst NO_x conversion and thus should be examined as well. Because additional poison was suspected to be the reason for the discrepancy between field- and lab-aged catalysts, elemental analysis should be carried out on the field-aged catalysts.

Reviewer 5:

The reviewer noted that this project takes aim at reducing the gap between real-world, aged SCR catalysts and lab-aged catalysts. The researchers will use a multitude of characterization techniques to compare the field-aged and lab-aged catalysts to gain a fundamental understanding of the differences between the catalysts. The team is currently developing techniques such as EPR to monitor in situ active site changes. The reviewer believed that all these techniques should allow for the eventual understanding of the poisoning of the active site on the field-aged catalysts. The reviewer was curious to know—and was not sure this is sufficiently addressed enough in the slides—how the team intends to model the lab-aged catalysts to “copy” the field-aged ones. What techniques will be used to simulate a similar poisoning mechanism?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the results of finding new aging results—using hydrogen (H_2) temperature-programmed reduction (TPR) and other methods—helped with seeing new differences due to field aging.

Reviewer 2:

The reviewer remarked that technical accomplishments included identifying gaps between field-aged and existing simulated-aged catalyst behavior, developing a model catalyst synthesis and aging protocol, and using new tools and methods in studying field-aged catalysts.

Reviewer 3:

The project appeared to be running on schedule to the reviewer, and early results point toward a possible mechanism for the advanced aging.

Reviewer 4:

The reviewer believed some of the necessary steps were taken to understand the atomistic poisoning mechanism. The fundamental characterization of the active sites has occurred, but it would be better if there were more concrete evidence that Cu-sulfate formation occurs. The reviewer would like to have seen steps taken to bridge the gap and to synthesize model catalysts.

Reviewer 5:

The reviewer said hydrothermal and hydrothermally aged (HTA)/S aging protocols were used to compare with field aging. The team carried out extensive characterization of the Cu species and NH_3 storage in the aged catalysts and identified the gap between lab- and field-aged parts. Again, since the unknown poison could be the key missing piece to explain the discrepancy between lab- and field-aged parts, the reviewer asserted that elemental analysis of the field-aged parts seems to be urgently required. If confirmed, this poison component could be added to the lab-aging protocol to make it more representative of the field aging.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented this is a cooperative research and development agreement (CRADA) project with a leading HD engine and aftertreatment manufacturer Cummins. As such, 50% of the cost is contributed by Cummins and their involvement in the project is significant. Argonne National Laboratory (ANL) is a collaborator as are two universities (Purdue and Tsinghua).

Reviewer 2:

According to the reviewer, there is excellent collaboration with the CRADA partner and good leverage of the Environmental Molecular Sciences Laboratory (EMSL) analytical capabilities.

Reviewer 3:

It was clear to the reviewer that Cummins and PNNL are working together on this project, as Cummins is providing PNNL with the necessary catalysts. Cummins and PNNL seem to be coordinating their studies together.

Reviewer 4:

The reviewer commented collaboration occurs across multiple national laboratories, industry, and academia and appears to be well coordinated. The generation of aged samples at Cummins that are then characterized at PNNL appears vital to the project.

Reviewer 5:

Although it is hard to tell exactly who contributed what, this reviewer asserted that Cummins has proven to be an excellent partner over the years.

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 state project ended.

Reviewer 1:

The reviewer commented appropriate future work is proposed to complete the third and fourth milestones. This future work includes investigations of PNNL model catalysts and initiating aging model development with Cummins.

Reviewer 2:

The reviewer noted that very reasonable goals have been set for future research.

Reviewer 3:

The future work plan appeared to be reasonable to the reviewer, but there is no evidence of decision points or risk mitigation strategies.

Reviewer 4:

The reviewer believed that the intention to synthesize model catalysts to simulate real-world aged catalysts is clear, but was unsure about the steps that will be taken to achieve that. Will atomistic modeling, such as density functional theory, also be involved? The reviewer inquired, furthermore, whether this project will have to evolve and expand to tackle the new durability requirements. If so, how will the team overcome this impending barrier?

Reviewer 5:

It seemed to the reviewer that the critical information needed is whether or not there is additional poison in the field-aged parts and, if so, what the poison is. Therefore, it is unclear how the proposed work on the model catalysts could contribute to that. The reviewer said this concern also applies to the aging model development with the additional poison contributing to the catalyst deactivation mechanism. If confirmed, this poison could be added to the accelerated lab-aging protocol to better represent field aging.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports DOE objectives as it addresses a key aspect of the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Partnership's ACEC tech team's roadmap—aftertreatment technologies for clean diesel combustion. It also improves domestic fuel efficiency in the transportation sector and contributes to environmental protection.

Reviewer 2:

The reviewer stated this project directly addresses barriers in understanding the fundamentals of aging SCR catalysts and therefore supports the DOE objectives.

Reviewer 3:

SCR catalyst performance after aging is critical to achieving very high NO_x efficiencies in the field for diesel vehicles, according to the reviewer.

Reviewer 4:

The reviewer asserted that this project supports the overall objectives of the DOE by helping an industry partner to develop better aftertreatment options, which in turn may allow for increased fuel efficiency.

Reviewer 5:

This reviewer explained that improved emissions control allows original equipment manufacturers (OEMs) to optimize energy efficiency of the entire engine and aftertreatment 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 remarked that these laboratories have excellent resources for carrying out their tasks.

Reviewer 2:

The reviewer observed that $300,000 per year of DOE investment in a 50% cost-share CRADA with a major industry partner seems appropriate for this important project.

Reviewer 3:

Financial resources for this project appeared to be adequate to the reviewer. The team itself is very strong.

Reviewer 4:

The reviewer said the team indicated sufficient funding was already provided to complete this project.

Reviewer 5:

According to the reviewer, resources are sufficient for this project.

Presentation Number: ace032
Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems
Principal Investigator: William Partridge (ORNL)

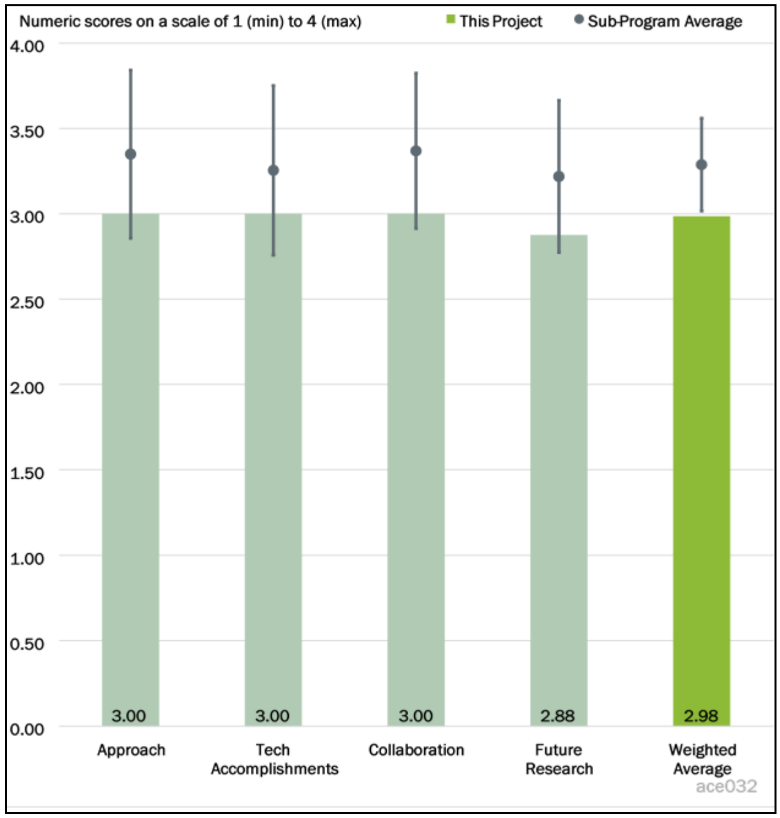


Figure 1-5 - Presentation Number: ace032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): Nitrogen Oxide Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: William Partridge (ORNL)

Presenter

William Partridge, ORNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the project seeks to address barriers to SCR aftertreatment for diesel engine NO_x control including emissions control cost, SCR effectiveness under low-temperature applications, and robustness and durability in real-world applications. The project focuses on the challenge of understanding the impact of field-aging on catalyst durability under real-world driving conditions.

According to the reviewer, key components of the approach are determining the kinetic impacts of field aging by analyzing transient reduction and oxidation half cycles (OHC) to quantify the impact of aging on each half cycle and validating a Cummins SCR kinetic model using the experimental results.

The project approach is well designed and has been adapted to address barriers, prior reviewer comments, and the different characteristics of a new commercial Cu-SSZ-13 SCR catalyst.

Reviewer 2:

The reviewer remarked that the recent work has focused on obtaining the kinetic parameters for a rather detailed model that is being developed in collaboration with the industry partner, Cummins. It is good to see the new reactor is running, as this should accelerate the work and model development. It was a little surprising to the reviewer that there was a switch in catalyst "late" in the project, which hopefully was not a delayed switch from a formulation dropped in 2015. This catalyst switch may be not so critical as the chemistry should be primarily the same, except for the aging aspects. The reviewer said, overall, it is apparent the results are beneficial in understanding how the SCR catalyst works and will be extrapolatable to aging.

Reviewer 3:

The work has generally been executed with sound technical approaches. However, there appeared to the reviewer to be some limitations associated with the correlation between the aged samples and the functional mechanistic behaviors. The catalysts used for the work performed were field-aged parts, which provide the most realistic aging behavior. However, the reviewer noted that this catalyst choice results in significant unknowns that limit the technical success of the work. For example, the aging conditions seem to be completely unknown to the researchers, and the individual aging parameters (S, hydrothermal, inorganic metals, etc.) are unknown and not decoupled. The reviewer asserted that these aging conditions will limit the technical success of this work.

Reviewer 4:

The reviewer stated the work includes examining SCR catalysts (one newer one) in field testing, matching their performance versus an OHC/reduction half cycle (OHC/RHC) kinetic model, also matching it against the CLEERS model. From that perspective, the work is satisfactory, though not exemplary. Further, the cornerstone of the project is to focus on low-temperature SCR performance; however, it was unclear to the reviewer why most of the analysis focused on the temperature range 200–400˚C, barely considered low temperature. It would have been more relevant had it mainly focused on 150–250˚C, a far more challenging "low-temperature" consideration.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated an improved transient response reactor was developed, enabling unattended programmed operation to improve efficiency and reduce time needed to complete experiments. Although previous reviewer comments raised concerns that too much effort had been devoted to reactor improvements, the investigators maintain that the improved reactor was necessary to effectively evaluate the new Cu-SSZ-13 SCR catalyst and that the improved reactor has enhanced the project.

The reviewer observed that experimental work characterized the effect of field aging on limiting the redox half cycle and demonstrated that field aging selectively degrades the OHC at a higher rate, shifting the optimum temperature to higher values.

The Cummins kinetic model was shown to capture important features of catalyst behavior with temperature, including the fast initial transients, bimodal nature of the transient response, and the faster overall transient response with increasing temperature.

Reviewer 2:

Again, bringing the new reactor online should accelerate results becoming available, as will the inclusion of a new researcher, of course. The reviewer indicated that the recognition of a need and development of a new protocol for characterizing the aged catalysts should also lend confidence in the results. And, of course, the results supporting the model development internal to Cummins as well as being used to validate the open source CLEERS models are important.

Reviewer 3:

The reviewer commented progress is generally proceeding according to schedule and milestones.

Reviewer 4:

The reviewer said while there is progress relative to last year, only investigating "one" newer SCR catalyst (Cu-SSZ-13) does not signify substantial progress. The entire project is about field-aged catalysts; however, the presenter did not know "how field-aged" the catalysts were. Lightly aged? Moderately aged? Strongly aged? The reviewer further highlighted that a histogram was unavailable to show mileage and temperature distribution.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good collaboration with Cummins to provide field-aged samples for the experimental evaluation and kinetic modeling of catalysts. Johnson Matthey provided model catalyst samples. The addition of Johnson Matthey as a CRADA participant is a positive development that will strengthen the CRADA work.

Reviewer 2:

Judging from the presentation, the collaboration among the team members appeared to be fine to the reviewer.

Reviewer 3:

It was apparent to the reviewer that Cummins is using the data obtained to tune and develop the project team's kinetic models. The sample switch is concerning and not necessarily from the fact that sometimes formulations change, but more from why the switch occurred. The reviewer commented that this answer would have helped justify.

Reviewer 4:

The reviewer said collaboration generally appears to be meeting expectations. However, there were some examples where it appeared that communication between the partners was limiting project success.

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 state project ended.

Reviewer 1:

The proposed future research topics were relatively limited in scope, according to the reviewer. This work focused on significant catalyst performance characterization and detailed microscale changes.

Reviewer 2:

The reviewer stated that there appears to be a long list of future work to be done (Slide 29). That said, again, while there are some good topics included, judging from that list, a focus on low-temperature performance appears missing.

Reviewer 3:

The proposed work appeared ambitious to the reviewer, given past rates. Yes, there is a reactor now online, but to characterize and confidently assign kinetic parameters for the de-greened, field-aged, and hydrothermally aged catalysts is a lot, given the technique and effort needed. The reviewer also said it appears the focus is about to switch to the ammonia slip catalyst (ASC), without closure on the SCR.

Reviewer 4:

The project is 86% completed in the final year. The reviewer was not clear on what work was planned to complete the current scope of work and what work was planned as part of a planned renewal.

The reviewer said a future renewal is planned to focus on adding an ASC to address NH_3 emissions and to determine the impact of field aging on the kinetics of commercial CU-SSZ-13 SCR catalysts.

The presentation identified several remaining challenges and opportunities for future work but did not present a detailed plan for specific work that will be proposed in a renewal application.

According to the reviewer, the project needs a more detailed plan for completing the work under the current project scope.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project supports DOE VTO objectives of improving diesel efficiency by enabling NO_x aftertreatment solutions for advanced low-temperature combustion (LTC) technologies for diesel engines through development of advanced SCR catalysts.

Reviewer 2:

The reviewer remarked that good SCR means good fuel economy, which coincides with DOE fuel economy goals and other targets.

Reviewer 3:

The reviewer stated HD diesel is not being eliminated via electrification. Therefore, emissions from these engine types need to be mitigated. With engines lasting longer, the aftertreatment system must also last longer, and the results from this effort will help achieve this.

Reviewer 4:

The project does an acceptable job supporting DOE objectives. However, the reviewer thought that the body of research is not as advanced as it could or should be for a DOE-funded project. There are many similar projects going on in the public and private domains, executing very similar (if not identical) work as part of application development programs.

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

Reviewer 1:

With a reactor online to take the data and personnel now available, the reviewer said that results will flow.

Reviewer 2:

Resources seemed to be sufficient to the reviewer for the planned work scope.

Reviewer 3:

The reviewer observed no resource issues.

Reviewer 4:

According to the reviewer, improved programmable transient reactor will increase efficiency of experimental work.

Presentation Number: ace033
Presentation Title: Emission Control for Lean Gasoline Engines
Principal Investigator: Vitaly Prikhodko (ORNL)

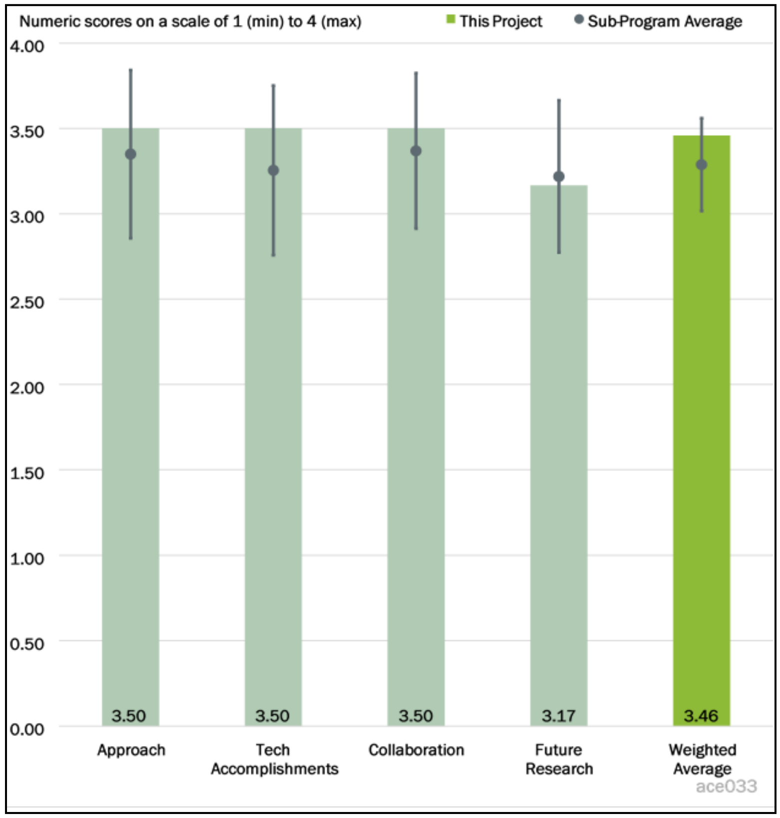


Figure 1-6 - Presentation Number: ace033 Presentation Title: Emission Control for Lean Gasoline Engines Principal Investigator: Vitaly Prikhodko (ORNL)

Presenter

Vitaly Prikhodko, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented the approach to study passive SCR strategy using a flow reactor and engine study is a great approach. Using the MAHLE jet ignition engine is another excellent approach.

Reviewer 2:

The reviewer stated the project continues to be a good blend of reactor testing and engine testing. The assessment of the SCR durability as a function of aging temperature and air/fuel (A/F) ratio (lean, stoichiometric, and rich) is particularly commendable. It will be interesting to see the early emission and fuel economy results on the new MAHLE engine, although the higher HC emissions and lower exhaust temperatures (from the Annual Merit Review [AMR] 2020 presentation) may present a challenge.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said there is great work on the SCR durability research. The NH_3 temperature programmed desorption (TPD) and H_2 temperature programmed reduction (H_2 TPR) results were helpful for characterizing the catalysts after aging. It appears the SCR B2 formulation was a significant improvement over the earlier generation of SCR catalysts. The reviewer commended the project team for being able to install the new dynamometer and engine during a pandemic.

Reviewer 2:

The reviewer asserted that installing the MAHLE jet engine is significant progress in this research. In addition, improving the engine testing capability with the new AVL dynamometer is an important accomplishment. NH_3storage at high exhaust temperatures during stoichiometric operation appeared to be a concern to the reviewer. Air injection could potentially cool the exhaust by diluting it; however, oxidation of NH_3 could be an issue.

The reviewer suggested that some computational fluid dynamics (CFD) analysis for cooling the exhaust could help develop exhaust heat transfer technology to lower exhaust temperatures prior to the SCR and help in NH_3 storage.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good collaborations with GM and Umicore.

Reviewer 2:

GM and Umicore participation in this work is vital, and the project team appeared to the reviewer to have a strong collaborative effort.

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 state project ended.

Reviewer 1:

The reviewer noted that the clean-up-catalyst increased the NO_x emissions by oxidizing NH_3, and it also significantly increased the PGM content of the system (150 gallons per cubic foot [gpcf] Pt/Rh in the clean-up catalyst [CUC]). Adding air injection will only make the NH_3 oxidation worse and increase the system cost as well. The reviewer commented that other methods to reduce the carbon monoxide (CO) emissions need to be explored. If the exhaust O_2 could be reduced during the rich periods with better A/F mixing, then NH_3 could be generated over the three-way catalyst (TWC) while running less rich. The reviewer opined that better mixing will also result in less CO and possibly eliminate the need for additional aftertreatment just for the CO. If the engine had both a direct-injection (DI) injector and a port fuel injection (PFI) injector as found on some production engines, the PFI injector could be used during the rich periods to obtain better A/F mixing and thereby generate less O_2 and CO. The reviewer asserted that lower O_2 will allow the project to run less rich while still generating NH_3 over the TWC, and this rich reduction will further reduce CO emissions. The effects of S on the aftertreatment will need to be revisited with the new engine and catalyst system.

Reviewer 2:

Future research work appeared to the reviewer to target all important questions. Engine dynamometer testing will be the ultimate judge of the fuel reduction capabilities of a passive SCR approach.

The reviewer asked whether the project team will look at other technology additions, such as air injection, exhaust design, and a high thermal inertia TWC to improve NH_3 storage in SCR catalyst to improve the duration of lean operation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated lean burn engine use can reduce the fuel consumption of gasoline engines by up to 15%, which will help satisfy DOE's goal of reducing our dependence on foreign oil. This project is particularly relevant because it is developing aftertreatment for a lean burn engine that can satisfy Tier 3 Bin 3 emission standards after realistic aging while significantly increasing the fuel economy of the engine.

Reviewer 2:

The reviewer commented lowering fuel consumption from gasoline engines can be effectively achieved with lean-burn systems. However, urea as a consumable is not attractive for passenger cars; therefore, the success of a passive SCR system can be a game changer.

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

Reviewer 1:

Resources seemed to be sufficient to the reviewer for now.

Reviewer 2:

The new dynamometer and MAHLE engine are interesting resources to the reviewer to test the efficacy of this approach.

Presentation Number: ace056
Presentation Title: Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs)
Principal Investigator: Yong Wang (PNNL)

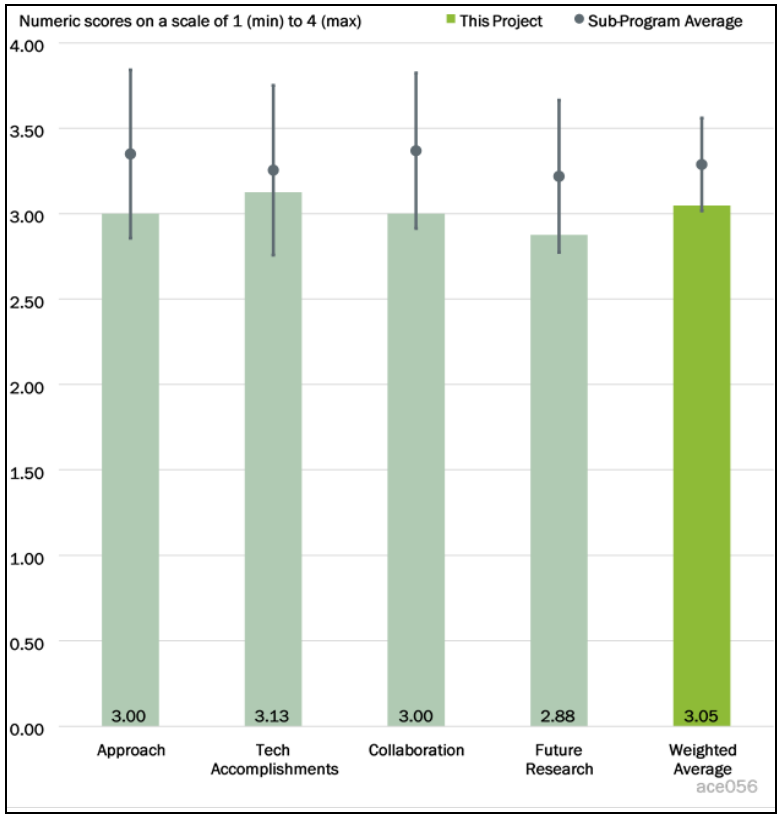


Figure 1-7 - Presentation Number: ace056 Presentation Title: Platinum Group Metals (PGM) Reduction in Three-Way Catalysts (TWCs) Principal Investigator: Yong Wang (PNNL)

Presenter

Yong Wang, PNNL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the approach to research to be based on sound scientific principles to address technical challenges associated with the project.

Reviewer 2:

The reviewer stated the summary of last year's results included evaluation of reduced Rh contents through SAC, evaluating ruthenium (Ru) as a replacement for other PGM components and also evaluating Pd and Pt SAC. SAC, for a variety of chemistries, has grown in interest and focus over the last several years, so the team is able to leverage the knowledge being gained for synthesis and chemistry. The Rh results were interesting to the reviewer, who encouraged the team to include the rates for the higher than 0.1 loaded samples to support the conclusion that the 0.5 Rh is also a single atom throughout the experiment. Q&A suggested the rate versus loading flattened out, and such a finding would be critical for those working in this area. The findings with cerium-zirconium (CeZr) supports were also intriguing to the reviewer, who inquired as to why the performance shifted in temperature and how might the synthesis be tuned to mitigate the addition of the Zr effect? This is exciting work.

Of the work done, the reviewer's primary concern would be the inclusion of Ru in the study, rather than focusing on the single-atom aspects. Ru has known volatility issues, which are one of the focus points, but from a manufacturing aspect that volatility would or could be challenging. The reviewer opined that the industry partner should provide support and justification for the effort put toward studying Ru.

Reviewer 3:

The PI did a good job presenting the work, displaying the highlights and interim results. The presenter noted that this is a tough problem, and the goals point to conflicting targets such as reducing PGM while going down in activity temperature (150C). The reviewer said the team is doing a good job in addressing the challenges. Ru is indeed a potential alternative to Rh, but its fate remains uncertain, especially in the view of prior work.

Reviewer 4:

The reviewer stated the project is focused on developing effective TWCs for low exhaust temperature applications (less than 50°C) and reducing PGM content in catalyst formulations. The approach includes investigating the interface between single metal atoms and the support needed. According to the reviewer, the approach requires developing special characterization tools needed to support this effort.

The presentation could provide more detail about the research approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said several, light-off, style tests were included, with computational and surface characterization studies from the partner supporting the view of what the surface looks like and what the surface is doing. The team has published two papers on the Rh work for NO mitigation. The reviewer said there is a third paper noted for natural gas, although this paper was also brought up in the response to last year's reviewers' comments as not an area of focus. The results regarding NH_3 are quite interesting to the reviewer. Overall, when reviewing the main material and the supporting slides, it is apparent that meaningful work is ongoing.

Reviewer 2:

According to the reviewer, technical progress achieved to date is equal to expectations for this project.

Reviewer 3:

The reviewer remarked that progress has been good, but further challenges remain (aging, poisoning, manufacturing, and cost considerations), as obvious from the presenter's statements.

Reviewer 4:

Although there is still a need to evaluate S tolerance of the catalysts, this reviewer observed commendable accomplishments date, which include the following:

- Synthesized thermally stable Rh atoms that are highly active for NO reduction by CO with full NO consumption achieved at 115°C.
- Demonstrated 0.1 weight percent (wt.%) RH1/CeO2 catalyst with full NO conversion at 125°C, which similar performance to 0.5 wt.% RH/CeO2.
- Demonstrated minimal effect of propylene addition.
- Demonstrated undegraded catalyst after hydrothermal aging at 900°C.
- Identified promising Pd and Ru/CeO2 catalysts.
- Made progress overcoming Ru volatility by trapping Ru as single atoms in 0.1 wt.% and 0.5 wt.% Ru.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that collaboration with the project team has been good, thus far, in the project.

Reviewer 2:

The reviewer said the interaction between PNNL and the University of Sophia was obvious. The integration of the computational aspects and experimental aspects was presented for the Ru case. The contribution from Stellantis was not made obvious.

Reviewer 3:

The roles of the collaborators appear to be well coordinated. The reviewer suggested that the project team provide more specifics about the work each partner is performing.

Reviewer 4:

The team has Stellantis and Sofia University onboard. In the reviewer's opinion, these team members are definitely not sufficient, however, given the tremendous challenges the project faces and will face. The presence of an entity strong in materials research and development (R&D) (beyond PNNL) or an OEM strong in catalyst research (i.e., Ford) is warranted. While PNNL is outstanding in fundamentals and leading-edge instrumentation, the reviewer did not believe that it has sufficient real-life (fieldwork-type) experience to decipher, when it is all done and good, what will remain a scientific experiment versus what will work as a practical catalyst in the end. Hence, a commercial material R&D entity could fill that gap, lowering the risk.

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 state project ended.

Reviewer 1:

According to the reviewer, the proposed future work is entirely appropriate. The team is converging on the Rh single atoms and will dive further into understanding its chemistry, but also probing its stability. Rh is notorious for moving between atomic and particulate forms, so this should help the field understand its chemistry further. The reviewer suggested that other gases should also be explored during this phase.

Reviewer 2:

The reviewer stated the scope of this project is basic research. For the scope of basic research, the project has been very successful. The reviewer, however, wanted to see further planning and proposals for future applied research to ensure the increased likelihood of successful implementation of this technology.

Reviewer 3:

The reviewer commented the team has not sufficiently sifted through manufacturing potentials of likely catalysts; this was also brought up by another member of the audience and it could be a significant barrier, a potential showstopper. Likewise, more focus on aging (longer aging) and poisoning is warranted.

Reviewer 4:

Future plans to investigate hydrothermal stability, S tolerance, reasons behind TWC deactivation, and development of theoretical models to evaluate the NO conversion pathways are relevant to the scope or the project and DOE objectives. The reviewer needed information about decision points and the risks associated with the proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated the project is directly relevant to the DOE goals of reducing criteria pollutant emissions from ICEs.

Reviewer 2:

The reviewer indicated that the lower temperature catalytic activity can help save fuel (especially in the view of engine-out temperatures continuing to drop), consistent with the DOE goals of energy policy.

Reviewer 3:

The reviewer observed that PGM prices are extreme currently and reducing their content in aftertreatment catalysts while also improving the performance of such systems is critical for OEMs as well as minimizing emissions.

Reviewer 4:

The reviewer noted that the project addresses the DOE goal of improving fuel efficiency by enabling aftertreatment technologies that are effective at low exhaust temperatures typical of higher efficiency engines and the DOE goal of further reducing criteria pollutants.

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

Reviewer 1:

Resources appeared sufficient to the reviewer, with this conclusion based on what has been achieved and what is proposed.

Reviewer 2:

The reviewer stated resources seem sufficient to execute the proposed body of work.

Reviewer 3:

According to the reviewer, resources appear to be sufficient to accomplish the proposed scope of work.

Reviewer 4:

This reviewer referenced earlier comments and indicated that stronger aging considerations, more S emphasis, broader materials considerations, and integration of capabilities of a R&D-strong commercial entity are warranted.

Presentation Number: ace085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (ORNL)

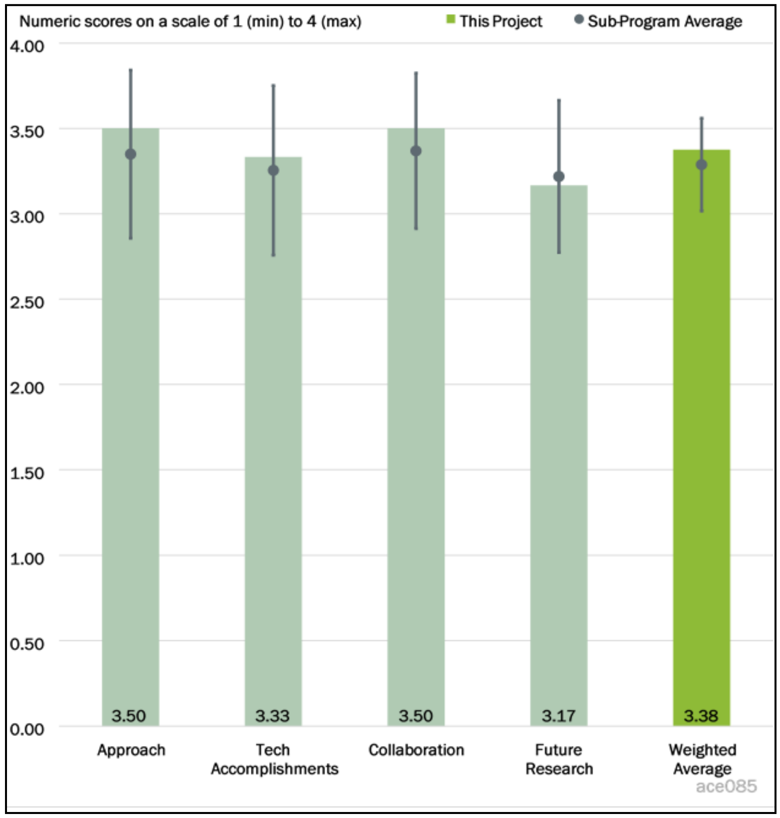


Figure 1-8 - Presentation Number: ace085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (ORNL)

Presenter

Todd Toops, ORNL

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project team did a good job on using the ACEC testing protocols for the catalyst evaluations. The reviewer gave extra kudos for performing multiple NO_x adsorption tests on the PNAs and for investigating the addition of other materials (Cu, silver [Ag], and cobalt [Co]) in an effort to reduce the deactivation from CO. Also, the work on Pt catalysts is welcome, considering the high prices of Pd and Rh currently.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated good work on investigating the effect of the Ce level with the Pt catalysts and showing that 60% Ce provided similar performance as the Rh-only reference catalyst. Nice work on showing the equivalent NO_x adsorption performance with the Pd/Cu combination with only half the Pd loading as the Pd-only sample. The reviewer stated the diesel oxidation catalyst (DOC), HCT, and PNA combination was interesting.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented good collaborations with the University at Buffalo, Harvard University, the University of Virginia, DOE Basic Energy Sciences (BES), and PNNL.

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 state project ended.

Reviewer 1:

The PNA work needs to be expanded to other zeolites besides chabazite (CHA), BEA, and zeolite Socony Mobil 5 (ZSM-5) since these three zeolites always show some deactivation after tests with CO. The reviewer suggested considering lowering the total HC level to a level more consistent with diesel exhaust during a cold start, such as 1,000 parts per million (ppm), and encouraged investigating system approaches to minimize the deactivation from CO, such as a front DOC. In addition to the 600℃ ramps, the reviewer said that the project team might consider performing the temperature ramps to 400˚C or even 300˚C, as these are more realistic maximum temperatures for diesel engines. For the TWC work intended for stoichiometric applications, the reviewer encouraged the team to evaluate the more promising catalysts after aging at 900C and even 950C. The OSC of the catalysts still needs to be assessed, particularly with the Pt-only samples as Pt is known to be less effective for promoting OSC compared to Pd and Rh.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Developing low-temperature catalysts is important for meeting stringent emission standards on future fuel-efficient engines that generate lower exhaust temperatures. Assessing catalysts with reduced Pd and Rh loadings (e.g., Pt-only and Pd with co-cations) is also important, given the current market price of Pd and Rh. The reviewer asserted that this assessment will enable automotive manufacturers to produce fuel-efficient engines, while cost-effectively meeting strict emission standards.

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

Reviewer 1:

Resources seemed sufficient to the reviewer for now, although additional testing resources could be needed to explore different PNA formulations with different zeolites and/or active metals. Extra testing and aging resources might be necessary to perform OSC tests and for aging TWCs at higher temperatures.

Presentation Number: ace100
Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2
Principal Investigator: Darek Villeneuve (Daimler Trucks North AmerIca)

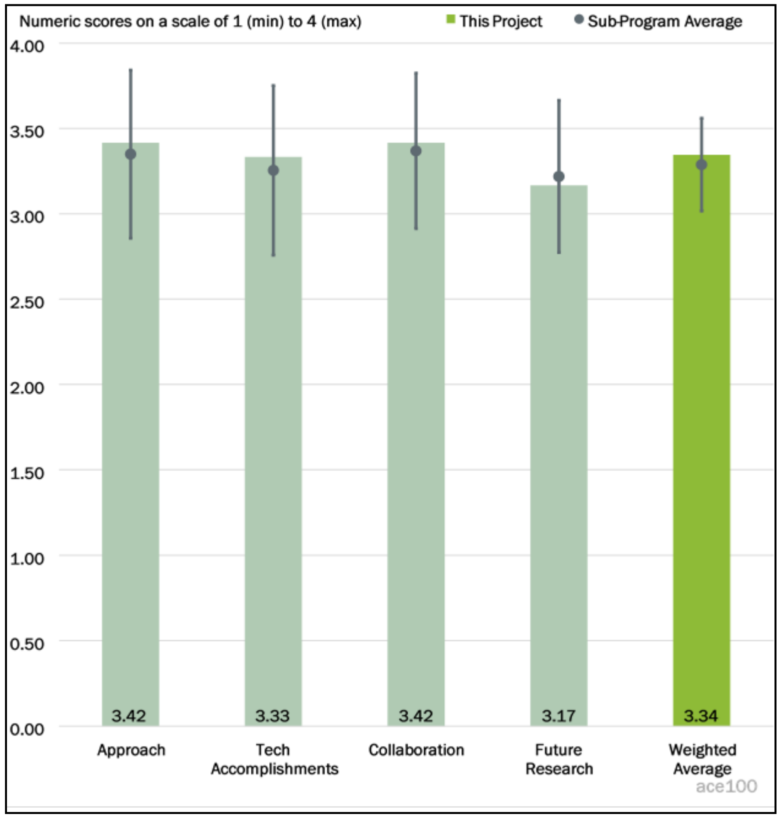


Figure 1-9 - Presentation Number: ace100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research - SuperTruck 2 Principal Investigator: Darek Villeneuve (Daimler Trucks North AmerIca)

Presenter

Darek Villeneuve, Daimler Trucks North AmerIca

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented all technical barriers have been addressed adequately. The approach considers various aspects of engine and chassis level improvements.

Reviewer 2:

The reviewer found that the approach to the project is broad-based and appears to continue to focus on all aspects of the truck and trailer efficiency picture. Most of the discussed technical approaches are a stretch target beyond current off-the-shelf technologies, but not way out there. According to the reviewer, some technologies have been considered, which are pretty far out there (phase change cooling, for example). Including some of these advanced technologies, but not fully relying on them, has made the project more robust against challenges that come up during execution.

Reviewer 3:

The roadmap on Slide 4 clearly lays out the pathway to meeting the vehicle-level goals. The pathway to 55% brake thermal efficiency (BTE) on Slide 10 was a little more difficult for the reviewer to understand. It would have been helpful to the reviewer for the project team to identify the pieces of the bar chart (particularly for the combustion and air handling) regarding which technology each portion came from.

Reviewer 4:

The reviewer indicated that the project reported coronavirus disease 2019 (COVID-19) supply chain and workplace schedule impacts, which is an industry-wide challenge. This challenge included an 8-month delay in engine delivery; however, the project instituted recovery plans and is essentially on track for the original technical and project milestones, which reflects an effectively managed project. The reviewer commented that the team employed interim prototype hardware and analyses to validate the approach for the final demonstrator. This process has successfully identified risks and challenges in meeting targets, then taken steps to mitigate those.

Reviewer 5:

The reviewer stated the project is well planned and, given that it is near the end, the reviewer expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 6:

The approaches taken for both the engine and the vehicle are comprehensive, including all necessary puzzles to fulfill the vehicle project goal. However, the reviewer was not so sure if the project can achieve the engine goals of 55% BTE, partially because the technology roadmap depends on the progress of phase change cooling waste heat recovery (WHR). At this time, only simulated results are shown, and testing is on hold without any specific reasons.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Given the challenges of project execution during the COVID-19 pandemic, the reviewer found that the progress on the project is excellent. The reviewer did not recall the exact timing of when the project started, but with the stated plan to complete the project during 2021, the accomplishments are quite good. The reviewer would like to have seen some preliminary numbers on where the powertrain efficiency was after the ORNL testing and ideally some indication of the freight efficiency level after the first prototype testing. The reviewer opined that it is a little hard to judge exactly how close the progress is relative to targets the way the efficiency stack-ups are shown with both tested and simulated results all included along the way.

Reviewer 2:

According to the reviewer, there are excellent accomplishments. The only gap is the WHR system, and it was not clear to the reviewer whether the 55% BTE can be achieved with the cyclopentane system. Slide 10 shows that the project is currently falling short of the goal. Also, it would have been good to see some results on criteria pollutants with the close-coupled (cc)-SCR used.

Reviewer 3:

The reviewer commented technical accomplishments were good, even though some delays were encountered due to COVID-19.

Reviewer 4:

The reviewer said the system design approach has seen some elements, such as tractor aerodynamics, not quite meeting original goals, but compensated for by better than planned improvements in other vehicle areas such as trailer aerodynamics. Much of the technical validation remains to be completed as the project team is waiting for vehicle completion and testing of the final demonstration vehicle in the final phase of the project. Prototype testing and analysis has provided confidence that the final demonstrator will exceed targets with some margin.

Reviewer 5:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 6:

The reviewer stated significant progress has been made on the vehicle, including weight reduction, axles, tires, and energy management, which seems to indicate that the project should be able to achieve the vehicle goal.

The accomplishment on the engine seemed to be a little bit murky to the reviewer. Without phase change cooling WHR, it would be challenging to meet 55% BTE goal. Also murky is the current status of the engine BTE because the project team did not provide a clear current status report.

The reviewer asserted that another thing that needs clarification is what final version of the engine will be used for the final vehicle demonstration. The engine size due to twin turbo seems to be big, and the reviewer was not sure whether the engine targeted to 55% BTE can fit under the hood. Therefore, there is a disconnect between the engine and vehicle research.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the project has effectively coordinated activities between participants during a challenging industry period dealing with COVID-19 supply chain and workplace issues. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an engine manufacturer, a fleet, a trailer manufacturer, a tire company, two DOE national laboratories, and two universities. The team has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 2:

The project looked like a well-coordinated effort to the reviewer.

Reviewer 3:

The reviewer said collaboration and coordination with all partners seem to be strong.

Reviewer 4:

The reviewer rated project as excellent because it does appear that several partners have been heavily used to achieve gains (trailer manufacturer, Michelin, and ORNL primarily). In a project as large as this one, it is clear there are many partners, but it is not clear how well things are coordinated at a detailed level.

Reviewer 5:

According to the reviewer, team members and their specific contributions were well laid out. It looks like a good team with industry, academia, and national laboratory members.

Reviewer 6:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated the demonstrator truck and demonstration of a 55% BTE engine are clearly identified in the future plans.

Reviewer 2:

The reviewer noted that the project is basically completed.

Reviewer 3:

According to the reviewer, the project is effectively planned and remaining work is tied to the availability of the final demonstrator. Interim steps were taken previously to reduce risk through the use of prototypes, virtual analysis, bench, test cell, track, and road testing.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a model year (MY) 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 4:

The reviewer said at this point the proposed future work is just to finish the outstanding tasks. It looks like the phase change WHR was dropped from the project. If so, the reviewer was disappointed as it would have been really interesting to see. However, it is also a challenging and high-risk technology so the reviewer could see why it might have to go as the end approaches.

Reviewer 5:

The reviewer remarked that it will be good to see results for NO_x emissions after all is done. Also, the status on WHR is not very clear, and it will be good to get a clear recommendation on whether the researchers find that phase change cooling has some significant barriers and should not be pursued in the future.

Reviewer 6:

The reviewer said the proposed future research should provide more details on how those technical barriers need to be overcome. Specific examples would include the potential issues of lacking phase cooling WHR, and the seem-to-be oversized engine. The reviewer said the project team will have an issue integrating the new engine into the final vehicle demonstration.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 2:

The reviewer remarked that the project remains well aligned with the DOE objectives as of the time the project was started. Of course, the past 4 years have seen numerous changes in DOE objectives, so there is far less focus on decarbonization than would be desired right now. According to the reviewer, the project is still successful as it appears to address the DOE goals as set forth.

Reviewer 3:

The reviewer indicated that the project is clearly very relevant to improving fuel economy for transportation.

Reviewer 4:

The reviewer commented the project clearly contributes to the increased efficiency of freight transport and reduced energy consumption. The project meets DOE objectives.

Reviewer 5:

The reviewer stated the project supports the overall DOE objectives because of the significant improvement in the engine and vehicle performance and fuel economy.

Reviewer 6:

The reviewer found the project to be very 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 resources continue to look appropriate for the size of the project.

Reviewer 2:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the milestones in a timely fashion.

Reviewer 3:

Looking back, the reviewer commented that maybe more resources could have been devoted to the aftertreatment system evaluation (understanding that it is not the main focus here).

Reviewer 4:

The reviewer stated that the team needed to overspend this past year, although it was not clear what the exact reasons were for this overspending. More details would be needed to determine whether an increase in funding would be appropriate.

Reviewer 5:

The project should have resources to complete the work, but t the reviewer was not sure if the project can achieve the engine 55% BTE goal with the current resources.

Reviewer 6:

The reviewer indicated that the project is 85% complete as of June 2021. Spending to date and the remaining budget were not clearly articulated; however, the project did not identify budget as an issue. The reviewer noted that much of the project rests on completing the build of the final demonstration vehicle, which may still be impacted by industry-wide COVID-19 supply chain related issues.

Presentation Number: ace101
Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency
Principal Investigator: Pascal Amar (Volvo Trucks North America)

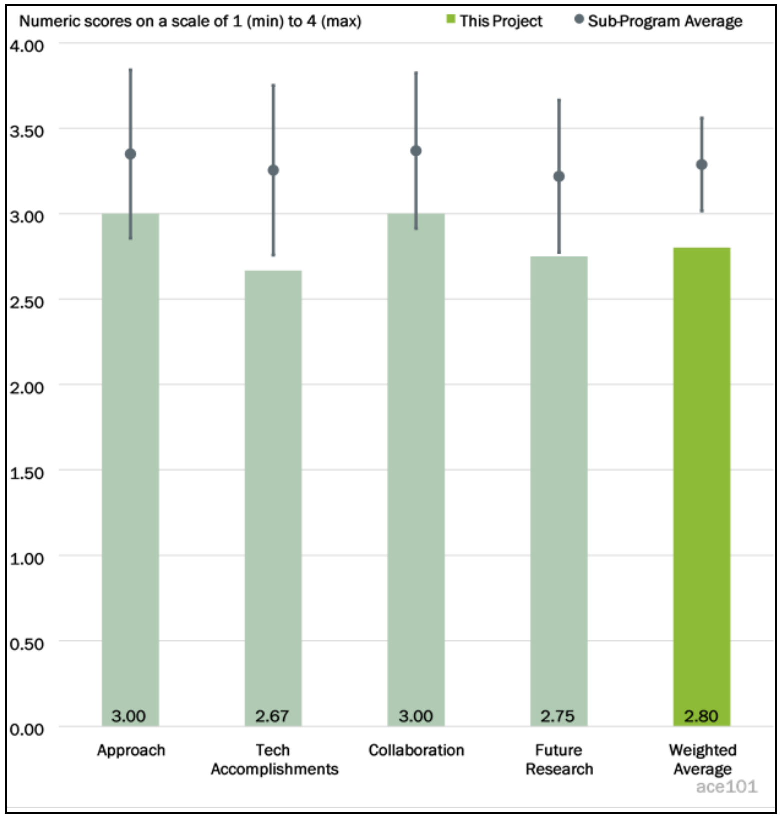


Figure 1-10 - Presentation Number: ace101 Presentation Title: Volvo SuperTruck 2: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America)

Presenter

Pascal Amar, Volvo Trucks North America

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the proposed approach appears to be satisfactory to conduct the planned body of research. Investigators have done a good job managing simulation, bench testing, and engine test portions of work consistent with typical OEM product development.

Reviewer 2:

The reviewer stated all aspects of the project are covered by the approach.

Reviewer 3:

The approach is comprehensively described at a high level, but it was difficult for the reviewer to determine if the details are well designed for a project of this scale in a short presentation.

Reviewer 4:

The reviewer stated the project is well planned and expects it will be completed, given it is near the end. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 5:

According to the reviewer, the overall approach to the project has been executed well, dealing with impacts from COVID-19 supply chain and workplace related challenges. However, fundamental project configuration decisions have not been adequately explained. The fundamental assumption that a MY 2009 6×4 tractor capable of 80,000 pound (lb) gross vehicle weight rating (GVWR) can be replaced with a 4×2 tractor tuned to 65,000 lb GVWR remains questionable for fleets that carry a range of payloads on a daily basis. The project has not supported this decision in AMR review material. The reviewer indicated that this base assumption also has implications for residual value of the vehicle, which is a key factor in total cost of ownership (TCO) of fleet technology choices and a commercialization concern relevant to the project deliverables. Providing a comparison to a MY 2009 4x2 would make sense and/or comparison of a SuperTruck 2 6x4 configuration to a MY 2009 6x4. further confusion results from an inadequate discussion of 11 liter (L) versus 13 L engine aspects of the project. Since the project team stated the truck has designed for 6x2 and 6x4, at least some analysis of apples-to-apples comparison to the MY 2009 baseline 6x4 should be included in future review. These factors reflect on the project design and feasibility.

Reviewer 6:

Approaches taken for engine and vehicles have a few debatable flaws. The reviewer asserted that the 4x2 axle for a Class 8 vehicle is highly questionable for real-world applications due to the lack of traction and load distribution. The reviewer said that issues should be addressed. Regarding the engine, the reviewer wanted to know why two different engine platforms would be used for the vehicle and engine project separately. More specifically, a 13 L engine is being used for the engine development, targeting 55% BTE, while an 11 L engine is being used for vehicle development. Due to the engine size and displacement, whatever is being developed on the 13 L engine would not be directly applicable to the 11 L engine. The reviewer commented there is a strong disconnect between the engine and vehicle development.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the technical progress and achievements to date are very impressive and show that the goals will likely be met. The “simulated - validation pending” items shown on Slide 10 (notably WHR) are a concern as these account for 5% BTE improvements, and it remains to be seen how much is actually achieved on the engine.

Regarding aftertreatment, it would be very valuable if a clear indication were given whether the electrically heated catalyst (EHC) is needed or not (for future regulations) and especially relevant to this project. The reviewer inquired about the fuel penalty.

Reviewer 2:

The reviewer stated the technical accomplishments look very good. Even with the explanation in the backup slides, it is still not clear on the Slide 10 bar charts what is accomplished going from the 11 L to the 13 L engine toward the 55% BTE goal. It would also be helpful if each bar of BTE gain were more explicit as to where those percentages came from in the list of technologies along the x-axis. The reviewer asserted that the 23:1 compression ratio (CR) seems really high for a turbocharged engine to stay under the peak cylinder pressure (PCP) limit of 250 bar, and it is likely absorbing much of the friction reduction from the liner friction reduction effort. Some additional explanation of this would be helpful.

Reviewer 3:

The reviewer commented the project presented again the project 55% BTE engine is a 13 L, but the demonstration vehicle is an 11 L engine. The presenter confirmed this is a slide responding to 2020 reviewer comments. While an efficiency waterfall chart was shown for the engine, none was shown for the entire vehicle, so reviewers were unable to assess state of contributions by system versus plan or actuals toward the 120% freight-ton efficiency (FTE) goal.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

The current status of the engine BTE was still not clear to this reviewer. Although the roadmap presented in the progress slide—Validation of Powertrain Technologies—does provide a little sense of the progress, it did not give the reviewer any clear sense when combining the simulation with validated results in the same graphic.

A similar observation can be applied to vehicle progress as there are essentially no tangible achievements that can be assessed. For example, a 15% weight reduction in the trailer was mentioned. This 15% value lacks meaning if no baseline value is provided.

Reviewer 6:

Progress on this project is incredibly disappointing for a project so far along in its planned timeline. Actual demonstrated success (particularly on the powertrain) has been very limited, according to the reviewer. To date, the investigators have only demonstrated 48%-49% BTE on the engine. There are production engines for sale with higher BTE. Another 1%-2% improvement in BTE has only been demonstrated on bench tests, and the remaining 4%-5% BTE improvement exists simply in simulation at this time. The reviewer was not certain how the project will achieve the agreed upon milestones with the limited time remaining.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the project seems like a well-coordinated effort across teams.

Reviewer 2:

A good team has been assembled and has well-defined roles. The presentation obviously does not have contributions from all the members. The reviewer assumed that some of project members have completed their work in prior years; that would explain why there was no mention of prior work in this report.

Reviewer 3:

The reviewer noted that the project has coordinated and collaborated while impacted by COVID-19 supply chain and workplace challenges. There have been delays, forcing some serial activities to become parallel ones. The reviewer said the project tapped outside parties to evaluate cruise control usage by industry drivers to help tune the technology use in the SuperTruck 2 demonstrator. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an engine manufacturer, two fleets, a trailer manufacturer, a tire manufacturer, one DOE national laboratory, one major university, an industry group, and several major technology suppliers. The reviewer opined that the team has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 4:

Collaboration across the development team seemed limited to the reviewer and is likely responsible for some of the developmental delays encountered.

Reviewer 5:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

Reviewer 6:

It was not clear to the reviewer throughout the entire presentation how the individual team members help the project, although there is a slide to show the team members and their responsibilities. It would be clearer if each team member logo or something can be inserted into each of the progress slides.

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 state project ended.

Reviewer 1:

The reviewer stated that the project is nearly done.

Reviewer 2:

The reviewer commented that the vehicle demonstration and engine BTE demonstration are scheduled to complete the project.

Reviewer 3:

The reviewer said there has been limited future research proposed to ensure continued development of efficient and clean internal combustion transport.

Reviewer 4:

The reviewer remarked that the proposed research is summarized in one bullet—perhaps indicative of the fact the project is in the last phase—but it would be good to see some more granularity on the next steps. It would also be good to include criteria pollutant measurements in the final demonstration.

Reviewer 5:

The reviewer said progress toward the 55% BTE engine appears on track for completion by the end of FY 2021, but the demonstration is not slated until the end of the project in parallel with the complete demonstrator vehicle, likely due to the 8-month slip in engine delivery to the project. This slip represents some risk that the engine in the demonstration vehicle does not meet engine tests cell performance project objectives, or that changes coming out of the engine testing will necessitate vehicle changes mid-stream in validation testing. The reviewer indicated that these risks may impact validation test schedules and/or budgets. Some contingency planning may be needed if road testing needs to be repeated due to unexpected configuration changes to the engine. The reviewer noted that an approved project slip into FY 2022 would permit a more sequential validation of the engine in the test cell, then validation of the completed vehicle with the engine. It would also permit validation of the 11 L engine in the test cell in addition to the 13 L engine because the demonstrator is slated for the 11 L engine.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 6:

The reviewer stated the proposed future research is over-simplified with just a few sentences that do not address the technical issues faced to achieve the project goal, specifically on the engine side.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the project clearly contributes to the increased energy efficiency of on-road freight movement and therefore meets the DOE objectives.

Reviewer 2:

The reviewer said the project focuses on improving transportation energy efficiency.

Reviewer 3:

The reviewer stated the project's objectives are clearly relevant to improving the fuel economy of the HD fleet.

Reviewer 4:

The reviewer commented that the project supports the overall DOE objectives.

Reviewer 5:

The reviewer noted that the project supports the overall DOE objectives of improved engine and vehicle performance and fuel economy.

Reviewer 6:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

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

Reviewer 1:

Resources looked sufficient to the reviewer.

Reviewer 2:

No funding issues were brought up in the presentation, so the reviewer assumed that funding is good, in spite of COVID-19.

Reviewer 3:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer stated the project reports 80% complete as of June 2021. Spending to date and the remaining budget were not clearly articulated; however, the project did not identify budget as an issue. The reviewer stated much of the project rests on completing the build of the final demonstration vehicle and parallel engine validation, which may still be impacted by industry-wide COVID-19 supply chain related issues or unforeseen technical challenges. The project team requested a schedule extension due to COVID-19-related schedule slips; this may have budget impacts on labor, where expedited fabrication and shipping or prioritization of facilities must be funded.

Reviewer 5:

Based on the success achieved to date relative to the funding level provided, the reviewer felt that the resources provided to the project team are too great for the results demonstrated.

Reviewer 6:

The reviewer wished that the rating included one more between sufficient and insufficient. It is not clear whether the project will have enough resources to achieve the engine BTE goal, given the way it was presented by the current form. The reviewer stated the contractor should be more transparent on the progress.

Presentation Number: ace102
Presentation Title: Cummins-Peterbilt SuperTruck 2
Principal Investigator: Jon Dickson (Cummins-Peterbilt)

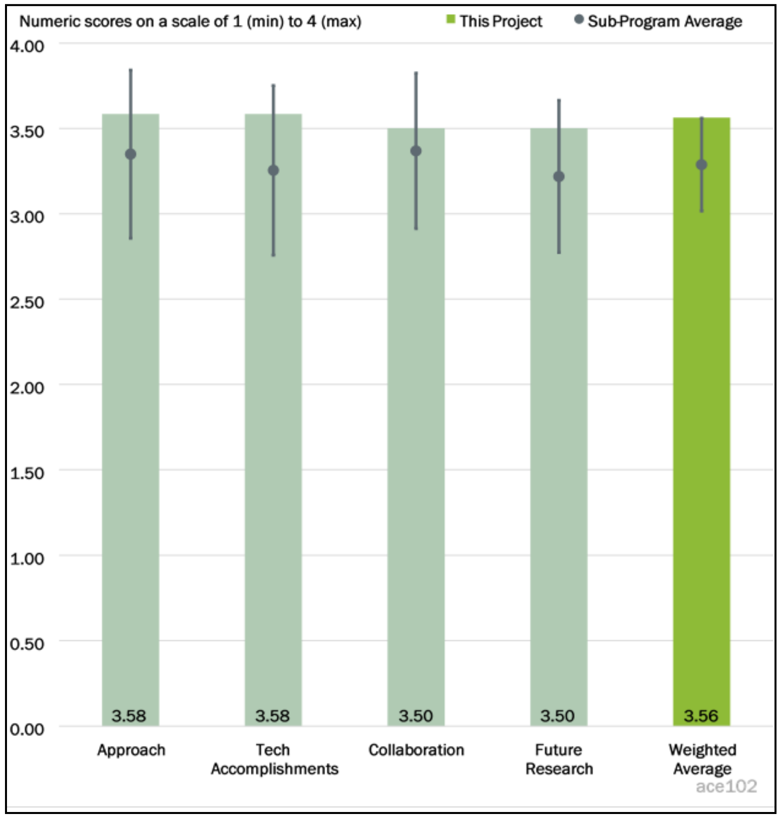


Figure 1-11 - Presentation Number: ace102 Presentation Title: Cummins-Peterbilt SuperTruck 2 Principal Investigator: Jon Dickson (Cummins-Peterbilt)

Presenter

Jon Dickson, Cummins-Peterbilt

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that Cummins achieved 55% BTE on its engine and addressed other project goals very well. Using a Walmart-simulated route is a great idea to demonstrate the improvements on a practical and important fleet.

Reviewer 2:

The reviewer stated Cummins/Peterbilt team has an excellent and thorough approach to the SuperTruck project goals and called the work well done.

Reviewer 3:

The reviewer said the project reports being on track toward validating the 55% BTE engine goal in early 2021 and on track to greatly exceed the original DOE 100% FTE target estimated now at exceeding 170%. The overall project management was the only team proactively stating to DOE that COVID-19 would impact project schedules at the AMR 2020 review and took steps to responsibly extend the project. The vehicle design shows significant innovation across a range of technologies, for example, using active aerodynamic systems such as the variable extender device for yaw conditions and the lightweight hybrid material chassis. The project has effectively employed analysis and early prototype mule and bucks to expedite validating project assumptions and integrating hardware and software systems. The reviewer said engaging the National Renewable Energy Laboratory (NREL) to obtain and analyze 56 Walmart routes with real vehicles and loads for use in designing the SuperTruck 2 demonstrator and choosing a representative test route spoke to the project's confidence level and project and team integration maturity.

Reviewer 4:

The reviewer opined that the project has been very well defined and, more importantly, very well executed. All technical approaches taken were very well justified and represent beyond SOA technologies.

Reviewer 5:

The reviewer commented that the project is well-planned and expects that it will be completed, given it is near the end. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that meeting 55% BTE on its most advanced engine platform is a great achievement. The project will also be on the way to overachieving the vehicle performance goal well beyond the minimum 125%.

Reviewer 2:

The reviewer thanked the project team for the nice summary of vehicle-level accomplishments on Slide 10 and Slide 21, as well as the additional information in the "Reviewer Only" slides. That additional information was very helpful to see the full depth of accomplishments the team made. The reviewer stated well done.

Reviewer 3:

The reviewer praised the great progress in achieving 55% BTE. The reliance on WHR for more than 4% improvement is a bit concerning, not for this project but overall. The reviewer inquired about what the economics of WHR are and whether the team is running out of levers if WHR is not used.

Unlike other teams, the reviewer noted that there seems very little emphasis on aftertreatment system, and while that is not the focus here, it would be good to understand the thoughts on how cc-SCR or other advanced components are expected to impact the solutions in this project.

Finally, the reviewer indicated that all eyes are on the final fleet demonstration.

Reviewer 4:

The reviewer remarked the project achieved a 55% BTE in early 2021. NREL's collecting and analyzing duty cycle data for 56 Walmart actual routes and loads is a significant accomplishment and deliverable on its own as this level of current granularity is needed for understanding freight system optimization. Hardware design for the entire vehicle is largely complete. The reviewer noted that tare weight reduction goals have been exceeded without compromising GVWR. Rolling resistance targets have been exceeded. Technology commercialization is demonstrated as impacting near-term product designs. The reviewer said key long lead components have been procured or are in process to support vehicle completion at the end of 2021.

Reviewer 5:

The reviewer stated that, in the past few years, a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments has been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency. The reviewer stated the project was weak on evidence.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that there was great collaboration.

Reviewer 2:

The reviewer stated the number of partners and suppliers involved in the vehicle looks quite extensive. This project has a strong team with excellent leadership.

Reviewer 3:

The reviewer remarked that the project has effectively coordinated activities between participants during a challenging industry period dealing with COVID-19 supply chain and workplace issues. The team assembled is representative of appropriate expertise groups, including a tractor manufacturer, an independent engine manufacturer, a fleet, a trailer manufacturer, a tire company, a DOE national laboratory, and multiple Tier 1 and Tier 2 suppliers. The reviewer said the project has effectively made use of available testing assets for virtual, bench, test cell, track, and road testing.

Reviewer 4:

The reviewer asserted that collaboration with all team members is amazing, which is one of the major reasons that the team has achieved the project goals so aggressively and early.

Reviewer 5:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. There should be more effort on fleet and other engagements in these 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the future research and remaining work are all very defined, which shows that the team is on the way to achieve all the project goals.

Reviewer 2:

The reviewer reported that it was very good to see the cost and payback model included in the future research.

Reviewer 3:

Completing the vehicle demonstration looked to be well on track to the reviewer.

Reviewer 4:

The reviewer stated the project is nearing completion.

Reviewer 5:

The reviewer said the project scope and deliverables in the remaining work are significantly beyond the original DOE targets. The total system effectiveness depends on final completion of the vehicle build in 2021, then adequate testing in 2022. The project steps to this end appeared organized and coordinated to the reviewer. Confidence with total vehicle integration is due to interim use of mule and bucks to identify and resolve issues prior to final design and build.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, project support is very relevant to reducing fuel consumption in the HD transportation sector.

Reviewer 2:

The reviewer stated improvement in vehicle efficiency to reduce the energy needed to move U.S. cargo over the road meets the DOE program objectives.

Reviewer 3:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 4:

The reviewer commented that the project absolutely supported overall DOE objectives by substantially improving the engine and vehicle performance and fuel saving.

Reviewer 5:

The reviewer stated the project supported the overall DOE objectives very well.

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

Reviewer 1:

Resources looked sufficient to the reviewer.

Reviewer 2:

All looked to the reviewer to be on track with the original budget.

Reviewer 3:

The reviewer affirmed that, yes, resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer stated the project has all the resources needed to achieve the project goals.

Reviewer 5:

The reviewer remarked that this project stated in the AMR 2020 review that COVID-19 would impact the schedule significantly. The project maintained some level of progress on long lead supplier parts during this period, while project direct resources at Peterbilt were not charging to the project. The reviewer indicated that that seems to have preserved the project labor budget while keeping some progress on hardware going. Schedule impacts do not appear to have thus impacted the project budget, as the project reports it is 85% complete and spend to date is 94% of budget. The reviewer said the project is stretching into FY 2022, so there is some risk of labor overrun or hardware overrun if testing encounters any failures or issues.

Presentation Number: ace103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck
Principal Investigator: Russell Zukouski (Navistar)

Presenter

Russell Zukouski, Navistar

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

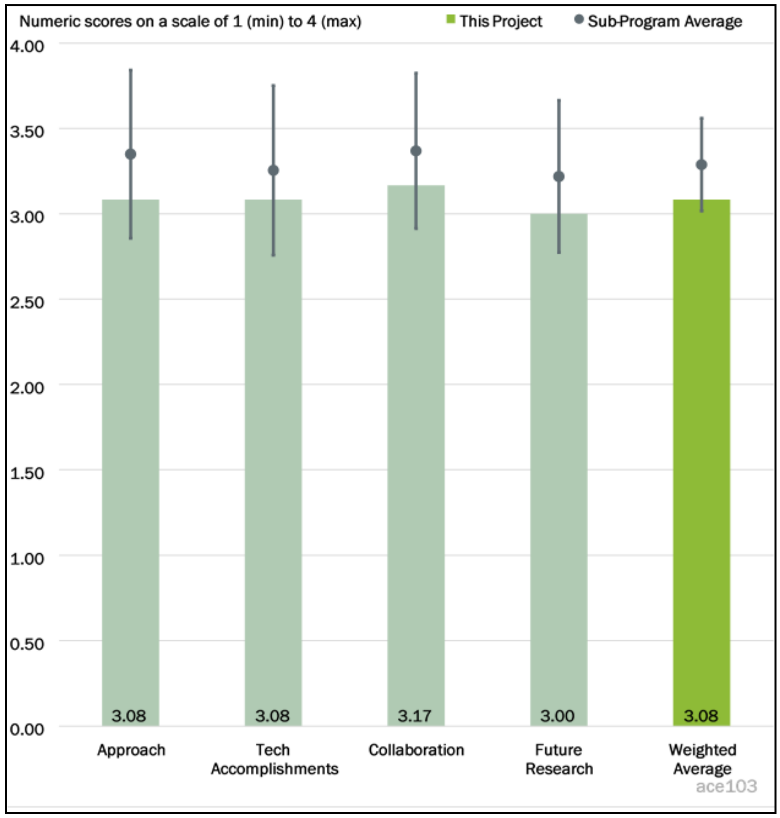


Figure 1-12 - Presentation Number: ace103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach examines all the key subsystems of the vehicle including engine, powertrain architecture, vehicle attributes of weight and aerodynamics, the trailer, and operations like cruise control. The reviewer noted innovative attempts to improve the engine with fuel injection, air management, and cylinder deactivation. There was a good effort on emission controls.

Reviewer 2:

The reviewer found a very good overall approach, touching on all aspects of the project and also considering the aftertreatment system (Slide 8) for low NO_x.

Reviewer 3:

The reviewer said the project is well planned and, given it is near the end, expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 4:

The reviewer remarked that the overall approach to the project demonstrated a systems' engineering approach by looking at multiple solutions, evaluating opportunities and challenges, then down-selecting to address maturity, cost, risk, and other competing factors. The use of composite materials instead of aluminum or steel has a mixed history with HD trucks due to cost and durability factors. The reviewer also said evaluating sourcing sustainable wood-based products and recycling ramifications of foam core-based products should be discussed in the next review as potential challenges to commercialization and TCO of these weight-saving concepts.

Reviewer 5:

The reviewer stated that the roadmap for the vehicle seems to have all the important technologies to achieve the vehicle performance goal.

It is programmatically correct to drop the gasoline compression ignition (GCI) engine project, which should have happened earlier, since this part of the project had no chance to meet the project goal. The reviewer, however, was not convinced that the approach taken has all the technology pieces to achieve the engine project goal at 55% BTE. The resources taken on cylinder deactivation and aftertreatment improvement on cold start do not have anything to do with 55% BTE, which is a single point at high loads.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the Navistar team made excellent progress in tractor and trailer lightweighting, the hybrid system seems on target, and there is innovation and progress in the ladder frame. The engine and WHR improvement are still in progress, but the effort is probably better focused by ending the GCI investigation. The reviewer said it will be interesting to see the impacts of cylinder deactivation.

Reviewer 2:

The reviewer found very good progress so far. It will be good to see the WHR improvements with the final specifications being achieved on the engine, given that it contributes more than 3 BTE points. It would be good to understand the cost-benefit considerations of WHR since all teams seem to need this capability, but also it is the one technology that has not yet been fully demonstrated and seems challenging.

The reviewer asserted that emphasis on the aftertreatment system is very good, as is the evaluation of more than one configuration including EHC. The reviewer asked the project team to please analyze the fuel penalty of EHC in future work.

Reviewer 3:

The reviewer said the technical accomplishments of the project are tied to completing the demonstrator vehicle and adequate validation testing. To date, the hardware, software, and design appear to be on track to supporting this goal. The reviewer commented that the system approach to the design added a hybrid system, which impacted vehicle weight, but was compensated for by improved energy efficiency.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

Lack of tangible improvements on the engine and vehicle make it hard for the reviewers to assess the project progress. It seems to point out that the engine may have trouble meeting the 55% BTE goal. It seemed to the reviewer that the project has cancelled one of the major project developments on gasoline engines during this year compared to last year, or no progress has been made. The project should report the status of this progress regardless.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The total team is very large (for the better), providing inputs in technology, testing, and analysis. The reviewer noted that the team, including suppliers and various contributors, is actually larger than the list shown on the summary slide.

Reviewer 2:

The reviewer emphatically stated that the project is well-collaborated.

Reviewer 3:

It seemed to the reviewer that each key team member plays a role in helping to develop this project.

Reviewer 4:

The reviewer stated there seems to be little evidence to the claims made concerning industry engagement outside the specific partners that are funded. There should be more effort on fleet and other engagements in these projects.

Reviewer 5:

The reviewer said the project assembled an expert team of collaborators, including university, fleet, national laboratory, tractor manufacturer, trailer manufacturer, engine supplier, and multiple Tier 1 and Tier 2 suppliers. The team effectively made use of virtual analysis, bench, test cell, and track and road testing in gaining confidence for the final demonstrator design. A concern for the reviewer was the level of participation of real-world fleet information. The project seems to be relying extensively on established internal duty-cycle information from historical projects. As the market has significantly been evolving in recent years with e-commerce, growth in third-party logistics companies (3PLs), reaction to supply chain shortages, etc., the reviewer opined that this project provides the OEM with an opportunity to validate market assumptions and duty cycles rather than just making use of existing historical data.

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 state project ended.

Reviewer 1:

The reviewer stated the project is nearing completion.

Reviewer 2:

The reviewer said there are indeed some remaining challenges and targets to be met. These challenges were clearly described and reviewed in the presentation.

Reviewer 3:

The reviewer asserted that the future work has not been spelled out separately, although some indications are given on individual slides. It will be good to understand with more clarity what remains to be done and by when. The reviewer stated it will be good to include the impact of advanced aftertreatment systems on the fuel penalty.

Reviewer 4:

In spite of delays due to COVID-19 supply chain and workplace challenges, the reviewer remarked that the path to completion appears to be on track. Some technical elements are still being fine-tuned. The reviewer said the inclusion of ultra-low NO_X objectives is proactive for future commercialization viability. Future planning was not presented in sufficient detail to evaluate the remaining project milestones in Budget Period (BP) 5.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Reviewer 5:

The reviewer stated the proposed future research seems to be too vague, which does not provide the enough details to address the technical challenging to achieve the project goals, specifically for the engine.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated this project is very relevant to reducing fuel consumption from the transportation sector.

Reviewer 2:

The reviewer said the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up adopting zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

Reviewer 3:

The reviewer said this project supports the overall DOE objectives to improve engine and vehicle performance and fuel economy.

Reviewer 4:

The reviewer stated project supports the overall DOE objectives very well.

Reviewer 5:

The reviewer observed that the project directly supports reducing fuel petroleum use, reduced carbon emissions, and reduced criteria pollutants—these accomplishments are all part of DOEs mission. The freight sector continues to grow in its fuel use and carbon emissions due to more freight movement and vehicle-miles traveled (VMT). The reviewer said the projects for higher efficiency and low emissions should continue with high priority. Projects would be even stronger if they include paths to using low-carbon fuels.

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

Reviewer 1:

Resources looked sufficient and well used to the reviewer.

Reviewer 2:

The reviewer affirmed that, yes, resources are sufficient for the project to achieve the stated milestones.

Reviewer 3:

The reviewer said the SuperTruck 2 program has not enjoyed funding as large as SuperTruck 1; so, this project is on the low end of sufficient. Cost share by industry is a key enabler.

Reviewer 4:

The reviewer wished that the rating included one more rating between sufficient and insufficient. It appears the project should have enough resources to achieve the vehicle goal, but the reviewer was not certain if it has all it needs to achieve the engine goal of 55% BTE.

Reviewer 5:

The reviewer said the project reported 80% project complete as of June 2021. The project did not report spend-to-date against plan. The project did not identify budget as a significant challenge. The reviewer said the project is estimating completion by the end of 2021. Conflicting information was presented on the state of the demonstrator build, which in one schedule slide was ticked as more advanced (complete) than in the subsequent detailed slides and Q&A discussion with reviewers. The reviewer said this discrepancy may indicate some level of risk with maturity of designs or hardware availability with respect to the stated schedule completion. Extending the schedule has budget ramifications on labor and/or facility use.

Presentation Number: ace118
Presentation Title: Advanced Nitrogen Oxide Storage
Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

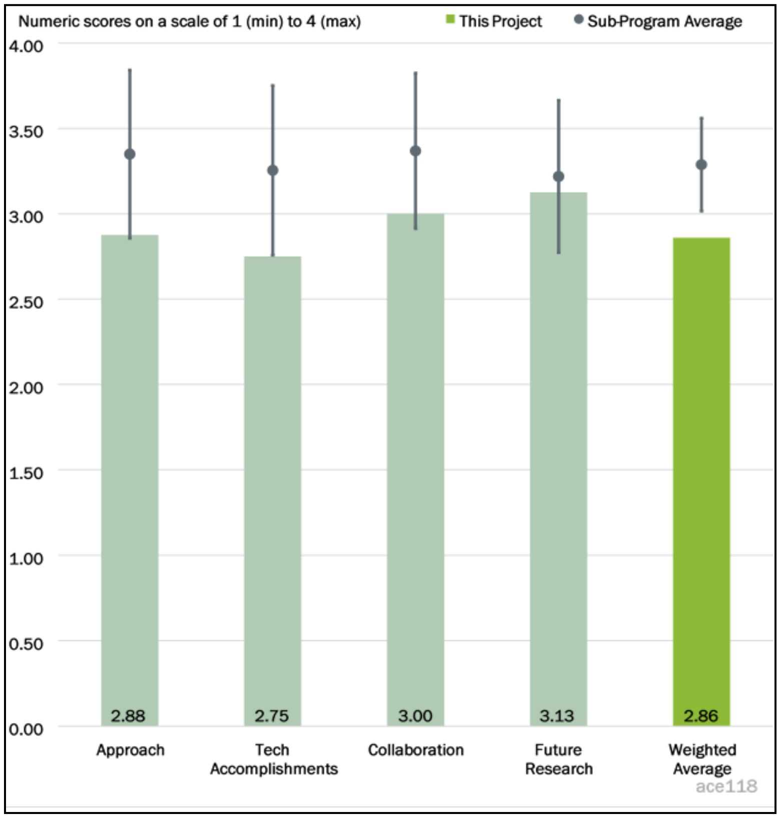


Figure 1-13 - Presentation Number: ace118 Presentation Title: Advanced Nitrogen Oxide Storage Principal Investigator: Janos Szanyi (Pacific Northwest National Laboratory)

Presenter

Janos Szanyi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that there is a good approach to leveraging core PNNL expertise in fundamental sciences (chemistry and catalytic materials) coupled with close collaboration with ORNL and industry BASF.

Reviewer 2:

According to the reviewer, the project makes good use of PNNL's strong characterization capabilities. It is good to see a non-Pd based approach being explored with the rubidium (Rb) work.

Reviewer 3:

With the stated application being a TWC for stoichiometric gasoline vehicles, the reviewer opined that the NO_x storage catalysts need to be aged and evaluated under simulated gasoline exhaust conditions (see the low-temperature aftertreatment [LTAT] protocol published by CLEERS). So far, only results relevant to diesel applications (lean aging and testing conditions) have been presented. The reviewer also stated that a well-known deactivation mechanism for PNA (Pd/zeolite) is exposure to rich feed (CO, etc.), and it should be examined if the PI intends to study the PNA deactivation mechanism.

Reviewer 4:

The reviewer saw that a previous reviewer said this project “seems like a report on making a few varieties of PNA… but it is not focused on understanding.” The reviewer generally agreed with this statement. While the technical aspect of the project is very strong, it appears to be an assortment of different projects tackling different problems without tying together any fundamental understanding to come up with just one PNA. Again, the fundamental work is very good, but the reviewer struggled to see a clear approach forward. Considering the rising costs of Pd and the slides on Ru/CeO_2, the reviewer wanted to know if the work is moving away from Pd and toward Ru. For the Ru work, the reviewer was worried about its stability, despite the 10 cycles of stability shown in one slide. In one of the slides using Pd, the project team mentioned going to 30 cycles; the reviewer, was interested in seeing more cycles performed after higher temperature aging. The reviewer did not believe that aging to 750°C is sufficient and asked what happens when these are aged to temperatures of around 900°C. The reviewer would also like to have seen how these PNAs react to poisoning, as well as more fundamental, experimental, and in-situ understanding of the adsorption mechanism on the Ru/CeO_2.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said good technical progress was made on improving hydrothermal stability and performance, as well as understanding active sites.

Reviewer 2:

Everything appeared to the to be proceeding on schedule. The increased resistance to hydrothermal aging and exploration of non-Pd materials is encouraging.

Reviewer 3:

The reviewer said NO_x storage results obtained after diesel (hydrothermal) aging and evaluated under lean conditions may not be relevant for their performance under stoichiometric exhaust conditions. Hence, it was not clear to the reviewer whether the evaluated NO_x storage catalysts could be useful for the stated gasoline applications. No result was presented for these catalysts under stoichiometric test conditions.

Reviewer 4:

The reviewer indicated that part of the issue is that the goals appear to be changing. Will a key milestone remain the understanding of the mechanism on Pd/ferrierite (FER)? If so, the reviewer saw degradation of the PNA after 30 cycles, but did not necessarily see a mechanistic understanding of how or why. If the goals shift to an understanding of Ru/CeO_2, then the reviewer thought that there is more significant progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaborators include ORNL (sample exchange for performance verification), Sofia University (DTF calculations), BASF (industry input), and Carus (input on reactive NO_x storage).

Reviewer 2:

According to the reviewer, collaborators span a good cross section of national laboratories, industry, and academia. The most evident collaborative effort appears to be with the computational team at Sofia University. The reviewer said most of the work is concentrated at PNNL.

Reviewer 3:

The reviewer stated leveraging ORNL and BASF expertise is helpful as both have extensive experience with gasoline TWC catalysts. They can also provide assistance on relevant catalyst aging and test conditions.

Reviewer 4:

While the reviewer could understand the collaboration between PNNL and ORNL, the reviewer did not understand how there is collaboration with BASF. The reviewer wanted to know what BASF provides besides samples and input on industrial feasibility?

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 state project ended.

Reviewer 1:

The proposed future work appeared reasonable and well planned to the reviewer, but there is no indication that decision points or any risk mitigation strategies have been implemented.

Reviewer 2:

The reviewer stated it is good the team plans to evaluate the Ru catalyst under stoichiometric conditions, and it is critical that a proper aging protocol is also used to address gasoline applications. The last bullet point in the Proposed Future Work "Understand the potential interference and interactions with DOC etc." was not clear to the reviewer, who asserted that the team should be clear about the targeted application (gasoline or diesel) and use the proper conditions to generate relevant results.

Reviewer 3:

The reviewer commented that four future work activities as presented are appropriate for completing the remaining two milestones in FY 2021. This work was presented as a core R&D project for PNNL, but only for a single fiscal year. It was unclear to the reviewer if the work was funded under a DOE VTO lab call (typically a 3-year effort), if the scope is determined on a year-to-year basis, or if it is part of another PNNL project. More clarity on what shapes this work for future years would be helpful.

Reviewer 4:

The reviewer believed that pivoting to focus on Ru/CeO_2 is an excellent idea but remained skeptical about the stability of the Ru atoms after aging at 900+°C. The reviewer agreed with the need to understand all fundamental mechanisms, as well as the need to study the effect of different poisons.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the work on passive NO_x adsorption is one possible pathway to address the 150°CC challenge.

Reviewer 2:

The reviewer remarked that achieving greater than 90% conversion of criteria pollutants at 150℃ is required to achieving the U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30 emission standard. This temperature requirement in turn allows increasing the efficiency of ICEs, which decreases dependence on foreign oil and reduces carbon emissions.

Reviewer 3:

The reviewer was not sure about the targeted application. Even though a TWC for gasoline applications was stated in the milestone, all the data presented so far are related to diesel applications.

Reviewer 4:

While the project does address the 150°C challenge that was posed years ago, the reviewer feared that the industrial need for PNAs has waned. With the rising costs of Pd; the lack of understanding of the multiple activation, deactivation, and degeneration-regeneration mechanisms; and the heavy influence of poisons on PNAs, the reviewer was concerned that the near future of PNAs in the automotive industry is in jeopardy unless there a radical new innovation in the field.

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 is part of ongoing core R&D under CLEERS at PNNL funded at $400,000 per year.

Reviewer 2:

The reviewer stated the resources are sufficient for the project to achieve the stated milestones.

Reviewer 3:

Funding appeared to be adequate to the reviewer for this undertaking. The team and facilities are also well= suited to the work.

Reviewer 4:

The reviewer believed that the fundamental work performed in this project has been very impressive. However, due to the lack of prevalence of PNAs in the industry, the reviewer feared that the work is slowly becoming irrelevant.

Presentation Number: ace119
Presentation Title: Advanced Multi-Functional Diesel Particulate Filters (Deer and Company)
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

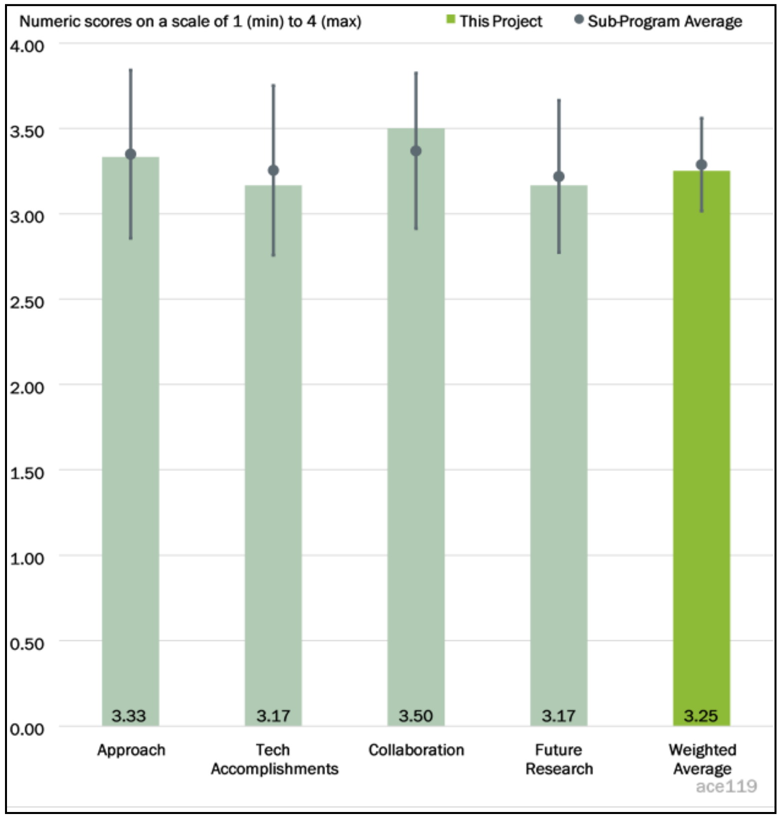


Figure 1-14 - Presentation Number: ace119 Presentation Title: Advanced Multi-Functional Diesel Particulate Filters (Deer and Company) Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found this to be appropriately near-term focused work for a 1-year CRADA project on a highly promising strategy of aftertreatment integration for cost reduction. It was a well-thought-out approach, starting with a literature review, followed by field-aged and accelerated testing to obtain characterization data for a DOC on a DPF (DOCF) to support model development.

Reviewer 2:

The reviewer stated the integrated DOCF concept has several potential benefits (compact volume, lower cost, etc.); however, it may also present some unique challenges. The catalyst washcoat and ash distribution in the device are clearly information factors, and they are adequately addressed in the project approach. The reviewer stated it will be helpful to also evaluate the effect of soot on the oxidation activities for both hydrocarbon and NO_x.

Reviewer 3:

The overall approach is good, though it was somewhat difficult for the reviewer to see the end application. Is the goal simply to develop and validate a DOCF model? The reviewer said it would be helpful to see some comparison to other systems, such as DOC + DPF + SCR or DOC + selective catalytic reduction on filter (SCRF) in order to assess the benefit of moving to DOCF.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said good progress has been made in this relatively short project. The first milestone has been met (characterization of ash distribution in DOCF), and the second one is 60% complete (spatially resolved capillary inlet mass spectroscopy [SpaciMS] for DOCF), with some delay due to COVID-19 pandemic (laboratory access and vendor availability).

Reviewer 2:

The reviewer stated there is good progress overall. The performance results are limited to modeling so far, and it will be beneficial to show the experimental data (if available) for model comparison. In particular, HC-NO light-off test results (with and without soot) are useful information to assess the efficiency of this integrated concept for filter regeneration and SCR deNO_x performance.

Reviewer 3:

Overall progress appeared to be on track to the reviewer. The delays due to COVID-19 are understandable, but unfortunate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the project is a good example of a short-term (1-year) industry CRADA that involves John Deere and Kymanetics.

Reviewer 2:

The reviewer stated there is good team collaboration with complementary capabilities.

Reviewer 3:

Collaboration partners are strong, but it was somewhat difficult for the reviewer to assess their levels of effort. Are there regularly scheduled meetings and/or 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project was a single-year CRADA that is 95% complete. Future research is appropriately focused on near-term completion of remaining tasking (X-ray computerized tomography [CT] data, parameterization study, and SpaciMS assembly).

Reviewer 2:

The reviewer referred to earlier comments along with saying that there is a good plan to have experimental data to validate the developed model.

Reviewer 3:

The proposed future work appeared reasonable to the reviewer, though there is no evidence using decision points or risk mitigation strategies. The reviewer wanted to know how the impact of aging is going to be studied and whether the impact of aging will add significant experimental scope to the project?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project supports the overall DOE objectives as it provides data and models to better understand the potential of DOCF as a promising strategy of aftertreatment integration that can reduce cost and space requirements on vehicles, reduce PGM use, and improve system responsiveness.

Reviewer 2:

According to the reviewer, the work supports the overall DOE goals through potential reduction in the cost and size of diesel aftertreatment systems.

Reviewer 3:

The reviewer commented that the project supports the overall DOE objectives of reducing emissions and improving fuel efficiency. The reviewer asked if this concept is uniquely suited to HD applications or if the device could also be applicable to light-duty (LD) vehicles too.

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 $200,000 of DOE funding with an 50% industry cost share was well spent on a 1-year CRADA project that investigated DOCF.

Reviewer 2:

The reviewer stated the resources were sufficient as indicated by the project team.

Reviewer 3:

Financial resources appeared to be adequate to the reviewer, and the team is well suited to do the work.

Presentation Number: ace124
Presentation Title: SuperTruck 2 - PACCAR
Principal Investigator: Maarten Meijer (PACCAR)

Presenter

Maarten Meijer, PACCAR

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

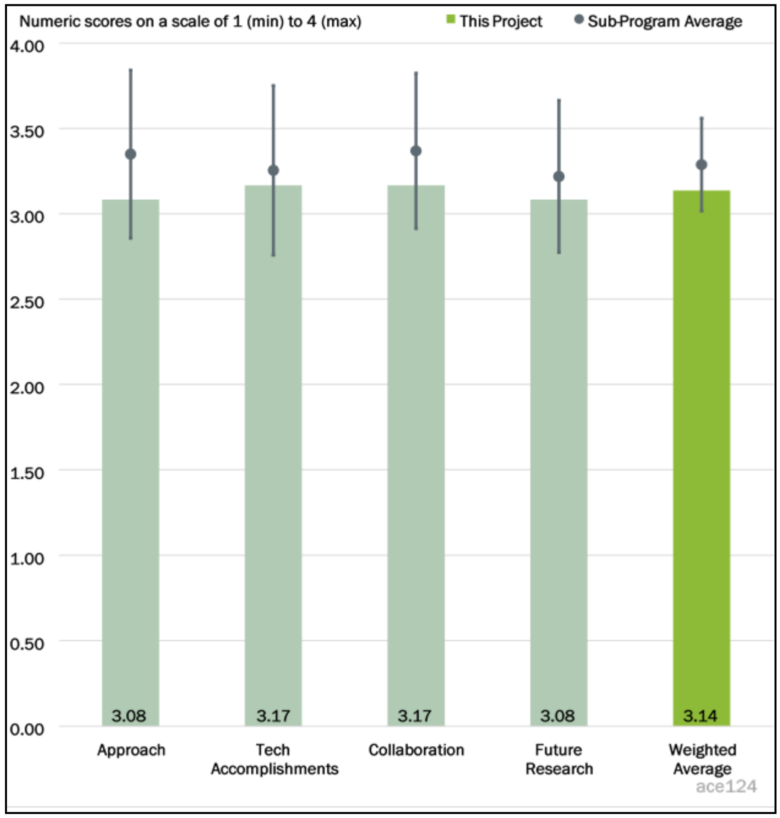


Figure 1-15 - Presentation Number: ace124 Presentation Title: SuperTruck 2 - PACCAR Principal Investigator: Maarten Meijer (PACCAR)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the approach to freight efficiency goals is very comprehensive across the engine, powertrain, and vehicle. It was a good use of electrification and some innovation in WHR and an impressive reduction in aerodynamic drag and weight. It will be interesting to see engine efficiency numbers through the long stroke.

Reviewer 2:

The reviewer said the project team reports that it is 75% complete as of June 2021; the project started 1 year later than the other SuperTruck 2 project teams. The project team is in the process of requesting a project extension due to COVID-19 challenges and stated that BP 3 extended 9 months. According to the reviewer, the team has an excellent systems approach to achieving project goals, with contributions from many systems, including an all-new non-conventional cab. The project has a path-to-target that greatly exceeds the original DOE objectives for the vehicle FTE improvement, now forecasted at 175% improvement. The reviewer found that the project team has effectively used team assets, such as virtual simulation, hardware-in-the-loop (HIL), test cells, track and engineering prototype mule to validate assumptions, and decisions for the demonstrator vehicle design, which reduced project risk. The team appears to have chosen a 4x2 configuration, which may limit its TCO, residual value, viability, and utility in the secondary market versus the baseline MY 2009 6x4 vehicle configuration.

Reviewer 3:

The reviewer stated the project is well planned and given it is near the end, expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 4:

Slide 7 indicated that 10% of the efficiency gain to reach 55% BTE was from friction reduction, but the reviewer did not see any mention of that variable in the presentation. If this was work done in previous AMR presentations, some supporting material in the backup slides for "reviewer only" would have been helpful as a refresher.

The reviewer said tackling the ultra-low NO_x in the project's engine demo and vehicle demo, are quite aggressive. The pathway to reach that goal was not detailed in the presentation, so the reviewer was hoping to see good things with that challenge next year.

Reviewer 5:

It seemed to the reviewer that the approach has most of the important elements to reach the projects goals; however, it is too early to tell or almost impossible to tell whether the approach taken can help the project achieve the engine project goal at 55% BTE, since there are no intermediate testing results to deduce the possibility. The project lacks a roadmap to see how the engine can achieve 55% BTE goal. It was hard for the reviewer to imagine that the engine can achieve the project goal at 55% BTE with one iteration of the new engine hardware, which sounds to be too optimistic, but not realistic. The vehicle has a fairly aggressive goal in achieving 175% improvement, but again, lack of a roadmap is a concern for how these technology building blocks can help the project to achieve this 175% goal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said good progress in spite of the COVID-19 situation. The description of the engine path needed more quantification of technology impacts. The reviewer noted good progress on electrification and chassis construction.

Reviewer 2:

The reviewer stated good technical progress is being made, but obviously at a slower rate with the 9-month COVID-19 related delay in BP 3. It will be interesting to see if the exploration of GCI for high efficiency and low NO_x works out, and it is good to see a SuperTruck 2 team explore some unique solutions.

It was not clear to the reviewer how much the team was going to rely on the exhaust aftertreatment (EAT) system to reach the ultra-low NO_x target. More information on that would be helpful.

Reviewer 3:

The reviewer asserted that the project has matured designs through analysis and prototype testing to achieve significant improvements. The project team reports tractor tare weight at 13,000 lb and trailer tare at 12,000 lb, representing significant reduction in tare weight while including all the new technologies. The reviewer said, however, the proposed demonstration vehicles appear to be a 4x2 configuration where the baseline MY 2009 would be a 6x4. The project team has not discussed at the AMR review the ramifications of tuning the vehicle to a 65,000 lb GVWR platform versus a baseline rated at 80,000 lb GVWR. The reviewer noted that aerodynamic improvement via CFD analysis shows a significant 60% improvement versus the MY 2009 baseline. Powertrain improvement has not yet been demonstrated for a 55% BTE but appears on track. Electrification of some accessory load is included in the design establishing a 48-volt (V) mild-hybrid system, including e-heating, ventilation, and air conditioning (HVAC) and e-steering.

Reviewer 4:

In the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently state that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Reviewer 5:

The reviewer reported that noticeable progress was made on the vehicle. Aerodynamic improvement seems to be coming along, with a total drag reduction of 60%. The reviewer said powertrain efficiency and weight reduction also provide the improved values. It would be helpful if absolute values can be provided to better assess progress of the project.

The reviewer said, however, there are no intermediate testing results on an integrated engine in terms of BTE, making it virtually impossible to assess whether the team is able to achieve the engine project goal of 55% BTE with one iteration of hardware development.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that PACCAR has assembled an impressive, large team. The roles and contributions are clearly presented.

Reviewer 2:

The reviewer stated the project has a good, diverse team, taking advantage of key industrial partners as well as universities and national laboratories.

Reviewer 3:

The reviewer commented there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed that there should be more effort on fleet and other engagements in these projects.

Reviewer 4:

The reviewer stated it would be helpful to show how each of the team members plays a specific role in helping the project succeed by inserting their names or logo on each technical progress slide.

Reviewer 5:

According to the reviewer, the project has assembled a qualified team of expertise, including a tractor manufacturer, a DOE national laboratory, two engine manufacturers, an engine technology company, two universities, and major Tier 1 and Tier 2 suppliers. The engagement of Cummins for WHR puts competing engine manufacturers on the same team, which should benefit the technology maturity for the demonstrator. The reviewer said fleet involvement was not itemized in the presentation material, either in the introductory partner slide or the later partnerships and collaboration slide. The presenters verbally discussed customer involvement in design development, but this exchange was not detailed in the presentation. The reviewer suggested that the next review should include details of fleet engagement.

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 state project ended.

Reviewer 1:

There are good plans to move from the mule vehicle demo to the final vehicle demo and to the engine high BTE demo next year. The reviewer emphatically stated that it will be interesting to see if the computational prediction of 175% freight efficiency improvement can be demonstrated.

Reviewer 2:

According to the reviewer, the project did an acceptable job planning its future work.

Reviewer 3:

The reviewer said there is much to be done to reach the project goals. The needed future work is clearly shown. The reviewer commented that the prime path for the engine is diesel based. If GCI research will continue, the team might consider showing carbon reduction (CO_2 per ton-mile) with a gasoline-like, low-carbon fuel in addition to BTE achieved.

Reviewer 4:

The reviewer indicated that the proposed research should provide a more detailed roadmap, specifically for the engine, to show what barriers need to be overcome to achieve the project goal. Again, at this level, there is no idea of whether this project can achieve the engine BTE goal, since there is no baseline established and no intermediate results demonstrated. This sounds like a high-risk project to the reviewer.

Reviewer 5:

The reviewer said the project is three-quarters complete per the presenter, and with an approved extension it may be complete as late as FY 2023. While the technical, hardware, and software appear to be on track to achieving targets, the completion level at 75% with perhaps an estimated 2 years remaining of scheduled work indicate a five to six-year project. A final demonstration vehicle planned validation test program was not discussed in any detail in the AMR 2021 review.

With respect to meeting project goals, the reviewer asserted that the stated improvement versus a MY 2009 tractor is not very relevant with respect to current commercial technology decisions by fleets or R&D budgeters. In the final review, the project team should also include an estimate and/or comparison of performance against a comparable current model year product because investment in SuperTruck 2 technologies is against current competing production products, not MY 2009 ones, which are several generations behind in emission levels and technical capability.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that R&D toward reduced energy consumption and emissions in the freight sector is in line with DOE objectives and national needs.

Reviewer 2:

According to the reviewer, increased efficiency in freight movement of goods in the United States is in line with DOE objectives.

Reviewer 3:

The reviewer said the project supported the overall DOE objectives very well.

Reviewer 4:

The reviewer remarked that the project supported the overall DOE objectives by improving vehicle freight efficiency and engine BTE.

Reviewer 5:

The reviewer found that the project is relevant to the DOE objectives of improving energy use efficiency in freight transportation. The administration and DOE focus is also on transitioning to net-zero emissions, but that transition requires improving diesels in parallel with ramping up the adoption of zero emission alternatives. The reviewer said research on improved aerodynamics to reduce drag, improved tire rolling resistance, weight reduction, advanced trailers, electrification of accessory systems, etc., are all directly applicable and critical to helping zero emission vehicles to success.

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 the project has been designed to fit a budget of reasonable size, with large industry cost-share.

Reviewer 2:

The reviewer asserted that the project team gave no indication that the 9-month COVID-19 delay impacted the cost of the project, so funds are assumed sufficient.

Reviewer 3:

The reviewer affirmed that, yes, the resources are sufficient for the project to achieve the stated milestones.

Reviewer 4:

The reviewer said the project should have adequate resources to achieve the vehicle goal, but was not certain for the engine, since no reference and no baseline can be assessed.

Reviewer 5:

The reviewer asserted that the project team did not present spend-to-date versus plan nor detail the impact to the budget of the requested project extension. The project did not identify budget as a major challenge or issue. According to the reviewer, insufficient detail was provided at the AMR 2021 to accurately assess adequacy of resources. The project extension may require additional funding for labor or to obtain prioritization of vehicle validation resources.

Presentation Number: ace128
Presentation Title: Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles
Principal Investigator: Michael Harold (University of Houston)

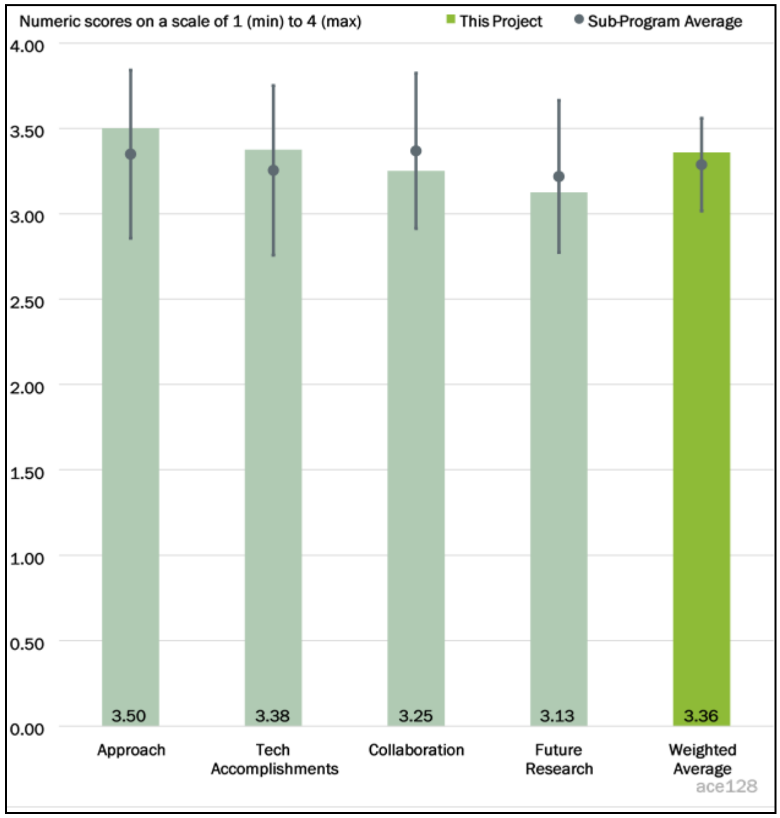


Figure 1-16 - Presentation Number: ace128 Presentation Title: Reduced Precious Metal Catalysts for Methane and Nitrogen Oxide Emission Control of Natural Gas Vehicles Principal Investigator: Michael Harold (University of Houston)

Presenter

Michael Harold, University of Houston

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to performing work is based on sound technical principles and includes a combination of experimental and simulation capabilities, according to the reviewer.

Reviewer 2:

The reviewer said the project seeks to develop a four-way catalyst that reduces methane emissions from natural gas engines in addition to NO_x, CO, and non-methane hydrocarbons (NMHCs) by combining a spinel catalyst layer below a PGM catalyst layer.

The approach was logical to the reviewer as it proceeds from synthesis and screening of catalyst formulation, mechanistic and kinematic modeling, flow reactor testing, reactor model development and validation, feed modulation, S effects evaluation, identification of best materials, and prototype testing on a natural gas engine.

Reviewer 3:

The reviewer opined that the approach includes a good mix of material selection, experimental stages, and kinetic considerations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the technical accomplishments and progress toward project goals to be excellent. Investigators are making sound progress with the experimental tasks and are able to effectively describe the experimental observations using simulation.

Reviewer 2:

According to the reviewer, the work appears to shed light on fundamentals of spinel impact along with H_2 formation and impact on methane (CH_4) oxidation. The accomplishments include insights on materials, kinetics, and modeling.

Reviewer 3:

The reviewer inquired whether this review is for BP 2 or BP 3? The slides show a BP 3 milestone, but the summary slide states that all BP 2 milestones have been achieved. A progress summary slide showing the project timeline and progress on meeting each milestone would help in evaluating project progress against budget period milestones and performance indicators. The reviewer found the organization of the presentation confusing as it pertains to the progress compared to milestones.

Progress includes an evaluation of $NiCo_2O_4$ spinel with results showing that adding CeO_2/ZrO_2 increases durability, spinel mitigates PGM S poisoning under certain conditions, and there is evidence of Fe migration to the PGM layer at high temperature. It appeared to the reviewer that the addition of more spinels is planned. The reviewer said that an addition of spinel results in a large transient spike in CH_4 conversion at the transition from lean to rich conditions. The spinel layer enhances conversion through removal or inhibitors CO and H_2 through oxidation by the spinel. The reviewer also remarked that the monolith reactor model development was progressing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Excellent collaboration is evident in the progress being made with all aspects of the project, according to the reviewer.

Reviewer 2:

The reviewer noted that the chart (Slide 5) describes the broad team involved. However, the presentation almost entirely focused on the work at University of Houston (UH) (and to some extent the University of Virginia [UVA]).

Reviewer 3:

The reviewer opined that this presentation better addresses the role each collaborator plays in the project, but does not provide many specifics of each team member's activities. Some additional detail could be provided in 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research is good, but to enable successful future product implementation, the reviewer would like to have seen more planning, proposed applied research, and a strawman for uncertainties around future product development.

Reviewer 2:

The reviewer said the project lead, Professor Harold, is clear on what needs to be done next—a deeper dive into characterization, lower light-off temperature, spatial changes during modulation, model development, etc., as indicated on Slide 21.

Reviewer 3:

It was not clear to the reviewer from the presentation as to where the work stands on meeting the project milestones and what work needs to be done to complete the milestones of the existing scope of work. The proposed future work is to converge on a next-generation catalyst, integration, modeling, and optimization. The reviewer stated this statement is somewhat vague. More detail is needed on the plan going forward. Where does the project stand in terms of completing the eight steps listed in the approach on Slide 5? What is the plan to complete that work going forward? Has the project met the BP 3 milestones?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the project goal supports DOE objectives to reduce criteria pollutant emissions.

Reviewer 2:

The reviewer asserted that efficient CH_4 oxidation is energy resource management, a DOE charter.

Reviewer 3:

The reviewer found that the project is relevant to the goal of reducing emissions of CH_4 as a GHG from natural gas engines.

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 resources appear to be sufficient for the work scope proposed.

Reviewer 2:

The reviewer stated the UH team and the ORNL team appear to have the instruments and resources needed to keep the project on track.

Reviewer 3:

The reviewer reported that resources seem to be sufficient to meet the project objectives and scope of work.

Presentation Number: ace133
Presentation Title: Next-Generation Heavy-Duty Powertrains
Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

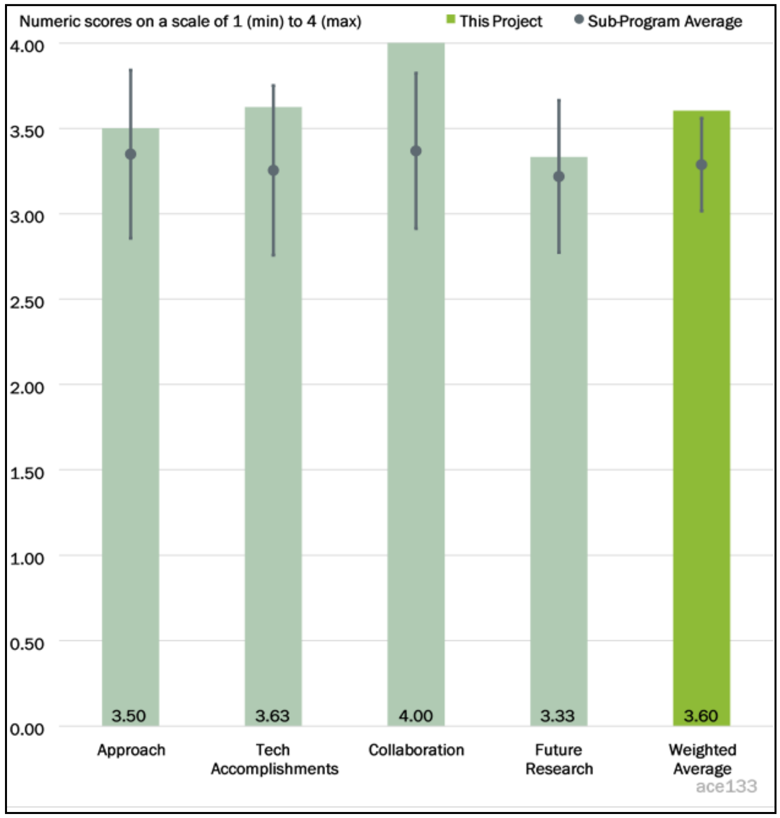


Figure 1-17 - Presentation Number: ace133 Presentation Title: Next-Generation Heavy-Duty Powertrains Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Presenter

Scott Curran, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Critical barriers and the approach for performing the work are well defined, according to the reviewer, who enthusiastically praised the work.

Reviewer 2:

The reviewer stated the project is a complex and diverse set of four tasks. The project team has done an excellent job of combining task areas where relevant (diagnostics from Task 1 in Task 2 and common engines in Tasks 3 and 4). There is clear line of sight for the project to be feasible and achieve the goals of each task or at least make significant research progress on each task.

Reviewer 3:

The reviewer remarked that this project covers a large body of diverse work and is well executed, though the reviewer was not sure how it is all related. Given the very specialized facility required for neutron imaging, the reviewer questioned if this is the best method to rely on or if other methods can be used to diagnose injector issues, etc. GCI seems to have the emissions problems of diesel with less efficiency. What is the “why buy” for GCI? The reviewer commented that a comparison to diesel would be helpful. Stop-start emissions are a relevant problem, and the reviewer looked forward to seeing that work.

Reviewer 4:

The entire project seemed to the reviewer to have an integrated approach to each of the tasks supporting the overall goal. Task 1, if successful, should provide valuable temperature information in-cylinder. This information should be helpful to validate simulations, particularly in conjugate heat transfer (CHT). Task 2, especially the running engine at the Spallation Neutron Source (SNS), should provide valuable information about the materials in-cylinder during actual engine operation. The reviewer said Task 3 appears to be exploring some useful areas in GCI, although the investigation into different injection strategies is likely reaching a useful asymptote. There is essentially zero pathway toward commercialization for partial fuel stratification (PFS) and, at this stage, the scientific understanding is well-enough developed that additional PFS work has a very limited rate of return. The reviewer opined that it would be helpful to see other advanced engine technologies and their influence on a GCI engine, such as cylinder de-activation (CDA). The goal might be better served to study strategies that produce a maximum of 2.0 gram per horsepower-hour (g/hp-hr), and focus attention on documenting exhaust temperature and improving efficiency using different parameter sweeps around that NO_x output. Task 4 should be quite useful for MD applications, with limited usefulness for HD applications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Good progress has been made on this project with a majority of the milestones being met, and the reviewer asserted that the team is on track to complete the remaining tasks in time to meet the remaining milestones.

Reviewer 2:

The reviewer found that the technical progress demonstrated to this point has been impressive. There has been a large amount of work done and the results are very encouraging.

Reviewer 3:

The reviewer noted that Task 1 progress is excellent to outstanding, given the diagnostic development, initial demonstration, and 95% accuracy validation. The Generation 2 probe indicates significant knowledge from Generation 1 and seems to be moving to a very useful tool directly used by industry. The reviewer asked for comments on the bounds of use for this tool regarding different engine combustion environments that are more optically thick. The current application looks to be limited to low cylinder density flame propagation engines and not mixing-controlled compression ignition (MCCI).

The reviewer observed that Task 2 neutron imaging development for engine applications is making progress, as evidenced by the new 2x-3x resolution detector. This is more of an open-ended research project in that there is not a precise problem to be solved here, but rather many areas where this unique capability could be used. The reviewer found the combination with Task 1 to be really encouraging and also suggested combining it with more traditional industry temperature measurement techniques. It is unclear if all the neutronic engine efforts fall into this Task 2, but this progress is also very encouraging.

According to the reviewer, Task 3 looks to have made significant progress based on the engine data and the control authority evaluation at low-load GCI between PFS and high fuel stratification (HFS). Despite this progress, the reviewer really struggled with GCI enabling MD and HD fuel efficiency as 50% EGR is not a real solution for the industry. The reviewer thought that this whole GCI strategy needs to be mapped out, considering the electrification in Task 4. The reviewer asked if the project team can articulate where the project will run GCI with reasonable EGR levels (less than 25%), where the hybridization will take over, what the full-load GCI strategy looks like, and how the project will idle the engine with GCI. These are the challenges the industry needs help with more than incremental fuel consumption improvements by burning gasoline instead of diesel fuel.

Task 4 has also made great progress, with four different data sets having been completed and the upcoming publication. This progress shows useful data for benchmarking and strategy development. The reviewer opined that the comments about engine calibration and thermal management of aftertreatment and the interaction with the hybridization and start-stop are correct. It is curious as to why the NO_x is lower on the hybrid plus start-stop than the hybrid, given the lower exhaust temperatures. It is also curious the hybrid plus start-stop has more fuel economy gain than the conventional start-stop has.

Reviewer 4:

The reviewer observed good progress on all fronts. Understanding hybridization and stop-start impacts on emissions is important. The reviewer wanted to know if hybridization can be used to improve cycle emissions, whether stop-start improves or degrades emissions performance, and how the fuel consumption benefit of stop-start is impacted if co-optimizing for emissions as well.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found outstanding collaboration across the broad-based project team, which includes national laboratories, universities, and industry partners and praised the collaboration as well done.

Reviewer 2:

Collaboration and communication among team members appeared outstanding to the reviewer. The projects have been well supported by each partner, and there appears to be excellent coordination among team members, even among people at different labs and different organizations.

Reviewer 3:

There is very clear collaboration between the many teams, and this is one of the benchmark examples for VTO, according to the reviewer. The leveraging of the labs, industry, and past industry projects is clearly collaborative and intentional.

Reviewer 4:

There is a large body of diverse work with multiple participants and supporting team members. The reviewer applauded the good job keeping this work all coordinated with good progress this year.

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 state project ended.

Reviewer 1:

This is the last year for the project, and the team has some tasks that need to be completed in FY 2021 to meet the defined goals. The reviewer suggested that the team please continue to work in a collaborative manner to get over the finish line.

Reviewer 2:

The reviewer stated all four tasks have clear paths for future research to complete the milestones and deliverables.

Reviewer 3:

The reviewer said most of the proposed future work appears to be relevant and sensible. Task 3 might be better focused on the suggestions highlighted in the previous comments for Approach.

Reviewer 4:

As stated previously, the GCI work should be laid out versus a SOA diesel comparator. The reviewer asked if emissions aftertreatment requirements are the same at lower efficiency and what is the "why buy"? The reviewer encouraged an expansion of Task 4 to include the overall benefits of hybridization to criteria emissions as well as fuel consumption.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the project will play a critical role in advancing the foundational knowledge base for the next generation of MD and HD engine systems. It has developed critical enabling technologies that have been leveraged in some of the other projects like the 21st Century Truck Partnership, which supports the overall DOE objectives to decarbonize transportation across all modes as well transition to a clean energy economy.

Reviewer 2:

The reviewer remarked that the project is highly relevant to DOE goals for MD and HD engines and vehicles and addresses fundamental understanding and practical applications.

Reviewer 3:

There is clear relevance for these projects as they are aligned with the VTO lab call and the 21st Century Truck Partnership. Given the new VTO budget and the orientation of on-road work toward electrification, the reviewer proposed focusing the application of these tasks away from on-road and toward off-road, marine, and rail applications.

Reviewer 4:

Neutron imaging, in the reviewer's opinion, is less relevant due to the limited availability of this type of resource and may only be usable as a last resort if all other methods have failed to address the issue.

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 is projected to be completed on budget.

Reviewer 2:

Based on the broad scope and quantity of work, it seemed to the reviewer that resources are adequate.

Reviewer 3:

Looking at the results and the opportunity for future progress, the reviewer opined that the project could use some additional support.

Reviewer 4:

The reviewer said there is not an issue with time, money, people, or facility resources projected that would inhibit the upcoming deliverables. Of course, more can always be done, and the reviewer urged DOE not to reduce this funding and to help support the project to transition toward more off-road applications.

Presentation Number: ace138
Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium
Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

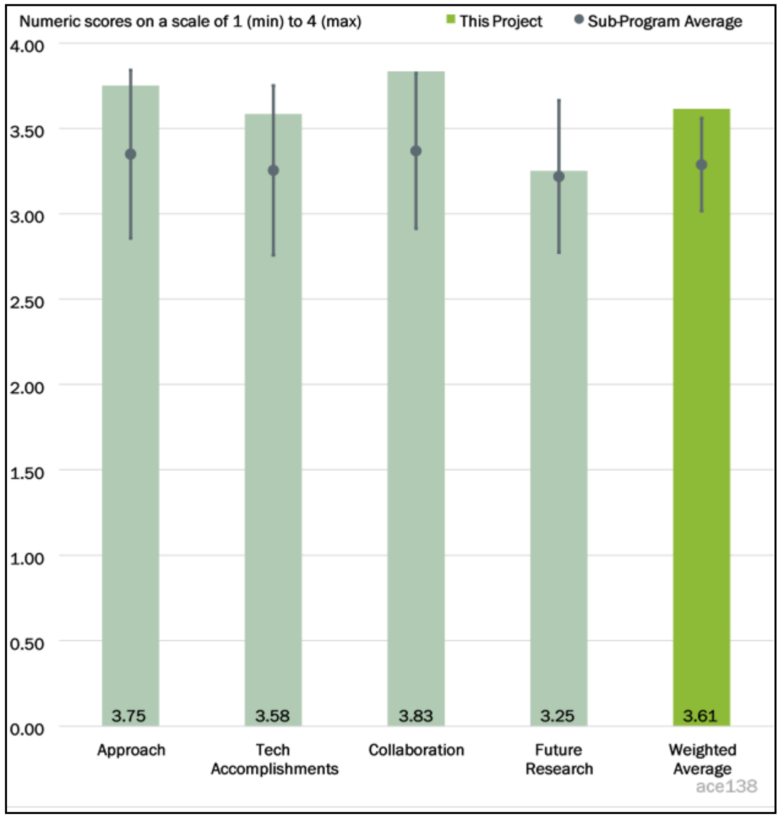


Figure 1-18 - Presentation Number: ace138 Presentation Title: Partnership for Advanced Combustion Engines (PACE) - A Light-Duty National Laboratory Combustion Consortium Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Presenter

Matthew McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is critical work for the industry and the collaboration between labs has already led to breakthrough results. The reviewer expected that this project will continue to make significant improvements in simulation tools.

Reviewer 2:

The reviewer observed that the approach is aligned with industry priorities and is partnering with major software vendors by leveraging DOE investments in high performance computing (HPC), machine learning (ML), and artificial intelligence (AI).

Reviewer 3:

This is a comprehensive approach to addressing problems that, when solved, will have a direct impact on efficiency and emissions. The reviewer noted that major outcome 7, LTC combustion metrics, is out of project, which is good.

Reviewer 4:

The reviewer remarked that the PACE project has the technical targets of addressing limits to SI engine efficiency (e.g., knock and LSPI); the barriers to highly dilute combustion; and emissions reduction during cold start. These are all research areas that are high priorities for industry. Through its open-source models, the reviewer asserted that this project has a direct path to impacting industry workflows. The project is well designed, feasible, and there is very little concern that it will not meet its goals. The reviewer's concern at this point is that the funding may be reduced (or cut) going forward due to updated DOE priorities, which would be unfortunate and a missed opportunity to ensure the most efficient and cleanest engines going forward.

Reviewer 5:

The reviewer said the work is sharply focused and appears to be in-sync with the industry stakeholder needs. It is an excellent project; however, within the time frame for which this project is focused, the need for even larger reductions in CO_2 emissions from the mobility sector (in addition to maintaining very low criterial pollutants) will likely be demanded. Engine efficiency improvements alone with be insufficient to accomplish the needed CO_2 reduction. Life-cycle analyses—which are dependent on the boundary conditions and assumptions— indicate that when electricity generation, mineral extraction, and production processes required for the large increase in electrified vehicles are considered, the CO_2 reduction of large-scale electrification may not be as large as currently assumed. It seemed to the reviewer that it would be prudent to couple the activities of the Partnership for Advanced Combustion Engines (PACE) with the need for introduction of lower carbon fuels. The reviewer wanted to know if one examines likely scenarios where reduced carbon fuels could start to be introduced into the market, will the operating constraints or boundary conditions for the engine change? Will PACE activities need to be modified in such scenarios? Personally, the reviewer did not think that the idea of e-fuels should be dismissed so quickly, which is another discussion completely.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Given the COVID pandemic, this reviewer believed that the technical accomplishments and progress have been remarkable. Most of the milestones were delivered on time.

Reviewer 2:

The reviewer found good progress getting the new engines installed in test labs.

Reviewer 3:

According to the reviewer, steady progress was made despite COVID-19 delays.

Reviewer 4:

The focus is on two DOE exascale computing program codes, namely NEK5000 and Pele. It was not clear to an outside reviewer what the focus is of each of these codes.

Reviewer 5:

The reviewer stated the results reported are impressive, and the effort to make the computation tools available to the stakeholders as quickly as possible seems to be robust. However, the reviewer was concerned about the results shown in Slide 17, or perhaps the reviewer did not understand the reporting of them. Slide 17 says, "Success measures are for the predicted accuracy of the target for a design change with fixed model parameters," in which case, the 10% and 20% success rates seemed quite low to the reviewer. The plots show reasonable agreement between the experimental mean and the model prediction mean, but the experimental outliers are quite significant; there is a large difference between the spread in the variability in the engine cycles versus the CFD cycles. The reviewer thought that the extreme variations of the experimental data would likely have the most adverse impact on such things as emissions and inquired if this means the simulation needs to be tuned for each design change. If so, it will be a hinderance to analysis-led design.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the work is very complete and seems to be synergistic.

Reviewer 2:

The reviewer found the collaborations between labs, experimentalists, and simulation teams to be excellent.

Reviewer 3:

The reviewer noted that this project is a shining example of how the labs can work together to achieve DOE goals, with ANL, Lawrence Livermore National Laboratory (LLNL), NREL, ORNL, and Sandia National Laboratories (SNL) all part of this project. This project also has collaborations with software vendors, universities, and the OEMs themselves.

Reviewer 4:

The reviewer commented that adding CONVERGE in FY 2020 is good.

Reviewer 5:

The reviewer said most of the OEMs, commercial-off-the-shelf (COTS) software vendors, universities, and labs are involved with the project to leverage the work being done.

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 state project ended.

Reviewer 1:

The reviewer referenced earlier comments in Technical Accomplishments regarding lower carbon fuels.

Reviewer 2:

This reviewer described future work for this project as well laid out. Of particular interest is the website that will include models, mechanisms, best practices, etc., to provide the developed resources to all stakeholders.

Reviewer 3:

The reviewer stated the project plans are good and take into account simulation needs of OEMs customers.

Reviewer 4:

The proposed future research topics related to closer coordination and enhancing industry software adoption are very well planned. It was not clear to the reviewer what the project team means by building partnerships with other DOE offices, including BES.

Reviewer 5:

The reviewer encouraged the team to continue to pursue project objectives. Providing improved and validated simulation tools to the industry will directly impact engine design and calibration, leading to improved efficiency and emissions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project support addresses the overall DOE objectives and referenced previous comments about considering lower carbon fuels.

Reviewer 2:

The reviewer stated the project supports the overall DOE objective because the focus of the research is to maximize engine efficiency and lower emissions.

Reviewer 3:

Project results will have an immediate impact when employed by OEMs, according to the reviewer.

Reviewer 4:

The reviewer remarked that improved simulation tools will lead to better engines with reduced fuel consumption, achieving DOE goals.

Reviewer 5:

The reviewer indicated that yes, this project supports the overall DOE objectives of producing more efficient and cleaner propulsion 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 stated the PACE project is poised to make a real, substantive impact on improving engine simulation capability, and resources should be increased so the goals can be achieved sooner.

Reviewer 2:

This reviewer believed that the resources are sufficient and hoped that funding would not be reduced going forward as this is a very important project.

Reviewer 3:

The reviewer said the project team has curtailed work on some of the original objectives in order to make faster progress on higher priority objectives. The project is managing the resources provided well.

Reviewer 4:

Based on the information presented, the reviewer was not completely sure whether the project has access to sufficient computational resources.

Reviewer 5:

The reviewer encouraged continued funding of this project and expressed concern that FY 2022 budget cuts will diminish the project.

Presentation Number: ace139
Presentation Title: Chemical Kinetic Models for Surrogate Fuels
Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

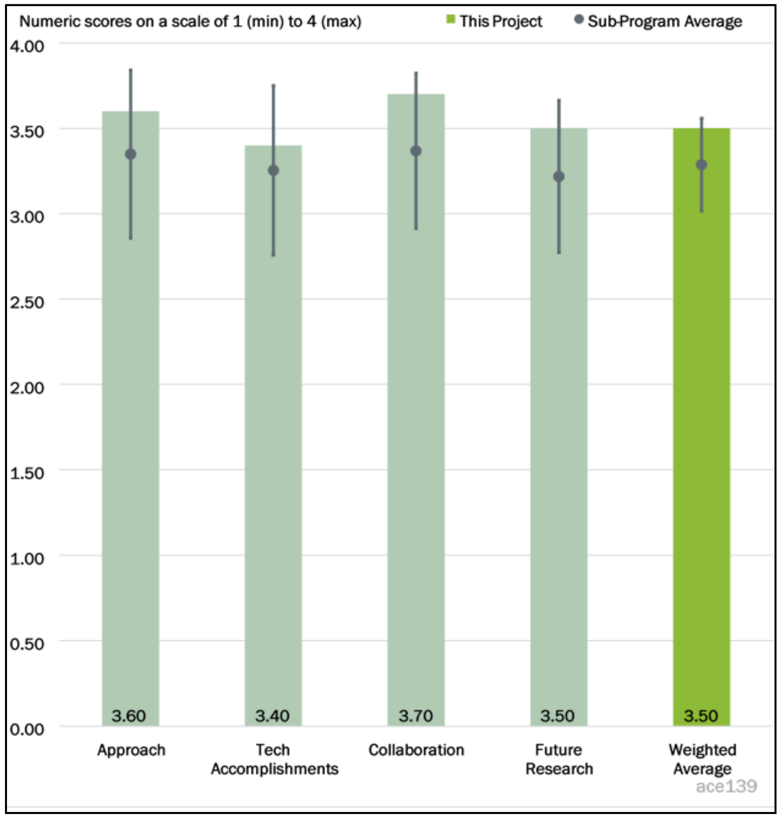


Figure 1-19 - Presentation Number: ace139 Presentation Title: Chemical Kinetic Models for Surrogate Fuels Principal Investigator: Scott Wagnon (Lawrence Livermore National Laboratory)

Presenter

Scott Wagnon, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the project has clearly identified barriers and cross-functional groups to address the challenges.

Reviewer 2:

The reviewer said reaction mechanisms and kinetic models are crucial for an in-depth understanding of the combustion processes, such as low-speed pre-ignition (LSPI) and cold-start emissions. This capability requires combined efforts to develop surrogate fuel, mechanisms, data for model validation, and mechanism reduction for an accurate engine simulation. According to the reviewer, the project is very well designed to cover these areas.

Reviewer 3:

Understanding fuel combustion kinetics and complex interactions between engines and fuel combustion dynamics continues to be an impediment to further development of higher efficiency engines, both SI and CI, that are being researched by DOE and designed by OEMs. The reviewer remarked that the projects reviewed here continue to provide insight into kinetically controlled systems that are critical to engine performance—fuel auto-ignition reactions, fuel reactions leading to soot formation, and the ability to describe real fuels through chemical surrogates. The approach taken in the projects—to obtain high-quality experimental data that are directly based on kinetically controlled systems with a minimum of confounding factors to be subsequently used for kinetic model development— is a tried-and-true model that the reviewer indicated has steadily led to greater and greater understanding of combustion kinetics.

Reviewer 4:

The reviewer asserted that there are not enough real engine experiments to validate some of the directions of the research when considering "trial and error" is still used to find the components that "best" capture fuel behavior in real engine applications.

Reviewer 5:

The project focuses on the development of surrogate and subsequent kinetic models of PACE-1 and PACE-20. Following a classical approach, the reviewer noted that the models are comprehensively validated against engine and fundamental kinetic targets, such as ignition delay, flame speed, crank angle at 10% mass fraction burned (CA10) in engine conditions, and soot volume fraction. In general, very good confidence has been achieved for the application of these models for all potential users. One issue the reviewer had regarding this surrogate approach is on its generality when applying to other fuels. The current surrogate approach is on a trial-and-error basis and largely relies on the fuel components. It will be very nice if a general strategy can be developed to more systematically and quickly generating surrogates for novel alternative fuels. The reviewer remarked, furthermore, it will be tremendous if a surrogate model can be developed based on the desired fuel and engine properties without focusing on the fuel type and structure, if achievable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the project made significant progress in (1) defining and sharing the surrogate fuel, PACE-20, for all tasks, (2) developing and validating reduced kinetic models for PACE-20 and toluene primary reference fuel (TPRF) - 10% ethanol, 90% gasoline blend (E10) for engine simulations, (3) releasing an improved detailed gasoline surrogate model to consortium members, and (4) having new data for surrogate fuels and complex research-grade regular E10 gasoline (RD5-87).

Reviewer 2:

The reviewer asserted that there are not enough real engine experiments to validate some of the directions of the research when considering "trial and error" is still used to find the components that "best" capture fuel behavior in real engine applications.

Reviewer 3:

Overall, the progress and accomplishments are good. The reviewer made the following points:

- On Slide 9, the reviewer was not sure if the maximum error of 12.6% is acceptable, even though the presenter mentioned that it is acceptable. Perhaps a sensitivity study to figure out the "kinetic model reduction" versus "accuracy" trade-off is needed.
- On Slide 10, there must be a reason why the verification was not done over phi=1 for 10%, 20%, and 30% EGR levels. Please explain.
- On Slide 11, the reviewer said the ignition delay time at low-pressure level exhibits negative-temperature coefficient (NTC) behavior, while the model does not reproduce well.
- On Slide 12, the LLNL detailed model shows deviation from measurements. Is it possible to comfortably say that the detailed chemistry is the "golden" reference for developing a reduced mechanism?

Reviewer 4:

The reviewer stated continued progress on the science and art of developing fuel surrogate models, validating and refining models under lean combustion conditions, and implementing best practices for mechanism reduction all demonstrate good technical progress. Laminar burning velocity studies and insights will become more and more critical as SI engines continue to move toward dilute conditions for higher efficiencies.

Reviewer 5:

The reviewer observed that the accuracy of surrogate and kinetic models has been thoroughly validated against different kinetic targets through direct comparison; the technical accomplishments and progress toward the overall project are satisfactory and can substantially benefit other teams. New measurements of fundamental and engine targets have been acquired, and the models can reproduce the target reasonably well. A minor concern is that the size of the kinetic model is still quite large and includes more than 300 species, which is too large for practical engine and combustion simulation and will be addressed in the future work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer praised the collaboration and coordination across the project team as outstanding, with more than 15 partners across industry, academia, and national laboratories. The results can benefit many teams within and beyond the project.

Reviewer 2:

The reviewer thought the collaboration is great.

Reviewer 3:

The reviewer observed that many entities involved in the project collaborated well toward project goal.

Reviewer 4:

The reviewer stated the project includes a number of collaborators that are well integrated with the project's efforts.

Reviewer 5:

The reviewer said collaborations across the national laboratories and universities help provide this effort with a wealth of experimental data to draw from when developing and validating models. One area that seems to be less well represented from the collaboration list is specific collaborations with industry that demonstrate these models are able to be used by 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the proposed future research has logical next steps.

Reviewer 2:

The reviewer stated the future research is well planned to continue characterizing the RD5-87 and the surrogate fuel, PACE-20; collecting data using the ANL rapid compression machine (RCM) and other fundamental devices and engines for model validation; using new analytical and computational approaches to rapidly establish and implement more accurate models of the important surrogate fuel chemistry; and working with the LLNL numerics team to quickly reduce kinetic models to deliver to PACE members and industry.

Reviewer 3:

The reviewer said the proposed future work continues to push the boundaries of knowledge in key areas—heat release and autoignition phenomena in lean mixtures, impacts of EGR constituents on combustion kinetics, and fuel kinetics in oxygen-deficient environments leading to soot precursors.

Reviewer 4:

The reviewer thought that it may be worthwhile going back to the detailed model and trying further improvement of its accuracy.

Reviewer 5:

The reviewer acknowledged that the proposed future research involving lean-dilute EGR, cold-start conditions is certainly relevant and interesting, and a further reduced mechanism with similar accuracy is also urgently needed. In addition to a more general approach for surrogate model development, one extra aspect that merits future investigation is the uncertainty quantification of the model, which can be evaluated through either Monte Carlo or a Bayesian type of analysis. According to the reviewer, both the model and the experimental target will inevitably contain uncertainties, which should be considered when comparing the modeling with the experimental target. A useful set of experiments will help to further reduce the uncertainty of the model.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated the project’s relevance to overall DOE objectives is outstanding.

Reviewer 2:

The reviewer indicated that fundamental fuel combustion research is the foundation of developing advanced clean and high-efficiency engines, and its contribution to support the overall DOE objectives should not be underestimated.

Reviewer 3:

The reviewer said the reviewed projects drive knowledge and insights that ultimately lead to higher efficiency and lower emissions engines, a key DOE goal.

Reviewer 4:

The reviewer observed that developing chemical kinetics for surrogate fuels is an important step in making more efficient engines with lower emissions.

Reviewer 5:

The reviewer said the project supports the DOE objectives to reduce carbon footprint by advancing technologies for more efficient and robust ICE 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 said the project’s resources are okay for the scope.

Reviewer 2:

The reviewer stated the project seems to have enough resources to achieve the stated milestones.

Reviewer 3:

It looked to this reviewer like the project has sufficient resources to achieve the stated milestones.

Reviewer 4:

There are sufficient resources to achieve the stated milestones, according to the reviewer.

Reviewer 5:

The reviewer said these projects are appropriately resourced, allowing the projects to fund collaborations that provide key validation data in the areas of ignition delay, flame speed, sooting tendency, etc. Reducing resources to the point these external collaborations could not be funded would significantly hinder the further development of kinetic models.

Presentation Number: ace140
Presentation Title: Accelerated Chemistry and Transport for Engine Simulations
Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

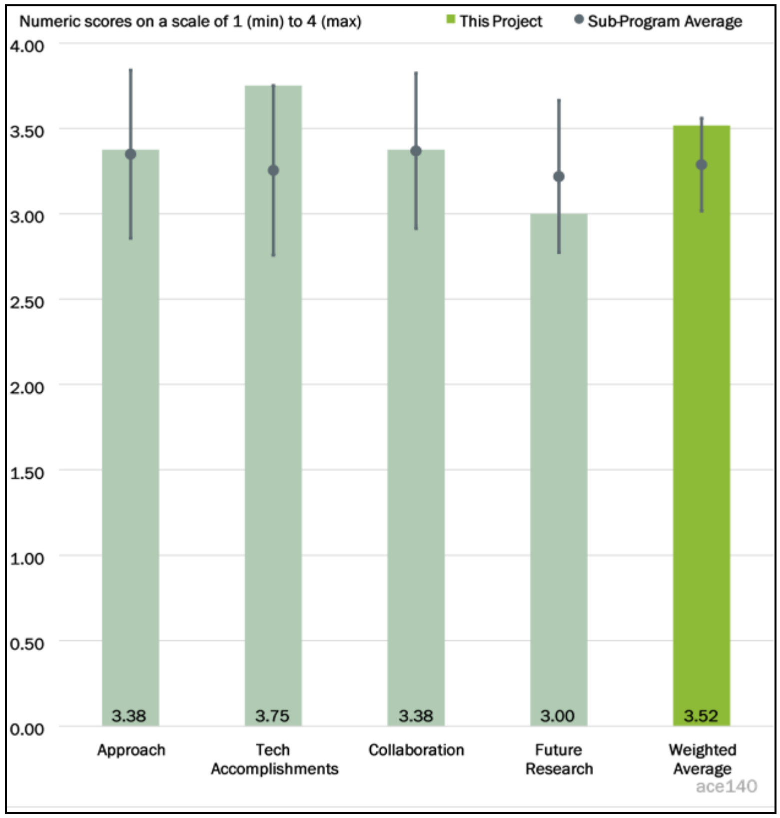


Figure 1-20 - Presentation Number: ace140 Presentation Title: Accelerated Chemistry and Transport for Engine Simulations Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the project is a very creative approach to identifying further pathways to speed up chemistry solvers.

Reviewer 2:

The reviewer stated it is a very solid approach for developing, optimizing, and deploying to partner labs. The fundamental detailed chemistry was either reduced or optimized or directly evaluated for CFD simulations.

Reviewer 3:

For HD diesel engines, the reviewer indicated that the pressure and temperature range need to be extended beyond what is mentioned in the approach. For high engine load conditions, cylinder peak pressures are reaching about 250–300 bar, and the reviewer wanted to make sure the proposed chemical kinetics perform well for these conditions.

Reviewer 4:

Key technical barriers for engine simulation tools are clearly defined, but the key technical barriers specific to this project were less clear to the reviewer. Advancement of computational tools is an understood goal, but more clarity on specific barriers at the project level would be useful to gauge the impact of this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found it amazing that further speed-ups in chemistry have been realized.

Reviewer 2:

Technical accomplishments related to kinetic rate parameter optimization framework, Zero-Order Reaction Kinetics (Zero-RK) implementation in Nek5000 and Pele, and rate optimization are significant, according to the reviewer.

Reviewer 3:

The reviewer said developed methods have been coupled to chemistry tools to accelerate engine CFD simulations, which is definitely an area of interest for the industry. With the number of species less than 100, the speed-up is still pretty decent. At this stage, the reviewer noted that the industry still uses relatively smaller chemical mechanism due to computational efficiency. The speed-up of chemistry calculation will be well received.

The speciation information is very interesting for developing a solid chemical mechanism. The reviewer emphasized that it is impressive to learn the mechanical reduction can be done in under one hour and called the research a great job. This would be welcomed by the community. It is interesting to see the practice of adjusting rate parameters for CFD simulations. The reviewer wanted to know what the basis of adjusting is and if there is any bond for adjusting ranges.

Reviewer 4:

Overall, the reviewer noted, progress is being made toward delivery of the milestones. The 2020 milestones were completed, but it was less clear to the reviewer where the progress in 2021 will be, with a delayed Q1 milestone and lower clarity on progress toward later-year milestones. From technical data presented, it appeared to the reviewer that the team is making significant strides in performance. End-user impact of this project's current effort is less concretely shown.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaborations between the national laboratories has been very productive and the collaboration with commercial simulation software providers provides a pathway for industrial utilization.

Reviewer 2:

Collaborations between the project team and others appeared to the reviewer to mainly focus on implementing the developed tools on other national laboratory systems and used by other national laboratory project teams. This focus, to roll out the tools to other researchers, is laudable. At the same time, it was less clear to the reviewer that there are collaborations that help to advance the efforts of this specific project.

Reviewer 3:

The collaborations slide is a comprehensive list of PACE and national laboratory staff, and commercial vendors, but the reviewer would like the PIs to have included other vendors, such as Ansys, Inc., and Siemens.

Reviewer 4:

The reviewer stated the collaboration was well connected to different parties. There is an indirect link to the industry through partners, and the reviewer strongly suggested a direct industry application, i.e., leveraged by an industry partner to product 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the project has a clearly defined path forward.

Reviewer 2:

Kinetic rate parameter optimization and specific items mentioned under detailed kinetics in scalable combustion CFD are highly relevant, according to the reviewer.

Reviewer 3:

In addition to what has been proposed, an industry adoption case would be very interesting to the reviewer.

Reviewer 4:

The reviewer stated another 2x speed-up would be great.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that improved simulation tools help engine developers design more efficient engines, reducing energy usage.

Reviewer 2:

The reviewer stated this topic is highly relevant for fuel efficiency and emissions, which is a high priority for the DOE.

Reviewer 3:

According to the reviewer, chemical kinetics are an important area for advanced engine concept exploration. It is a big knob to be able to get predictions right and to be predictive. Its development, reduction, and optimization will be highly relevant.

Reviewer 4:

The reviewer commented that improving computational techniques for engine combustion development is a key element of DOEs objectives for improving ICE efficiency and developing tools for industry to leverage to do so. At the most fundamental level, efforts to improve models and speed up solvers are aligned with that mission.

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

Reviewer 1:

From the technical achievement and progress, the resources were reasonable to the reviewer.

Reviewer 2:

The reviewer opined that the project is critical work that should be accelerated with additional resources.

Reviewer 3:

Chemical kinetics and algorithms are very important for accurate and faster engine simulations. Compared to other VTO efforts, the reviewer warned that this effort is relatively underfunded.

Presentation Number: ace141
Presentation Title: Advanced Ignition Barriers Research
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

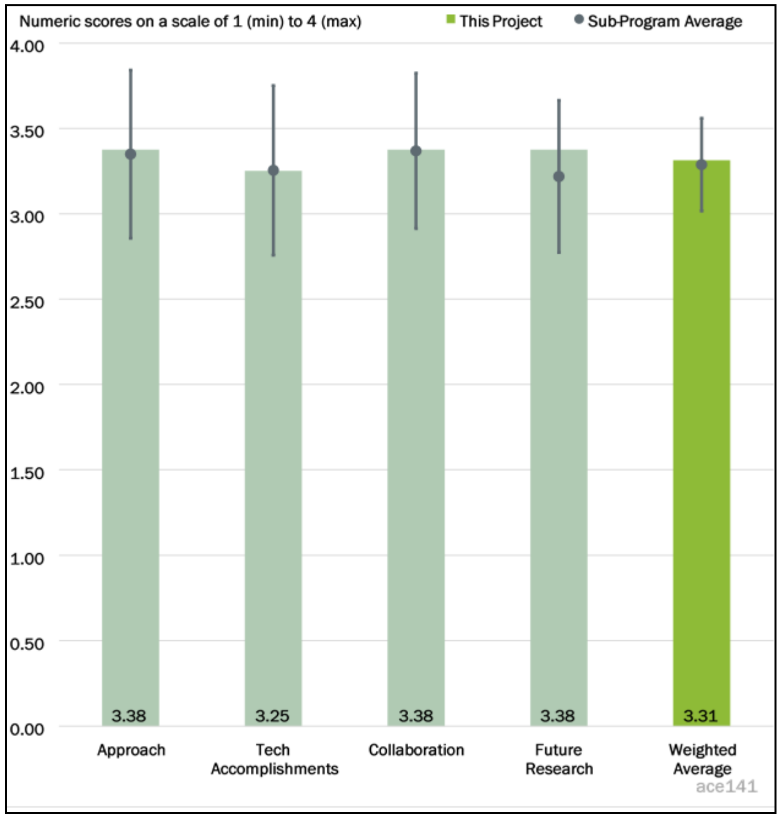


Figure 1-21 - Presentation Number: ace141 Presentation Title: Advanced Ignition Barriers Research Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter

Isaac Ekoto, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the fundamental approach to examining the potential for ignition technologies continues to bring new and valuable insights.

Reviewer 2:

The reviewer found that the approach is sound and addresses most technical barriers.

Reviewer 3:

According to the reviewer, the overall approach to this work is excellent, and the focus on steady-state, high EGR conditions and catalyst light-off conditions are very intelligent choices. The modeling and experiments are well planned and well approached.

A suggestion for future improvement from the reviewer would be to establish logic or a workflow for narrowing the technologies down or identifying the most promising technologies. As it stands, much of the work seems more like a screening effort for which the next step would be to use fundamentals or experimental results to prioritize technologies and guide their future development. The reviewer said, for example, if the 0%–10% burn duration is too long, that may explain the stability issues seen. Therefore, if a technology exhibits a 0%–10% burn duration that is too long, the team can either eliminate it or return to fundamentals to clearly outline what is or is not possible to improve it. The reviewer said a broader framework for evaluating and developing the technologies would be the ultimate goal.

A final comment from the reviewer is that the use of abbreviations in the presentation was a bit confusing and, in the future, fewer abbreviations and/or clearer reminders of what the abbreviations stood for would be immensely helpful.

Reviewer 4:

This reviewer asked whether the PI believes one-dimensional (1-D) modeling of the pre-chamber (PC) throat flow is sufficient to capture the trapped mass and overflow behavior. In particular, does the PI believe the model properly captures subsonic versus possible sonic flow into the PC?

Concerning indicated thermal efficiency (ITE), what is the uncertainty? In some figures, different EGR rates with different ignition strategies were compared and contrasted, which showed small differences on the ITE. The reviewer also asked how well the plasma kinetics were validated before applying them to the overall plasma modeling effort. Regarding experimentally indirectly determining flame speed (S) and time (t), how did the PI address heat losses? What is the uncertainty in estimating this heat loss?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Progress made since last year has been quite good, and the reviewer said that it addressed many of the comments from last year, also.

Reviewer 2:

According to the reviewer, good progress has been made, overall.

Reviewer 3:

The reviewer found the technical accomplishments in all areas to be impressive. It would really help to show very clearly how the efforts interconnect with one another to ultimately put forth a technology that is most promising.

Reviewer 4:

There seem to be a few sources of uncertainty in the modeling and experimental work that were not addressed in the presentation. Possibly the PI has already addressed these concerns in the past. The reviewer stated, directionally, this effort is addressing some barriers to lean combustion at cold conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said very good collaboration exists.

Reviewer 2:

The reviewer noted that the project is largely within Sandia, but the interactions with the partners have been quite effective.

Reviewer 3:

According to the reviewer, the effort appears fairly well coordinated within PACE, and the external collaborations are good. It would be excellent to see OEM involvement, if possible.

Reviewer 4:

The project fits well into a much larger, multi-organizational project addressing DOE needs in the IC area. The reviewer commented that one apparent missing element was direct university participation. There appears to be indirect participation, and possibly this makes sense for this particular project, though it is worth a discussion.

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 state project ended.

Reviewer 1:

The reviewer said future plans continue to consider key questions for industry.

Reviewer 2:

The proposed research is very sound and logical to the reviewer. The focus on the cold start catalyst light-off conditions will be very interesting as the project will pose some unique challenges (e.g., very high in-cylinder temperature conditions). As noted previously, the reviewer asserted that it would be good to explicitly state how the various efforts interconnect and how the modeling and experiments ultimately support one another.

Reviewer 3:

One suggestion from the reviewer is to closely look at the 1-D model for the PC case and consider if it is accurate enough for the purposes of this project while also considering a two-dimensional (2-D) model. Also, if it has not occurred yet, taking another look at validating plasma dynamic kinetics might be worthwhile.

Reviewer 4:

The reviewer stated more emphasis should be placed on passive PC ignition.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

These efforts aim to enable more efficient, lower emitting engines, and thus the reviewer indicated that they are very well aligned with DOE objectives.

Reviewer 2:

The reviewer stated the project directly supports lean combustion R&D by exploring different possible strategies to attain this goal at cold, low-load conditions with a possible extrapolation to higher load conditions. In particular, it supports improving IC engine ITE at part-load conditions and has shown some promise of allowing quite lean operations, though results are early and much work is ahead for other PIs and associates.

Reviewer 3:

According to the reviewer, the project supports DOE objectives to reduce petroleum consumption.

Reviewer 4:

Despite changes in DOE budget priorities, the reviewer opined that advanced ignition will still be needed for ongoing mobility 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 budget appeared good to the reviewer for the work scope as planned.

Reviewer 2:

The reviewer stated the project resources are appropriate to complete the planned work within the planned timeframe.

Reviewer 3:

The resources, both experimental and modeling, are sufficient to the reviewer.

Reviewer 4:

The reviewer had no comment.

Presentation Number: ace142
Presentation Title: Development and Validation of Predictive Ignition Models
Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

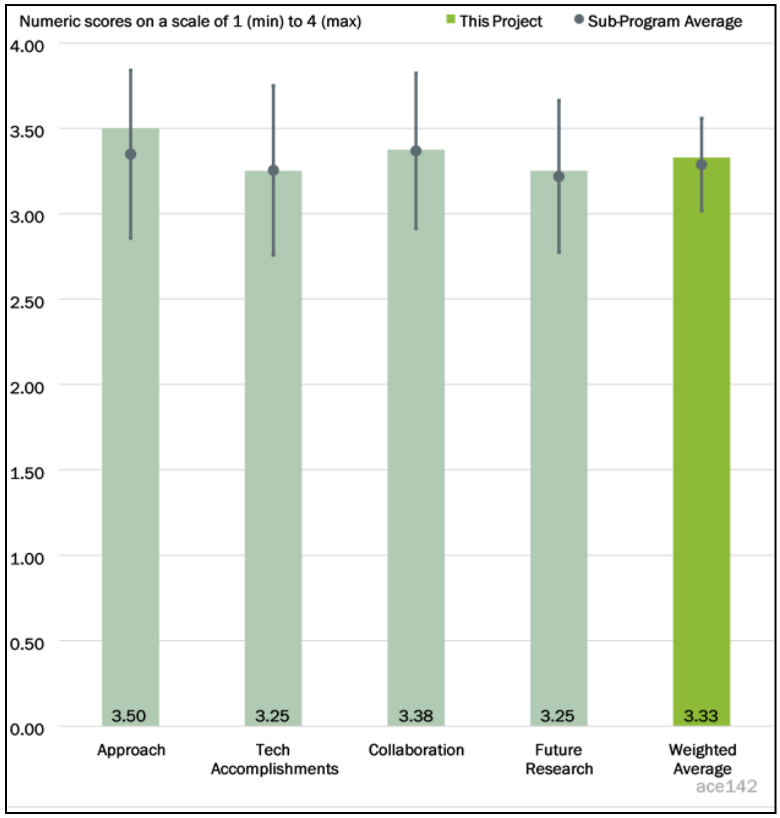


Figure 1-22 - Presentation Number: ace142 Presentation Title: Development and Validation of Predictive Ignition Models Principal Investigator: Riccardo Scarcelli (Argonne National Laboratory)

Presenter

Riccardo Scarcelli, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that there are many good connections between different steps in the modeling as well as the experiments. The different steps integrate well, and all support the overall goal of the project. The outcomes are integration of the models into CONVERGE and into user defined files (UDF) that can be implemented into commercial codes in industry. According to the reviewer, the only potential step missing is validating the UDFs in the commercial codes against the wealth of data that will be produced in the project. The UDF and spark process itself will be validated, but how these processes tie into subsequent flame propagation or the mixing both before and during the ignition process will likely be dependent on the models in the code. The reviewer noted that, by integrating directly into CONVERGE, the integration might be smoother there since everything can be integrated together.

Reviewer 2:

The reviewer asserted that predictive ignition models are extremely important for advanced SI combustion modes that are being evaluated by industry for improving efficiency and reducing emissions. This fact is particularly important for lean (air) and dilute (EGR) SI and cold-start predictions. The reviewer opined that evaluating and updating models such as G-Equation, extended coherent flame model (ECFM), etc., are critical.

Reviewer 3:

The reviewer stated the research approach should be independent of any one specific CFD vendor so the research had wider acceptance.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said experimental and computational accomplishments shown at different operating conditions is very impressive.

Reviewer 2:

According to the reviewer, technical accomplishments for the year are all individually impressive. Comparisons of spark kernel growth between the CONVERGE implementation and experiments are improving. Improved understanding from direct numerical simulation (DNS) may continue to help match the experiments and simulations. The PI provided a helpful answer about boundary conditions in the talk during AMR. Improvements in the sampling for ML models are good; the reviewer suggested that it would be excellent to see this work published as this is going to be a common issue for folks taking high-fidelity data sets and developing models using ML. The current comparisons between the DNS and ML results are good, although it will be interesting to see how far the ML is able to capture “limiting” events at less optimal operating conditions. The reviewer observed that it would be nice to see this integrated into the workplan, since prediction of misfire, incomplete combustion, etc., will be critical to the success of these models. The new crossflow experimental facility looks very nice and initial results look promising. Using discharge molecular tagging velocimetry (DMTV) will be challenging; it would be good to consider uncertainties with the technique, which may be difficult to quantify, but the reviewer agreed that particle image velocimetry (PIV) is not a good option. It will be interesting to see these comparisons with large eddy simulation (LES) and DNS at non-quiescent conditions, which is progressing nicely. The focus on cold start is an important step and the initial results looked promising to the reviewer in comparison with the experiments. Capturing the potentially wide variability at these conditions will be important.

Reviewer 3:

The overall progress of the project seemed fine to the reviewer. What the reviewer felt is lacing from the AMRs is the depth in validation of these models. Granted that lack of depth cannot be shown in a 30-minute presentation, additional material of the how the models perform over a wide range of lean and dilute and cold-start conditions should be shown. For example, the reviewer wanted to know how many varieties of cases were simulated and how the results aligned with the experiments. A summary of those with statistical analysis would have been useful to include in these presentations. It was also a bit unclear how the knowledge from DNS is used for model development (a statistical analysis of DNS data task in the future is seen, but more information on this topic will be helpful). The reviewer inquired about whether the model predicted flame speeds (both laminar and turbulent) and those obtained from DNS can be compared and correlated to guide whether the flame propagation is well established.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said only one COTS CFD vendor is included but including other software vendors will make for wider acceptance of the sub-models.

Reviewer 2:

The reviewer observed good collaboration between the team members, but as mentioned before, the role of the DNS work for model improvement is a bit vague.

Reviewer 3:

There are good collaborations within the labs, and the collaborations within the CRADA also seem strong. Connections with CONVERGE are very good, and integrating the new models seems to be going nicely. The reviewer referenced previous comment on the UDFs for other collaboration piece. While the PACE framework provides a good model for passing the UDFs to industry, it was not clear to the reviewer how much work is going to be done to test other codes (not CONVERGE) against the data collected at the labs and in the CRADA, which may be an issue if other sub-models within the commercial code interact with this UDF strongly.

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 state project ended.

Reviewer 1:

The proposed future work outlined on Slide 21 for three different conditions is informative. It was not completely clear to the reviewer how the priority is determined for these three conditions.

Reviewer 2:

The reviewer indicated that the future work plan is well laid out and the foundations for all the remaining steps are in place.

Reviewer 3:

The reviewer asserted that the future work should not focus on methane/air mixtures, but on gasoline.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the industry needs predictive ignition models for prediction of knock, capture misfire, and ignition at highly stratified conditions.

Reviewer 2:

Tight integration of this effort within the PACE framework ensures it is meeting overall DOE objectives. The PI has demonstrated to the reviewer how these results are critical to overall engine modeling outcomes, and the integration with industrial codes ensures a wider impact going forward.

Reviewer 3:

The reviewer affirmed that, absolutely, this work is exactly the kind of work national laboratories should be doing and helping the industry with. It perfectly aligns with DOE's mission.

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

Reviewer 1:

The resources seemed sufficient to the reviewer, especially given there was a new experimental facility brought online in the past year.

Reviewer 2:

The resources seemed to be sufficient to the reviewer to proceed with this work.

Reviewer 3:

The reviewer commented that additional computational resources may be needed for DNS simulations.

Presentation Number: ace143
Presentation Title: Fuel Injection and Spray Research
Principal Investigator: Chris Powell (Argonne National Laboratory)

Presenter

Chris Powell, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

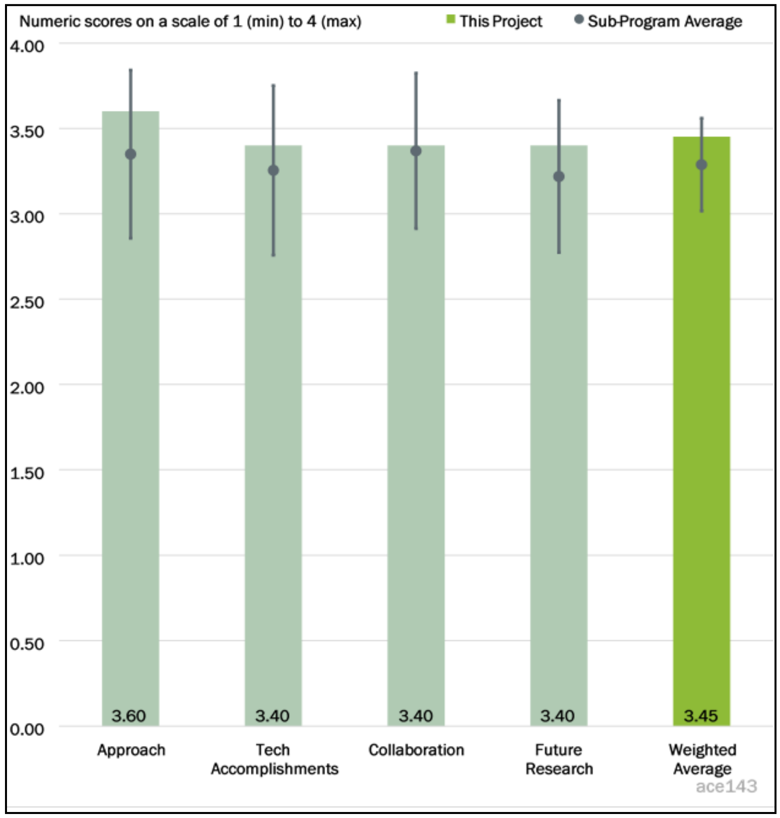


Figure 1-23 - Presentation Number: ace143 Presentation Title: Fuel Injection and Spray Research Principal Investigator: Chris Powell (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

A multi-pronged approach of the various national laboratory partners (both modeling and experimental) and sensible separation of tasks by spray type (free, wall interaction, etc.) are hard to improve upon, according to the reviewer. Thankfully, the team is switching to more modern injection hardware. Creating a merit function is a worthy objective.

Reviewer 2:

The reviewer indicated that the team has an excellent mix of experimental and simulation work. There has been remarkable progress in expanding the capability of diagnostics, as evidenced by the three-dimensional (3-D) SNL liquid volume fraction (LVF) work, which complements the ANL mass distribution work quite nicely. The simulation work also appears to be rapidly catching up to the experimental advances, with LES improving the predictions quite well. The concept of developing a merit function was also highly desirable to the reviewer, although this will be challenging as it will require deciding whether the merit function definition is strictly for spray parameters or if engine parameters would be incorporated—for example, any in-cylinder swirl/tumble, the density/pressure/temperature of the ambient gas into which the spray is injected. The more engine-like the merit function can be defined, the more useful it is likely to be. The reviewer commented that it would have been nice to see the shift toward the more updated hardware happen earlier.

Reviewer 3:

The reviewer asserted that it would be nice to have seen fuel-air vapor contours, or some other model-experimental indicator of the mixture preparation quality degree. Ultimately, especially for cold start, this is the great challenge with minimal liquid impingement.

Reviewer 4:

The reviewer remarked that each of the individual tasks is well planned and executed. The quality of the experimental data is high, it is good to see the team has obtained more modern injectors in response to last year's comments, and progress in the simulations is good. In particular, the reviewer noted that the development of a merit function will be very helpful not just to these activities but to PACE overall. The individual tasks, however, do not seem as integrated as they could be. Simulations are being compared to data from outside the collaboration, some of which have pretty old data. Finally, it was not clear to the reviewer how the Nek5000 development is using results from the rest of the activities; many of the models are older, more standard models.

Reviewer 5:

The reviewer recognized this project is still in the beginning stage and more results will be available next year. With this note in mind, there was minimal reference toward one goal of this project—ensuring good mixture preparation near the spark source at spark timing. Possibly more focus on this goal will occur this coming year. Also, there is quite a focus on multi-dimensional modeling including Reynolds-average Navier-Stokes (RANS) and LES comparisons, which do not agree so well near the injector tip. Given the challenges in this multi-dimensional domain, the reviewer wanted to know if the team has or will, consider zero dimensional (0-D) or 1-D modeling strategies for spray penetration and evaporation rates. Having a physics-based correlation could be helpful for future reference including boundary conditions expanded beyond the six points chosen for this effort.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Technical progress has been quite substantial for this project, according to the reviewer. Each of the aspects of this project, from different labs, consists of both experiment and simulation, and progress toward the goals has been steady and consistent. The development of the 3-D LVF technique is key to quantifying future coordinated work and quantifying the understanding of these sprays for future combustion system development.

Reviewer 2:

Even though the project is in Year 2 of 4, the reviewer was hoping to see connections to the three major outcomes on Slide 3. There was very little mention of how this work specifically leads to improved knock tolerance, lean-dilute combustion (especially challenging during cold start), and emissions reduction. The reviewer asserted that the bridge from the current work to the final objectives should be made more explicit.

Further, the reviewer wanted to know if it might be possible to include a new metric or merit function, which evaluates either the model or experimental results to the resulting mixture preparation (and lack of liquid impingement).

Reviewer 3:

The reviewer said the project was able to pivot its efforts and make up for lack of experimental access were noteworthy. Moving to the modernized injection hardware as early as possible will help the project overall.

Reviewer 4:

Each of the individual tasks has made significant progress in the past year, and the reviewer stated that there are some key outcomes of the work that will have a high impact. These four, in particular, will likely have a high impact:

- First, the inclusion of new injectors into the project.
- Second, the LVF measurements at elevated pressures and temperatures. This development will be very useful for better understanding and model validation at realistic conditions, whereas this was very difficult with the X-ray techniques that had to be run at less realistic conditions. The reviewer suggested that it would be helpful to identify what role the X-ray measurements will have now that this capability is online at SNL.
- Third, the inclusion of nozzle geometry in the RANS simulation. This is a dramatic improvement in results and is a high-impact outcome that can be incorporated immediately in industrial-standard work to improve prediction. The reviewer opined that it would be good to see the team publish this somewhere like the Society of Automotive Engineers (SAE) with broad industry reach.
- Finally, development of the merit function. This is an important step toward synthesizing all the knowledge from the project. As mentioned in the AMR presentation, the reviewer stated that it would be nice to connect this merit function, which is spray-centric, with some of the larger system-level considerations.

Reviewer 5:

said it appeared to the reviewer that COVID-19 did impact some of the X-ray work at a minimum. It would be nice to have seen more LVF measurements at more operating conditions and possibly such measurements are in the background or will be undertaken this current year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination among team members seemed to be outstanding to the reviewer. The experiments and the simulations mesh well together and feed the input-output needs of each aspect. The results from each sub-project feed into the input of other sub-projects, leading to a high level of coordination and cooperation among team members.

Reviewer 2:

From the three spray talks, the collaboration appeared to be excellent to the reviewer.

Reviewer 3:

The reviewer found the spray team to be extremely well organized. The close coupling and coordination of efforts from ANL, ORNL, and SNL are commendable. The team also receives input from the AEC Memorandum of Understanding (MOU) and the Engine Combustion Network (ECN).

Reviewer 4:

As indicated in previous comments about the project structure, the reviewer said that there could be better coordination between the elements of the program, especially since there are simultaneously nice experiments and simulations being run. In particular, the Nek5000 development does not seem to be pulling much knowledge from the other pieces of the program. The reviewer stated each of the individual tracks is doing good things and all working toward the same goals, but it would be good for the team to establish tighter coordination when the new injectors come online.

Reviewer 5:

The reviewer recognized that the project solely includes national laboratories while collaborating with other partners, such as Industry participants and, in cursory fashion, universities. It would be nice to see more university involvement for augmenting measurements and analysis and, in addition, to grow the next generation of researchers.

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 state project ended.

Reviewer 1:

The reviewer said chasing a merit function is a laudable goal; however, it will be challenging to draw the line between what is "spray" versus what is "engine." However, it is only in reference to the influence upon engine combustion that the spray information has value. The selection of merit function parameters will be crucial to the future rationale for continuing this work. The move toward updated hardware is overdue and very welcome.

Reviewer 2:

The reviewer suggested that the project team please continue to be mindful of how this work can ultimately improve understanding as well as the practical challenges of cold-start mixture preparation and emission mechanisms (and knock control).

Reviewer 3:

The reviewer said obtaining shot-to-shot data sets will be very important, as well as multi-component fuels. Both are on the planned list.

Reviewer 4:

The future research is a continuation of the current work, and all the planned tasks are reasonable. It was unclear to the reviewer what the timeline is for these tasks. Based on the descriptions, it looks like this all might wrap up relatively soon. If so, it would be helpful to identify "success criteria" for the overall program and how it will be integrated into the greater PACE effort as well as industry practice. In particular, the merit function might be a good vehicle for that integration.

Reviewer 5:

The reviewer opined that one area that could use potentially more attention is consideration of simplified physics-based modeling strategies for spray penetration and evaporation rate, as previously noted above. Such a model could be very useful moving forward toward addressing boundary conditions beyond this current study.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, one of DOE's stated overall objectives is to better understand gasoline direct injection (GDI) sprays to support future high technology SI engines. This project fits very well into that category.

Reviewer 2:

The reviewer stated cold-start GDI challenge is great and is what keeps gasoline SI engines from being nearly zero emissions (not including CO_2). It is agreed that a fundamental knowledge base is first required, and this fact is important. Hopefully, from this knowledge base, creative technical solutions can be discerned.

Reviewer 3:

The reviewer said clarifying the fundamental understand of these spray processes will enable improvement to GDI engine concepts, enhancing energy efficiency and reducing emissions for the majority of on-road vehicles.

Reviewer 4:

The components of the project all meet the goals of the PACE program, and hence DOE objectives. The reviewer found that there is good transferability to industry, particularly through the RANS developments, and the diagnostics that are being developed at SNL could be used to meet DOE objectives on this program and others.

Reviewer 5:

The reviewer commented that the project supports DOE goals for ICEs. Its focus should lead toward better understanding of improving spray formation control for possibly operating more dilute, better controlling emissions under cold conditions, and possibly improving ITE.

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 excellent and appear to be fine.

Reviewer 2:

Resources for the team to achieve future milestones and objectives appeared to be sufficient to the reviewer.

Reviewer 3:

The reviewer stated resources are sufficient and the project is on schedule.

Reviewer 4:

Provided the upgraded injector hardware can be procured economically, the reviewer commented that the team appears to have the required resources.

Reviewer 5:

No comment was indicated by this reviewer.

Presentation Number: ace144
Presentation Title: Spray Wall Interactions
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

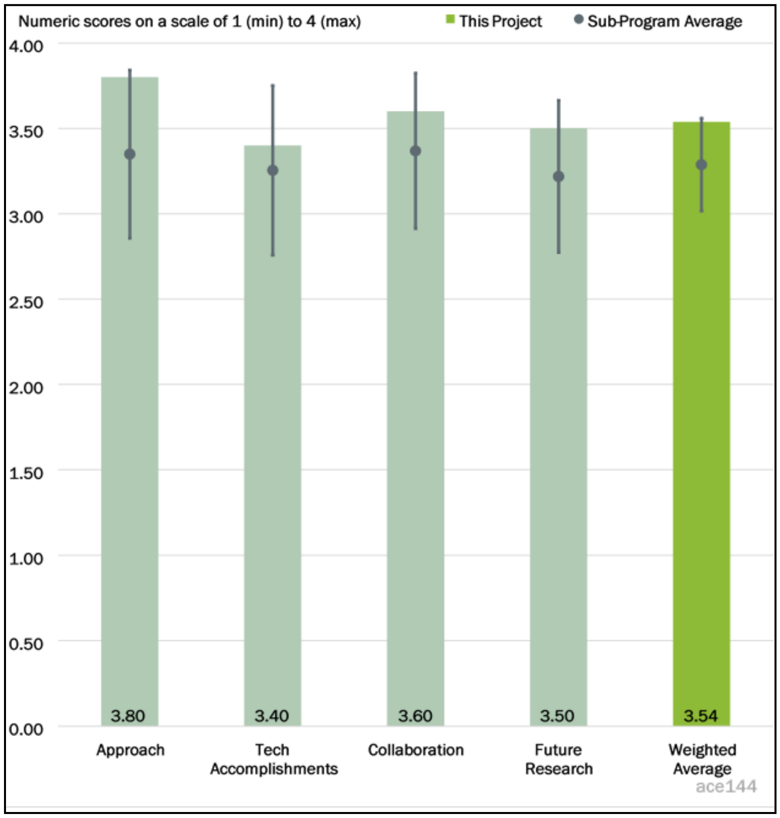


Figure 1-24 - Presentation Number: ace144 Presentation Title: Spray Wall Interactions Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter

Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

ACE144 seemed to the reviewer to have all the right elements to an outstanding approach by linking to the PACE Consortium goals and having multi-lab coordination in experimental and computational endeavors. The approach to break down the very complicated spray-wall interaction (SWI) physics is the clearest path forward. Additionally, the reviewer asserted that the use of unique capabilities from the labs (neutron imaging, high-fidelity simulations, HPC, etc.) is also outstanding.

Reviewer 2:

The reviewer praised the project as outstanding as the scientific study of cold engine in-cylinder liquid films is incredibly challenging. The fundamental approach currently being applied is excellent.

Reviewer 3:

The reviewer commented that the project uses established and novel techniques to investigate the important SWI and is a well-designed project.

Reviewer 4:

The reviewer found this to be a very useful approach to use multiple experimental pathways to gain insight into physical behaviors to compare to simulation results.

Reviewer 5:

According to the reviewer, the project's work does very well to address the major technical barriers and understand the complex spray-wall interactions that can occur in engines. A minor suggestion would be to somehow use dimensional analysis or scaling analysis to establish applicability of the results to a broader spectrum of engine conditions and fuels. For example, the reviewer inquired as to whether the models being developing could ultimately be used for diesel engines.

The reviewer suggested that the work by Ketterer at the Massachusetts Institute of Technology (MIT) roughly 5-10 years ago seems like it may be relevant to this work. If the PIs are not familiar with this work, it may be worthwhile to examine it.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The accomplishments by the project teams were very impressive to the reviewer, and moreover the team did very well to adapt and prepare in light of COVID-19-related impacts. The insights into double injections were particularly interesting for this reviewer.

Reviewer 2:

The reviewer found that the project's progress is excellent and tasks were completed as expected.

Reviewer 3:

According to the reviewer, the project made very relevant progress in identifying shortcomings in simulation predictions that should lead to improved spray behavior models.

Reviewer 4:

The reviewer stated that the accomplishments and progress are good. Even though the project is in Year 2 of 4, the reviewer was hoping to see more connections to the three major outcomes on Slide 3. There was very little mention of how this work-in-progress leads to improved lean-dilute combustion (especially challenging during and after cold start) and emissions reduction. The reviewer suggested that the bridge from the current work to the final objectives should be made more explicit.

Reviewer 5:

The reviewer noted that the project is complex and large with many areas which achieved progress. The fact that six of the seven milestones were completed or are on track is evidence of this progress and technical accomplishment. The reviewer said new experimental spray chamber upgrades at ORNL, ANL, and SNL show good progress as does ANLs completed splashing criterion SWI model implemented in a UDF. The additional diagnostics progress to quantify and speciate films is also encouraging.

The reviewer did not completely understand the OEM view of the importance of more understanding or better simulation of SWI during cold start. The reviewer asked if this increased effort was foreseen to still be needed within the PACE program, given future emissions regulations and the strong shift toward electrification. Does hybridization of ICEs make cold start more important with more frequent engine starts-stops?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

From the three spray talks, the collaboration appeared to be excellent to the reviewer.

Reviewer 2:

The reviewer commented many entities involved in the project collaborated well toward the project goal.

Reviewer 3:

The reviewer remarked that the PACE program has provided a great framework for collaborations between labs and facilities.

Reviewer 4:

As stated before, the clear multi-lab coordination was evident to the reviewer, and the alignment to PACE seems to be driving the right focus of the teams.

Reviewer 5:

According to the reviewer, the projects are well coordinated with each other. It would be good to try to involve industry a bit more beyond the ECN, even if it were only in an advisory fashion.

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 state project ended.

Reviewer 1:

Future research was logical to the reviewer.

Reviewer 2:

According to the reviewer, increased fuel pressure studies are of interest to industry.

Reviewer 3:

The proposed research is sound and logical. The reviewer thought that it will be particularly important to focus on a wide range of wall temperature conditions in the future as spray-wall interactions can be very non-linear as wall temperature varies (e.g, see the Leidenfrost effect).

Reviewer 4:

The reviewer asserted that the proposed future work is outstanding, and the proposed modeling and experimental efforts appear to be very appropriate. However, the reviewer’s only concern is that many GDI engines use side-mounted injectors. Perhaps the continuous (upward airflow) experiments will provide insights into the effect of gravity on vertical fuel films (not sure if this is important over the time scale of cold-start engine cycles; however, cold engine oil dilution by fuel can and does occur). Also, the reviewer asked if the project team has any thoughts on the second cold-start cycle.

Reviewer 5:

The reviewer said the future research proposed is clear and seems like the natural extension of the in-flight work. Specifically, the execution of the SWI experiments, film thickness quantification, experiments with the new GDI injector, and trying to match the simulations to the new data should move toward the PACE goal of being able to understand and accurately simulate cold-start engine physics and emissions. Maybe it is detailed within the PACE workflows, but there must be other downstream work to go from an accurate simulation prediction of SWI and the subsequent combustion and engine emissions. The reviewer asked the project team for help in orienting the reviewers as to the relative importance of the SWI understanding and modeling deficiency toward this PACE goal of minimizing tailpipe emissions and cold-start simulation. The reviewer wanted to know whether SWI is less or more important than kinetics, thermal boundary conditions, in-cylinder flows, and combustion.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project ultimately aims to develop tools to help reduce emissions from engines, and thus it supports DOE objectives.

Reviewer 2:

The reviewer affirmed that, yes, this project's support is aligned to the PACE program and the goal of enabling fuel-efficient, clean, cost-effective ICEs.

Reviewer 3:

The reviewer said cold-start GDI challenge is great and is what keeps gasoline SI engines from being nearly zero emissions (not including CO_2). It is agreed that a fundamental knowledge base is first required, and this fact is important. Hopefully, from this knowledge base, creative technical solutions can be discerned. While not directly related to this specific project, the reviewer encouraged an awareness and possible consideration of alternatives. For example, a number of newer engines were seen applying both PFI and GDI together to improve cold-start mixture preparation as well as high-load engine knock.

Reviewer 4:

According to the reviewer, an understanding the spray-wall interaction is a necessary step in designing more efficient engines with lower emissions.

Reviewer 5:

Fuel spray simulation is a fundamental building block for engine combustion simulations and must be improved in order to design better engines. The reviewer noted that improved models will help engineers make engines more efficient.

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 resources are adequate for completing the planned tasks within the planned timeframe.

Reviewer 2:

Resources appeared to be fine to the reviewer.

Reviewer 3:

Resources seemed sufficient to the reviewer for this project.

Reviewer 4:

The reviewer said the project is doing critical work that should be accelerated with additional resources.

Reviewer 5:

The reviewer commented that laboratories, computational resources, and staff seem appropriate, and the pacing item seemed to be delays from COVID-19 restrictions.

Presentation Number: ace145
Presentation Title: Cold Start Modeling and Experiments for Emissions Reduction
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

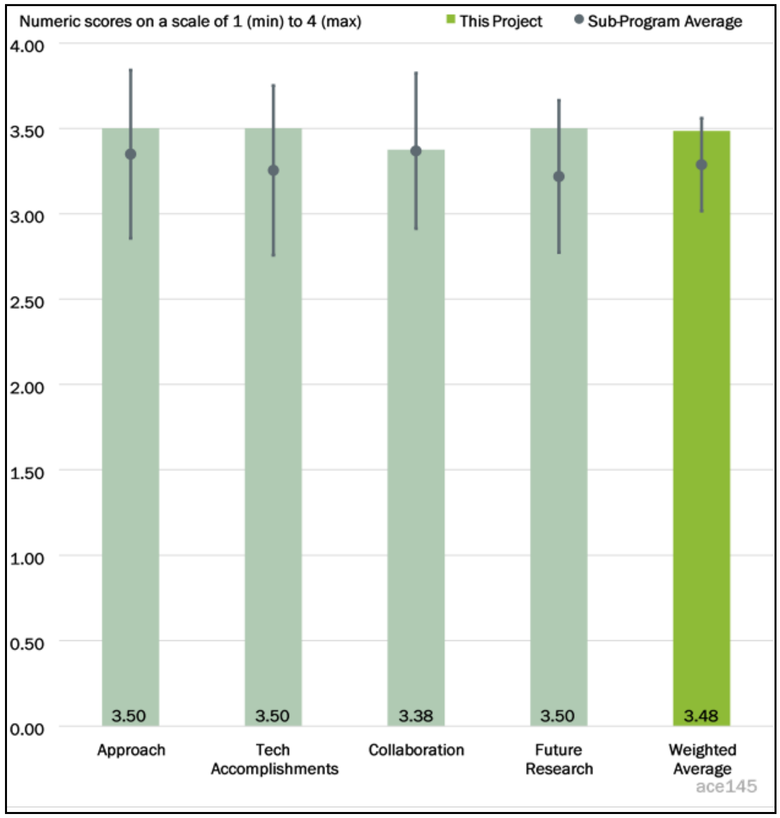


Figure 1-25 - Presentation Number: ace145 Presentation Title: Cold Start Modeling and Experiments for Emissions Reduction Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter

K. Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer suggested that, for the cold-start data, the team should consider using the fuel mass (or airflow if A/F mixture remains constant) as the control variable. Spark location, exhaust temperature, emissions all become responses. It is fuel flow that correlates most closely with exhaust temperatures and thus catalyst heating rate, which makes it the best independent variable. Stating that retarding the exhaust cam improves heat flux, while true, is only because more fuel is being injected. It would be far more insightful, the reviewer opined, to be able to say that at a given injected fuel mass, the chosen approach (injection timing, cam settings, and engine speed) improved emissions, exhaust temperature, or engine stability. Spark location can be used as an indication of burn rate. The reviewer said methods that achieve faster burn rates will have more retarded spark and vice versa.

The reviewer asserted that the neutronic engine is wild. Getting thermal boundary conditions for the engine start conditions is an important step and worth the effort.

Reviewer 2:

The reviewer stated that this project is focused on modeling and experiments to improve emissions from cold start. The highly-collaborative approach leverages expertise across multiple labs and teams. The reviewer further described the project as well designed, feasible, and very important during the move toward cleaner engines.

Reviewer 3:

The reviewer believed that it is a very well-designed approach to obtain solid validation data in the fired engine cylinder to benchmark models. However, presentation of the approach is confusing and needs to be better laid out. The reviewer acknowledged these types of data are highly valuable and difficult to obtain. The neutronic engine is a solid approach for performing measurement of large-scale object, like an engine.

Reviewer 4:

According to the reviewer, this is an extremely good project that ties neutronic engine measurements, multi-cylinder engine testing and simulations for quantifying/measuring and modeling/simulating cold-start emissions, which are critical. The question that needs to be answered is how relevant and useful the measurements from the neutronic engine will be for “real-world” conditions and how many measurements can be made since the beam is stationery and engine needs to be rotated. Coolants used are also differently. The reviewer suggested that a transfer function from these engine measurements to the multi-cylinder engine testing needs to be evaluated based on dimensional and scaling analysis or other methods for better validation and utility of the data.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found great progress toward modeling of cold start.

Reviewer 2:

The reviewer remarked that the engine-out soot data are very interesting and useful.

Reviewer 3:

This reviewer explained that the project has met or is on track to meet all of its major milestones on both the hardware side (neutronic engine design, etc.); experimental side (validation data); and modeling side (identifying gaps and needs for cold-start modeling, spray modeling with flash boiling phenomena, CHT for improved boundary conditions, etc).

Reviewer 4:

According to the reviewer, the technical accomplishments and progress seem to be in line with the schedule. For the CFD results, mixture fraction evolution during cold start should be shown along with vapor penetration to understand the fundamental mechanisms of combustion and emissions formation, especially with multi-component vaporization being predicted. The reviewer wanted to know how the model predicts soot attributed to wall wetting and whether that can be matched with the experimental results. The team should also think whether some of these results could be translated for engines employing thermal barrier coatings and its impact on fuel efficiency and exhaust temperatures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

As in all aspects of PACE, the reviewer found great collaboration.

Reviewer 2:

The reviewer said, though much of the work is spearheaded by ORNL, the complex chart with push pins shows how it is all tied together with other national laboratory work. OEM involvement will be important, and this work is critical for OEM engine development.

Reviewer 3:

Although this specific project is under ORNL, the reviewer stated that it is part of the overall PACE project that includes all of the national laboratories, OEMs, and software vendors. For the cold start modeling efforts, researchers from ORNL, LLNL, SNL, and ANL are all bringing their expertise to help attack this difficult problem.

Reviewer 4:

There are some collaborations and interactions between labs, but it was not entirely clear to the reviewer how they connected. A better presentation of the story and between teams will 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. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer observed clear and relevant future research, including modeling efforts (both performing simulations and implementing improved models) and a transition to the PACE common engine.

Reviewer 2:

The reviewer was looking forward to the MCE EcoBoost™ installation.

Reviewer 3:

The reviewer asserted that the proposed next steps are critical for accomplishing the goals of this project, especially the CHT runs. CFD modeling of soot will be critical to knowing the limitation of existing soot models.

Reviewer 4:

According to the reviewer, the proposed work is solid but needs to better coordinated between teams and labs.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

PACE goals directly support OEM goals of improving efficiency and emissions. When successful, the reviewer indicated that commercialization is likely.

Reviewer 2:

According to the reviewer, the cold-start effort is highly relevant, and it is very important to address the major emission issue and some design challenges.

Reviewer 3:

The reviewer opined that the project is doing very important work at accurately quantifying cold-start performance and emissions; this level of detail has not been done before.

Reviewer 4:

The reviewer asserted that this project supports the overall DOE objective of more efficient and cleaner engines. Cold start is the primary source for criteria pollutants for modern engines; so, this is a key area to work on.

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 resources are sufficient if maintained at the current level.

Reviewer 2:

The reviewer said the resources are deemed sufficient for this work.

Reviewer 3:

The reviewer stated the resources are reasonable and encourages better coordination with other labs.

Reviewer 4:

This reviewer described resources as sufficient.

Presentation Number: ace146
Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes
Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Presenter

Muhsin Ameen, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

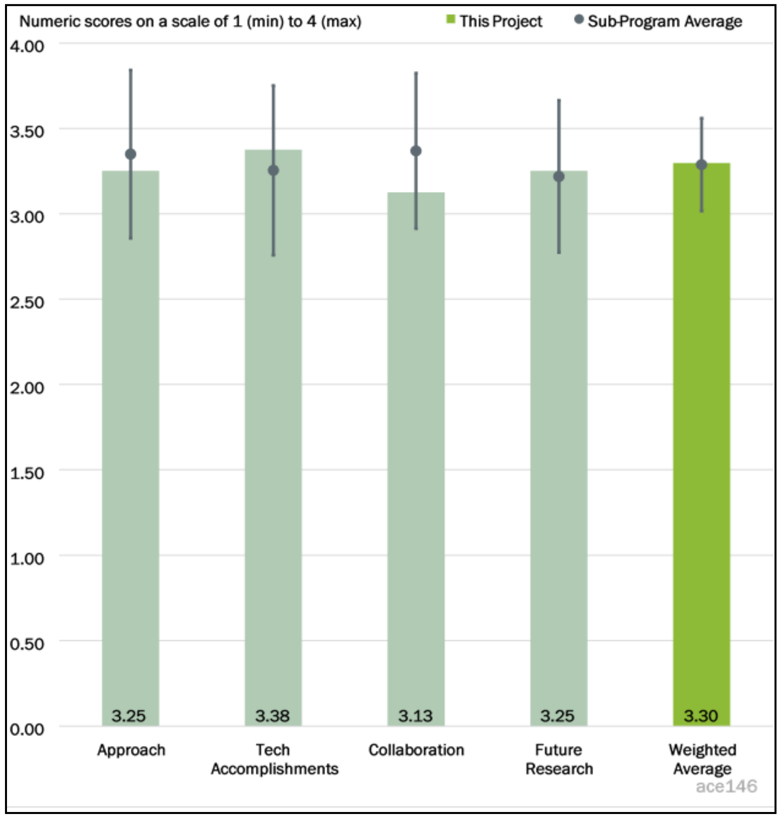


Figure 1-26 - Presentation Number: ace146 Presentation Title: Direct Numerical Simulation (DNS) and High-Fidelity Large Eddy Simulation (LES) for Improved Prediction of In-Cylinder Flow and Combustion Processes Principal Investigator: Muhsin Ameen (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of using and developing high-fidelity codes Nek5000 from ANL and S3D from SNL for accurate simulation of SI engine flow and combustion seemed fine to the reviewer.

Reviewer 2:

The reviewer noted that the project uses high-fidelity simulation tools and DOE leadership-class machines to develop accurate sub-models to improve understanding of in-cylinder combustion, knock, flame-wall interaction, heat transfer, and cycle-to-cycle variation.

Reviewer 3:

The approach looked valid to the reviewer, but it is not very clear what benefit Nek5000 is supposed to bring. Nek5000 is not an affordable solution for automotive industry.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project made significant progress in demonstrating the need for high-fidelity simulations to capture cycle-to-cycle variation (CCV), using high-fidelity simulations to provide insights on wall boundary layers and turbulent kinetic energy distribution, DNS on motored engine flows with experimental validation and improved high-temperature models, and two-dimensional (2-D) DNS of knock and detonation under boosted GDI engine conditions.

Reviewer 2:

The reviewer said it was a good idea to couple an engineering LES solution of open-cycle from the commercial CFD code CONVERGE with a high-fidelity LES solution of closed-cycle from Nek5000. However, the impact of the initial flow field from the engineering LES solution on further development during the compression stroke needs more study.

The reviewer noted that the project team solved DNS of compression/expansion motoring strokes on a transparent combustion chamber (TCC-III) engine at 500 revolutions per minute (rpm) and validated flow field and heat flux at a position on the cylinder head, which showed a reasonable match with the experiment.

The reviewer commented that spray sub-models and the ECFM combustion are implemented in Nek5000 and verified if the models work properly.

Reviewer 3:

Given the goals and the approach, the accomplishment is solid, but the positioning and usage of Nek5000 was unclear to the reviewer. The reviewer wanted to know what the primary use of Nek5000 is where there are DNS, LES (engineering level) and RANS and whether these tools provide a clear benefit to the industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found excellent collaboration across the project teams, as well as with external collaborators.

Reviewer 2:

The reviewer stated that overall, collaboration with PACE project teams and various external organizations seem good, but was somehow limited to all Nek5000-related.

Reviewer 3:

The DNS and the high-fidelity LES did make good accomplishments; however, it was not clear to the reviewer how they are leveraging each other. Slide 21 mentions that high-quality simulation data sets will be used to develop improved sub-models. A comprehensive plan is 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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the future work is well planned to address barriers to better understand the dynamics of A/F mixture preparation and stochastic combustion problems, such as CCV, misfire, and knock.

Reviewer 2:

All the proposed future work looked reasonable to the reviewer as it focuses on spray and combustion model implementation in Nek5000.

The reviewer opined that a very long simulation time and difficulties in meshing a real engine geometry with intake and exhaust manifolds and swirl or tumble control valves will make Nek5000 very difficult to make a tool for future handling of open-cycle flow simulation.

Reviewer 3:

The list of proposed research items looked reasonable to the reviewer, but the Nek5000 work seems to be a continuation of model implementation. The reviewer was afraid that, given the model development pace, it may be a little hard to keep it up with the paradigm shift (electrification).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project is relevant to and supports DOE objectives by developing a better predictive tool for engine development further optimized for highly transient and unstable operating conditions.

Reviewer 2:

The reviewer commented that the project supports PACE in developing accurate sub-models for in-cylinder flow, combustion, heat transfer, and combustion stability.

Reviewer 3:

The reviewer noted that the project is aligned in support of overall DOE objectives for clean and efficient transportation.

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 computer resources seemed insufficient.

Reviewer 2:

It appeared to the reviewer that the project has sufficient resources.

Reviewer 3:

The reviewer said the project has sufficient resources to achieve the stated milestones in a timely fashion.

Presentation Number: ace147
Presentation Title: Mitigation of Abnormal Combustion
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

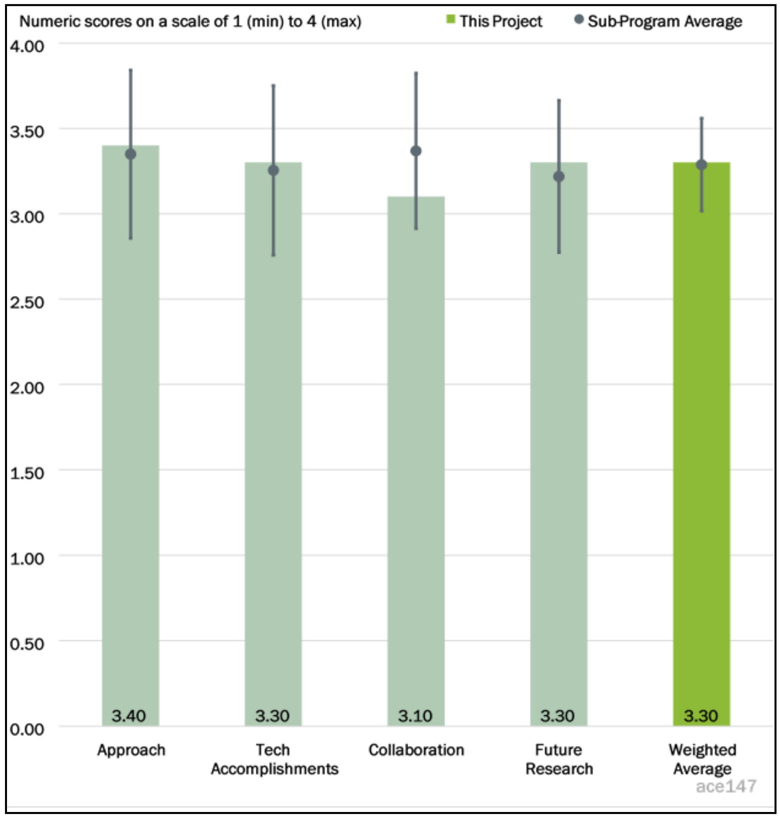


Figure 1-27 - Presentation Number: ace147 Presentation Title: Mitigation of Abnormal Combustion Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the three tasks that were reviewed are more or less unrelated: each task individually is well approached and planned to address key technical barriers and understand the fundamentals of the problems being examined.

For the stochastic pre-ignition (SPI) task, a comment is that the nitric oxide (NO)/nitrogen dioxide (NO_2) hypothesis is very interesting and could explain the commonly observed trend that SPI is more likely under slightly lean conditions (where oxides of nitrogen [NO_x] levels tend to be slightly higher). This is outstanding work by the project team to develop and plan to test that hypothesis.

Reviewer 2:

The reviewer stated that this is a creative approach to investigation of the notoriously difficult topic of pre-ignition.

Reviewer 3:

This reviewer remarked that technical barriers are addressed for the project, which is well-designed and feasible.

Reviewer 4:

According to the reviewer, low-speed pre-ignition (LSPI) is an ongoing challenge for industry. This work provides insight into processes leading to LSPI that continue to be important. The approach of focusing on fuel-oil interaction is appropriate, although over-reliance on a technique that measures bulk oil dilution could be misleading, as dynamics in the ring-pack could differ from what is seen as the oil returns to the reservoir.

The application of machine learning (ML) or other predictive models to combustion systems, such as abnormal combustion in spark-ignition (SI) engines, is a worthwhile research endeavor that has a low probability of success, but a high payoff if successful. The reviewer said that the approaches described herein are sound and appropriate but should also make use of learnings from previous efforts in this area from combustion researchers outside of the DOE laboratories.

Reviewer 5:

The reviewer remarked that this report details an ongoing research project in combustion abnormalities including stochastic pre-ignition.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer called the accomplishments of all three tasks impressive and stated that each of the individual projects has done an excellent job of explaining the observations the project team has made.

Reviewer 2:

This project continues to show good progress, according to the reviewer.

Reviewer 3:

The reviewer reported that this project is on track to meet all milestones for FY 2021, including tasks on the impact of spray wall wetting on LSPI, knock mitigation through EGR, and applying machine learning to evaluate the dynamics of abnormal combustion.

Reviewer 4:

The reviewer commented that Task O.E.09.01 continues to demonstrate progress in isolating and quantifying mechanisms, such as fuel impingement that may lead to LSPI.

Task O.E.08 demonstrates strong initial progress toward developing the datasets needed to train models for abnormal combustion prediction, as well as the ability to detect pre-ignition prior to the occurrence of “super-knock.” This progress sets the stage for the next stage of the project, where this information will be leveraged to attempt to inhibit the process, once detected.

Task O.E.02 accomplishments focused on the installation of a new experimental apparatus, but the reviewer noted that the project team was unable to demonstrate results in time for the Annual Merit Review (AMR).

Reviewer 5:

There are some interesting results and root cause speculation from the fuel impingement study, and the reviewer looked forward to NO/NO_2 experiments. The reviewer stated that the claim of “ML Approach Shows Promise for Knock Prediction” is not well substantiated with results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that specific collaborations exist both between the tasks within PACE and with industry partners. This helps both PACE objectives of scientific advancement and transfer of knowledge to industry.

Reviewer 2:

This project is part of the PACE program, which the reviewer indicated is a collaborative effort across multiple national laboratories. There is also significant collaboration with industry (Lubrizol and GM).

Reviewer 3:

The reviewer reiterated that the three tasks and projects are distinct. The collaboration and coordination of the projects with the overall Partnership to Advance Combustion Engines (PACE) effort appears to be very good. It would be helpful to have some industry engagement on the machine learning effort in the future, even if only in an advisory fashion.

Reviewer 4:

The reviewer stated that this project is predominantly Oak Ridge National Laboratory (ORNL) only.

Reviewer 5:

The reviewer suggested that simulation for the SPI project should be expanded to investigate some of the chemistry ideas in support of the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the proposed future research across all tasks is appropriate and very much in line with the overall goals of the tasks and the PACE program.

Reviewer 2:

The reviewer said that the proposed future work is a progression of the previous work. The addition of the next-cycle control is a useful adjunct.

Reviewer 3:

Future work was described by this reviewer as well-thought-out and presented. Challenges and barriers are also addressed and documented.

Reviewer 4:

According to the reviewer, all of the proposed future work is sound and logical. For the SPI effort, it might be good to include in the future work an explicit comparison and/or evaluation of the fuel-in-oil from the diagnostic method being used to other methods. This seemed to be implied as being part of the work, but an explicit focus on it might be helpful.

Reviewer 5:

Fuel-spray wall wetting may be a contributor to SPI, but the reviewer remarked that it may not be the only root cause. There is a need to expand the scope of this project to investigate other potential root causes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that improving SI engine efficiency by allowing engines to operate closer to the knock margin is a very useful objective.

Reviewer 2:

The reviewer commented that abnormal combustion (mainly knock and LSPI) is a barrier toward increased efficiency in SI engines. A project that addresses this definitely supports the overall DOE objectives.

Reviewer 3:

The reviewer noted that all three efforts aim to enable more efficient engines and thus are in support of U.S. Department of Energy's (DOE) objectives.

Reviewer 4:

According to the reviewer, pre-ignition can limit engine efficiency at some conditions so understanding it better will help engineers design better engines that are more efficient.

Reviewer 5:

The reviewer commented that the tasks reviewed here all directly support DOE's goals of supporting the continued development of next-generation, high-efficiency internal combustion engines that will lead to improved vehicle fuel economy and reduced emissions.

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 resources are sufficient, as long as funding is not reduced going forward.

Reviewer 2:

The reviewer said that ORNL is performing most of the work and the budget seems appropriate.

Reviewer 3:

The reviewer noted that the project teams all have adequate resources for reaching the stated goals in their respective timeframes.

Reviewer 4:

The reviewer found that resources for the projects are sufficient to continue to make progress commensurate with the goals and PACE timelines.

Reviewer 5:

According to the reviewer, resources should increase for the SPI project so that researchers can finally determine a root cause for the phenomenon.

Presentation Number: ace153
Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control
Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

Presenter

Melanie Moses-DeBusk, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

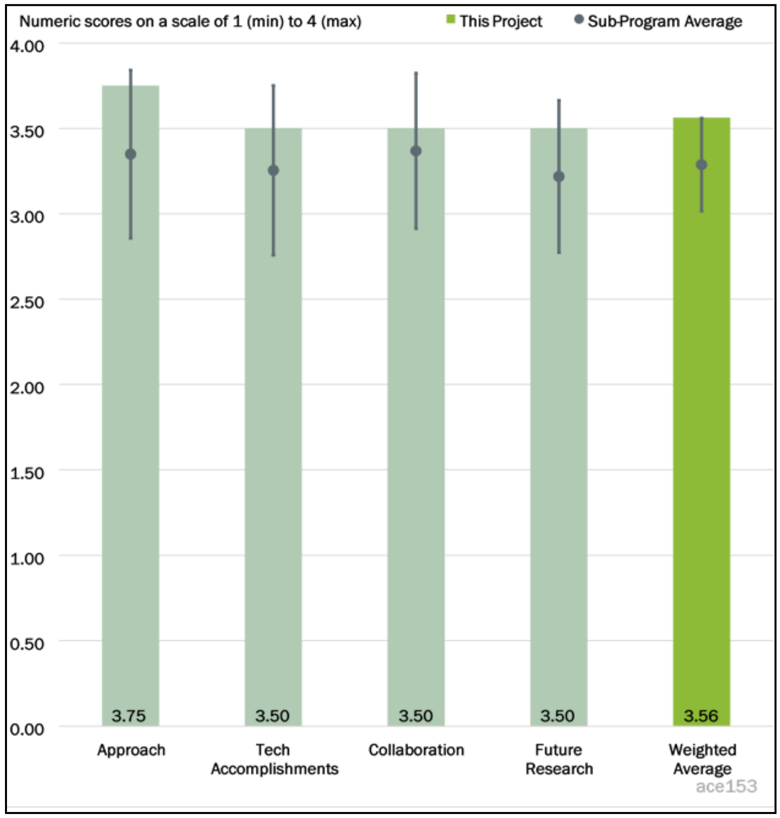


Figure 1-28 - Presentation Number: ace153 Presentation Title: Chemistry of Cold-Start Emissions and Impact of Emissions Control Principal Investigator: Melanie Moses-DeBusk (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer believed that the progress on this project has been excellent and has been very well designed and especially looked forward to the data on hybridized vehicles.

Reviewer 2:

The proposed approach is appropriate as hydrocarbon (HC) traps are a potential emissions control solution option for reducing cold-start hydrocarbon emissions. The reviewer noted that the project targets speciation of cold-start HC emissions from consumer, on-road vehicles. Specifically, vehicle platform (model year [MY] 2018 gasoline direct injection [GD] pickups) and chassis dynamometer test cycles (cold start [CS] and New York City Cycle [NYCC]) represent a relevant and challenging test environment.

Reviewer 3:

This is a thorough on-vehicle speciation work for HC traps. This should foster future HC trap development and optimization.

Reviewer 4:

There was a good choice of high-volume vehicles with significant challenges to achieve lower tailpipe emissions, according to the reviewer, who suggested that it would be beneficial to include both the Federal

Test Procedure (FTP) and the low speed NYCC to probe the feasibility of the technology in real world applications. It would be helpful to explore more realistic aging temperatures (700°Celsius [C] is very mild even for underfloor location or hybrid application).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project is on schedule and passes all of its necessary performance indicators. The dissemination of information through manuscripts, presentations, and databases will be important for the field.

Reviewer 2:

The review noted that there was excellent progress, especially with the HC speciation data. The challenge is how to best utilize the large amount of data to help develop a better HC trap and/or a better mathematical model.

Reviewer 3:

The reviewer observed good technical accomplishments in terms of understanding the effectiveness of HC traps and the addition of gasoline particulate filter (GPF) on the -cold-start emissions (especially on bag 1 and first 250 seconds of it). The reviewer also noted use of Fourier-transform infrared spectroscopy (FTIR) analysis methods to characterize the impact of the same aftertreatment combinations (compared to the three-way catalyst baseline) on non-methane (NM) paraffins, particulate matter and particle number.

Reviewer 4:

According to the reviewer, overall progress appears to be going well, with all milestones met or on target.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration is well organized as it includes informal technical advisors from Ford (original equipment manufacturer [OEM]) and Umicore (supplier) as well as participation in Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS) (sharing results with national laboratory researchers). Umicore also provides HC traps and gasoline particulate filters (source of new and used filters).

Reviewer 2:

The team is quite strong, with ORNL, Umicore, and Ford—a national laboratory, coater, and OEM—as well as the CLEERS and U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) communities.

Reviewer 3:

There appears to be strong collaboration between ORNL, Umicore, and Ford.

Reviewer 4:

The reviewer stated that the project team is excellent, with complimentary capabilities and skillsets (national laboratory, suppliers, OEM). It will be good to show the generated HC speciation results that could lead to better HC trap design; ultimately, catalyst suppliers need to further develop the HC trap technology for improved performance and durability. The reviewer suggested that collaboration with a modeling team could also be beneficial.

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 state project ended.

Reviewer 1:

While all milestones except submitting a manuscript have been met for this 3-year project (Fiscal Year [FY] 2021 is the last year), the reviewed opined that the proposed future work, while very relevant, is likely outside of the current scope (unclear from the Remaining Barriers and Future Work slide).

Reviewer 2:

The reviewer stated that there was a good plan to evaluate the HC performance under the low-speed NYCC and it will be beneficial to add another aging temperature if possible (800℃ or 900℃). It will also be helpful to put various HC species into three different buckets—not absorbed, absorbed and released, and absorbed and converted. This exercise may help HC catalyst design, and it may have implications on future fuel specifications to achieve near-zero emissions.

Reviewer 3:

As stated above, the reviewer was highly looking forward to data on hybridized vehicles. Stop-and-go data would also be incredibly useful.

Reviewer 4:

The reviewer stated that the future work looks interesting with expansion into stop-and-go and hybrid applications.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Per the U.S. DRIVE Advanced Combustion and Emission Control technical team roadmap, HC traps are important for controlling cold-start emissions from high efficiency engines to allow them to achieve the U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30 target. The reviewer commented that enablement of high efficiency engines directly contributes to reduction of imported petroleum use and carbon emissions.

Reviewer 2:

According to the reviewer, this project directly meets DOE objectives by providing fundamental understanding of speciation and targeted emissions reductions.

Reviewer 3:

The reviewer said that this project supports the overall DOE objectives by enabling technology development to reduce cold start emissions to meet stringent future regulations.

Reviewer 4:

The reviewer found that this project helps to reduce tailpipe emissions to improve air quality and address global climate change.

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 that the project has sufficient funding, especially since it should be coming to a close soon.

Reviewer 2:

According to the reviewer, this is a relatively well funded project at almost $500,000 per year over 3 years through a DOE VTO 2018 lab call.

Reviewer 3:

Sufficient resources were observed by this reviewer.

Reviewer 4:

Funding appeared to the reviewer to be sufficient. The team and facilities are well suited to the task.

Presentation Number: ace155
Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications
Principal Investigator: Qigui Wang (General Motors, LLC)

Presenter

Qigui Wang, General Motors, LLC

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

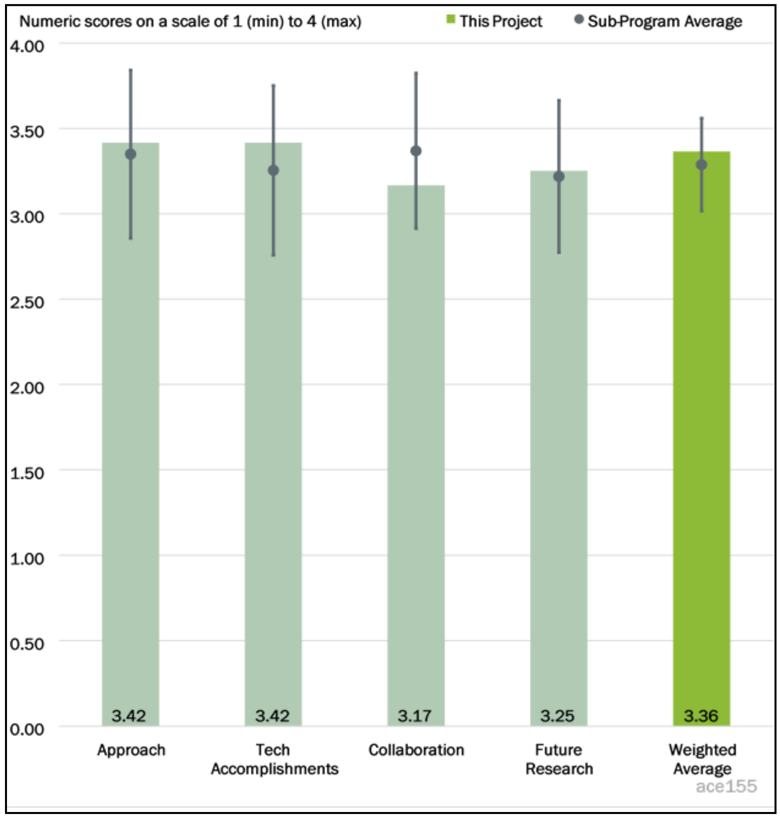


Figure 1-29 - Presentation Number: ace155 Presentation Title: Low-Mass and High-Efficiency Engine for Medium-Duty Truck Applications Principal Investigator: Qigui Wang (General Motors, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the approach to performing the work to be fine. It looked like the program team made good progress over the last 12-15 months, despite all of the disruptions of 2020.

Reviewer 2:

The reviewer said that the approach was nicely laid out in a flow chart on Slide 4. The decision to start with two engine options (V8 and 6 L) was interesting to see and showed that, had the metrics for success been different (absolute gains versus relative gains), a different solution may have been chosen.

Reviewer 3:

The reviewer stated that the approach of this project— developing techniques to use advanced combustion, lightweight materials, and manufacturing techniques to expand engine operating efficiency and to enable lighter weight engines for better performance and fuel economy—is feasible. The project has already shown good progress using this approach.

Reviewer 4:

The reviewer commented that the project is well planned and, given that it is near the end, expected that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 5:

According to the reviewer, the mass reduction approach is good and targets key areas of weight reduction opportunities. Combustion development effort is interesting but not very different from previous programs from the organization.

Reviewer 6:

The reviewer really questioned the baseline for this project. A greater than 10% improvement in fuel economy compared to a 2015 engine seemed rather weak. Current Corporate Average Fuel Economy (CAFE) regulations require approximately 3.7% reductions every year, and this is already a 2015 engine so lots of improvements can be readily made. The reviewer suggested raising the goal to perhaps a 25% improvement.

The reviewer requested that the project team please include a cost assessment relative to baseline, especially since the team is choosing the V8 over the downsized engine based on cost effectiveness (Slide 9).

The reviewer did not see a major bottleneck that the team is trying to address. There seems to be a bunch of incremental improvements; while these are not trivial or easy, the reviewer asked if there were any element that is especially hard to achieve commercially. If so, that might be worth highlighting.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the work progress to be good for the past year, given the challenges of COVID-19.

Reviewer 2:

The reviewer asked why the project team chose the ultra-high pressure (P) injection at 1,000 bar and suggested also adding 600 and 800 bar to see if there is any significant improvement versus cost.

The reason for rejecting the 3.7L turbo engine was not quite clear to the reviewer. If cost effectiveness, it will be important to show the calculations to guide future projects.

Reviewer 3:

The approach taken to date seemed good to the reviewer, especially with the mid-point program gateway for the technology downselect leading into Phase II (Validation and Demonstration). The reviewer looked forward to seeing what the effective, net fuel consumption benefit will be when the technologies are combined in the engine.

Reviewer 4:

Although many accomplishments were highlighted, the reviewer commented that it was unfortunate that time did not allow for more depth of detail on these. The reviewer thanked the project team for including additional information on the technical accomplishments in the backup slides.

Reviewer 5:

The reviewer commented that the project has shown the potential of overcoming its stated barriers. Those barriers that need to be overcome in the upcoming year have clear pathways and approaches to allow for solutions.

Reviewer 6:

In the past few years, the reviewer has seen a decrease in evidence presented in these AMR reviews to confidently share that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good coordination of partners.

Reviewer 2:

The collaboration seemed good to the reviewer. It may be a bit early to judge based on limited results.

Reviewer 3:

It seemed to the reviewer like most of the work done to date has been performed by GM. As the team moves into Phase II, the reviewer would expect to see the engagement from the project partners step up considerably, given their focus on materials and manufacturing methods.

Reviewer 4:

It was interesting to the reviewer to note that all of the outside collaborations were on the Lightweight Materials & Manufacturing Solutions part of the project. The reviewer asked if there were a reason that the Advanced Combustion Technologies part of the project did not have collaborators.

Reviewer 5:

The reviewer found the team put together by GM to be impressive. The only thing that can be seen as a detractor is that the advanced combustion research side of the project has only one contributor (GM). This leads to the question of why that area is less of a focus area than the light weighting. The team could have used members from ORNL, Argonne National Laboratory (ANL), or Sandia National Laboratories (SNL) as well as several universities, to aid in the advanced combustion area.

Reviewer 6:

There seems little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed that there should be more effort on fleet and other engagements in these programs.

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 state project ended.

Reviewer 1:

The proposed future research is outstanding, and the reviewer looked forward to seeing the team’s progress next year.

Reviewer 2:

According to the reviewer, the plan going forward looks reasonable and thorough.

Reviewer 3:

The plan for completing the program looked sensible to the reviewer.

Reviewer 4:

The reviewer said there was a good plan.

Reviewer 5:

The reviewer stated that ongoing plans will be interesting to see.

Reviewer 6:

It seemed to the reviewer that there is relatively limited time— a year and a half— to complete the objectives, so it would be good to speed up (understanding that COVID-19 may have played a role). As mentioned previously, please include the impact of lower P injection to assess whether there is a diminishing return beyond 600 bar (which is commercialized).

Lots of work has already been done on dedicated exhaust gas recirculation (EGR). Please make sure that you address any real OEM concerns on barriers to commercialization.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the project targets are good and in line with DOE objectives as they were stated at the start of the project.

Reviewer 2:

The reviewer observed that the project addresses fuel economy improvements, a very important task ahead for transportation.

Reviewer 3:

The reviewer found that this project supports overall DOE objectives of reducing fuel use within the United States to conserve energy resources and looks to be making good progress toward that goal.

Reviewer 4:

Objectives were to improve engine efficiency and simultaneously reduce engine weight. The reviewer opined that this project achieves both while reducing the fuel consumed and the associated greenhouse gases (GHG).

Reviewer 5:

The reviewer commented that light weighting and advanced combustion are two areas that can increase a vehicle's fuel efficiency. The advanced techniques proposed are complex enough that manufacturers may shy away from investigating them if DOE were not there to help fund the research. This project supports DOE's objectives.

Reviewer 6:

The reviewed responded that the project somewhat supported DOE objects because the reviewer believed that battery electric vehicles (BEVs) will begin to dominate medium-duty (MD) trucks in the next few years, bringing into question significant investments in engines.

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

Reviewer 1:

Resources seemed fine to the reviewer.

Reviewer 2:

Resources looked sufficient to the reviewer.

Reviewer 3:

The reviewer felt that the project was generously funded, but not overly so.

Reviewer 4:

This reviewer observed appropriate resources for the goals that were set and the achievements made.

Reviewer 5:

The resources appeared sufficient to this reviewer.

Reviewer 6:

This reviewer stated yes.

Presentation Number: ace156
Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development
Principal Investigator: Michael Shelby (Ford Motor Company)

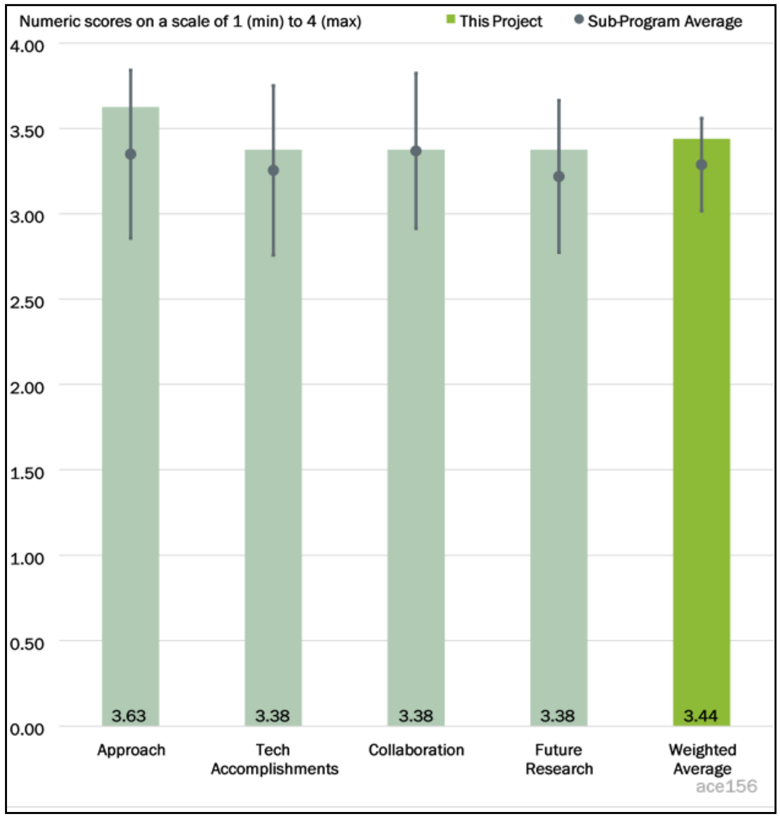


Figure 1-30 - Presentation Number: ace156 Presentation Title: Next-Generation, High-Efficiency Boosted Engine Development Principal Investigator: Michael Shelby (Ford Motor Company)

Presenter

Michael Shelby, Ford Motor Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

By focusing the projects approach on lightweighting and increasing the compression ratio through knock mitigation, dilute combustion, and thermal management, the reviewer pointed out that the project is attacking the critical barriers to increased fuel economy. The approach of using lean combustion and advanced ignition (active pre-chamber) is a solid approach.

Reviewer 2:

It looked to the reviewer like the technical team has taken a good approach to evaluate the two novel combustion systems in parallel to understand challenges and benefits of each.

Reviewer 3:

The reviewer commented that combining advanced computational fluid dynamics (CFD) with single-cylinder engine development and then moving to final multiple-cylinder engines is a technically sound approach and represents state-of-the-art technology development.

Reviewer 4:

This reviewer indicated that project goals are well clarified, but the focus is more evident in the combustion work than the weight reduction work. It was not clear to the reviewer that the weight reduction effort is as central to the project as it seemed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The single-cylinder engine (SCE) development and testing appear to have been delayed by a combination of COVID-19 capacity restrictions and "the usual" technical challenges encountered when dealing with new technologies. It looked to the reviewer like the team is making good overall progress against the timeline, especially with the multi-cylinder engine (MCE).

Reviewer 2:

The reviewer commented that the project team has shown mass reductions in parts between 20% -43% by using advanced materials and composites and making some of the parts structural components. The total of 17% reduction in mass (surpassing the goal) is an impressive feat.

The extension of the EGR limit by 10% should help mitigate knock, and the reviewer looked forward to seeing the results of the single- and multi-cylinder testing.

Reviewer 3:

According to the reviewer, progress is good on the combustion side. The weight reduction effort to date seems light relative to the time since the project award.

Reviewer 4:

Significant progress has been made on the analytical work and SCE developments. However, there has not been too much progress on MCE. One of the big concerns the reviewer had is weight reduction. Currently, the project may face challenges if the weight gain from EGR and cooling systems is added into the total weight reduction goal. It may be too late to have any hardware modification to the final MCE platform since time is running short before project completion at the end of 2022.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that Ford has put together an impressive team and the collaboration and coordination has so far paid off.

Reviewer 2:

The reviewer stated that project team coordination is much stronger this year.

Reviewer 3:

It looked to the reviewer like FEV has been brought in as a fully engaged partner after a slow start and that ORNL is meeting its obligations as well. The reviewer also thanked the team for highlighting how many additional (parts) suppliers are engaged in the technology evaluation and the multi-cylinder engine prototype build.

Reviewer 4:

While FEV and ORNL are mentioned, the reviewer suggested that other companies should be acknowledged as pointed out by the presenter: more than 20 additional companies are engaged in the development since the space of the presentation is not a limiting factor.

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 state project ended.

Reviewer 1:

The future work on this project looked sensible to the reviewer and achievable by the end of 2022.

Reviewer 2:

The reviewer commented that the proposed future work is tightly targeted at achieving the 15% mass reduction and 23% fuel economy improvement targets.

Reviewer 3:

The proposed future research seemed to be reasonable to the reviewer. It would be more thorough if research were done on how the risk can be mitigated after adding the weight from EGR and cooling system.

Reviewer 4:

The future plans are interesting. The reviewer remained unclear about the long-term potential for the projects under this DOE call.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the advanced technologies investigated in this project will reduce carbon dioxide (CO_2) emissions and increase fuel economy of the powertrains found in light-duty (LD) vehicles. This research can be applied across many, if not all, LD vehicle platforms and will lower overall foreign energy dependence.

Reviewer 2:

The reviewer found that the project is aligned with the DOE objectives of the time.

Reviewer 3:

According to the reviewer, the project supports the overall DOE objectives by improving the engine, thus vehicle, fuel economy.

Reviewer 4:

There is a pathway to improved engine fuel consumption with the engine technology packages being considered. The reviewer asked for clarification about whether the fuel economy target is CAFE (unweighted FTP-75 cycle and Highway Fuel Economy test [HFET]cycle only) or sticker (two or five cycles but weighted to predict the fuel economy seen by drivers). It may not make a difference so long as the baseline and improved values are being calculated the same way.

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 are good.

Reviewer 2:

It looked to the reviewer like the program is adequately funded for the scope of work.

Reviewer 3:

The reviewer commented that the project team should have all it needs to complete the project.

Reviewer 4:

While the budget looks large, the reviewer noted that it is not when you consider the number of prototype parts that must be designed and assembled for this project in order to perform the engine testing. This is an impressive undertaking.

Presentation Number: ace158
Presentation Title: Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach
Principal Investigator: Wei Li (General Motors, LLC)

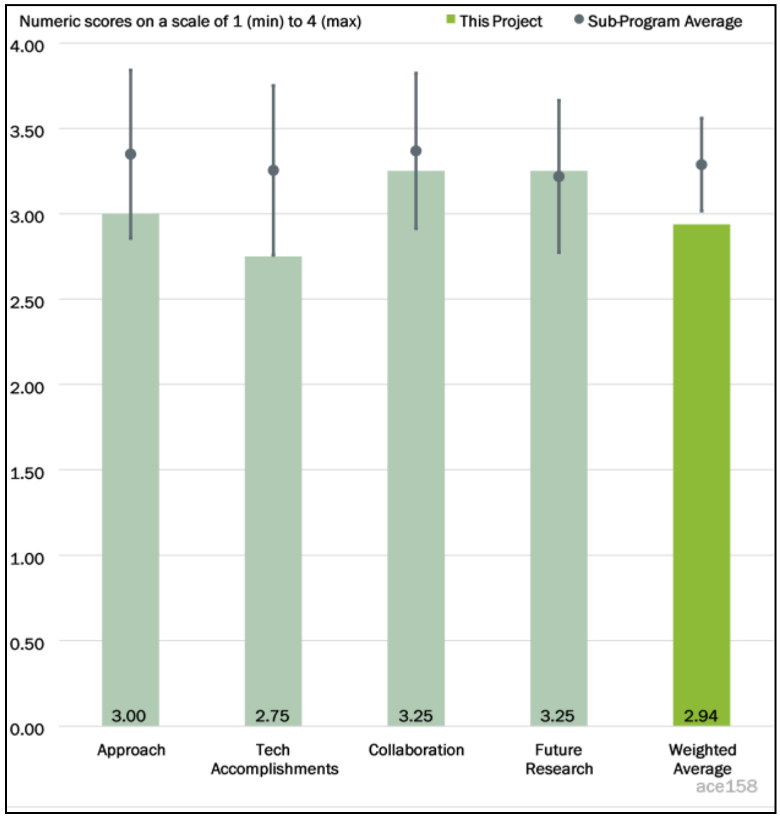


Figure 1-31 - Presentation Number: ace158 Presentation Title: Slashing Platinum Group Metals (PGM) in Catalytic Converters: An Atoms-to-Autos Approach Principal Investigator: Wei Li (General Motors, LLC)

Presenter

Wei Li, General Motors, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer understood that this project is in the early stages and probably also impacted by COVID-19. Having said that, the reviewer said that it will be good to broaden the baseline catalyst technology and asked several questions: Can another catalyst or vehicle combination be used to show the applicability of the technology to more than one catalyst? Is the catalyst currently zone coated? What about the impact of support (alumina, ceria, etc.) and substrate? Will sulfur resistance be included or should it be? Will oxygen storage be evaluated? There are many factors that need to be considered here.

Reviewer 2:

The reviewer appreciated the approach being deployed here, especially the aggressive aging procedure and recognition that single-atom catalysts have not shown high reactivity on their own (and thus they serve as agglomeration points). The reviewer thought that the starting point for the PGM loading for this project is also reasonable but was troubled by the two different projects using different starting points to show reduced PMG levels. Although the aging procedure is aggressive, the reviewer wondered if the project and community would benefit from a stepped approach to aging. With hybridization, it may be possible to limit high-temperature excursions, and the team could find a catalyst with ultra-low PGM that fails at 975°C. If the project team reports that this catalyst is good so long as this temperature is avoided, it would be good information to have.

Reviewer 3:

The reviewer stated that the approach briefly described the use of single-atom catalysts (SAC) and methods to slow platinum-group metals (PGM) sintering, which will help to reduce PGM use in three-way catalysts (TWC); however, limited details on this approach were given, making further assessment difficult.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that little to no details were given on results to date, making it difficult to evaluate technical progress. The early stage of this project at the time of these slides is likely the cause, and the reviewer looked forward to seeing more results under relevant conditions in next year's presentation.

Reviewer 2:

The reviewer stated that the project has essentially been planned out, but no experimental results have been obtained or presented; thus, it is difficult to fully assess the true progress.

Reviewer 3:

The reviewer commented that there was not much detail so far to make comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there was good coordination and task alignment to appropriate team partners. Partners are all well known for their respective capabilities.

Reviewer 2:

The reviewer remarked that this is an excellent team of researchers that brings a broad level of expertise to the project with extensive experience in emissions control research.

Reviewer 3:

The reviewer indicated that there is not much detail so far, but it looks like a good 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that a list of specific targets and go/no-go decision points was provided. Progress along this path will result in a successful project outcome.

Reviewer 2:

If successful, the proposed research will answer the question about viability of the TWCs developed here. As mentioned previously, the only concern the reviewer had was that the aggressive aging conditions may discard catalysts that may be of value if a lower temperature is not exceeded.

Reviewer 3:

There is a need to include the impact of sulfur resistance, washcoat support, substrate, oxygen storage, etc., to make this practical. Also, it was not clear to the reviewer whether the final goal includes coating on full-size monoliths and testing on a vehicle. That should be included.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that PGM prices are very high, and there need to be ways to reduce PGM usage.

Reviewer 2:

The reviewer pointed out that the project is specifically targeted at reducing PGM use by 50% in TWCs.

Reviewer 3:

Since indicators suggest severe PGM shortages are here to stay, the reviewer indicated that this research is important to alleviate these pressures and to identify solutions quickly.

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, funds are sufficient for this project.

Reviewer 2:

Resources seemed sufficient to the reviewer, and additional resources could be identified at the different industrial partners since this will likely affect their profitability.

Reviewer 3:

The reviewer encouraged the project team to please consider full monolith coating and vehicle testing (maybe already part of plan, but not clear).

Presentation Number: ace159
Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

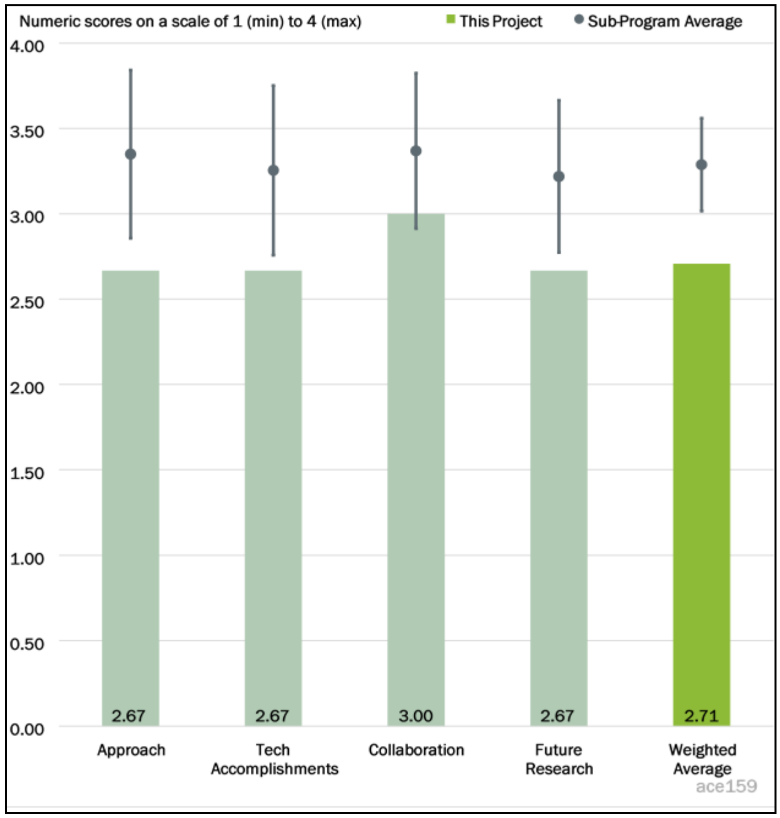


Figure 1-32 - Presentation Number: ace159 Presentation Title: Reduced Cost and Complexity for Off Highway Aftertreatment Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter

Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the approach good as it touches upon the main barriers and challenges for combining a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF). It might also be worth emphasizing soot management as it was not clear to the reviewer how much work will be done on evaluating regeneration under various conditions.

Reviewer 2:

According to the reviewer, the goal to reduce the complexity and cost of the emissions control system is an important one to pursue. However, the reviewer was not certain how the approach proposed will result in a functional device without some standalone DOC upstream of the DPF. If successful, the team will deserve a lot of credit for finding a solution to soot build-up on the front of the combined DOC and DPF (DOCF). The soot is a known inhibiting agent and will create issues, but perhaps there are solutions. With that being said, there was little discussion of this issue, and most importantly no plan to study this phenomenon on the bench reactor. It will only become an issue when moving to engine experiments later in the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It seemed to the reviewer that it is very early to comment on technical accomplishments, but the modeling work and engine selection look good so far.

Reviewer 2:

The reviewer understood that this project is just getting started and having results at this point would be difficult. However, this seems to build off work performed in a cooperative research and development agreement (CRADA), so it is not clear how this is differentiated from the CRADA and why the results from the CRADA could not be used here to indicate the direction of the research.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team seemed good to the reviewer.

Reviewer 2:

There are a lot of good team members listed in the project with a lot of relevant experience. The reviewer was curious to see how the implementation of the spatially resolved capillary inlet - mass spectroscopy (SPACI-MS) approach goes, as this complex research tool can be difficult to deploy, and the team is lacking experience in this 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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the future work is good. The inclusion of full engine testing is very good. The reviewer encouraged the project team to please consider soot regeneration as part of the test matrix.

Reviewer 2:

As discussed in the approach, the reviewer was concerned about not including soot in the bench reactor measurements. Ford researchers have reported a way to make particulate in flow reactors, and this should be considered.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

He reviewer stated that reducing cost and PGM usage is going to be important especially as we move toward tighter regulations.

Reviewer 2:

The reviewer indicated that off-road emissions are an increasingly important sector that DOE should be supporting in emission control research, and this project fits that mold.

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 is attempting to tackle a big problem from several fronts, and the level of support is sufficient to address the issues outlined.

Reviewer 2:

Resources looked sufficient to the reviewer.

Presentation Number: ace160
Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles
Principal Investigator: Zongxuan Sun (University of Minnesota)

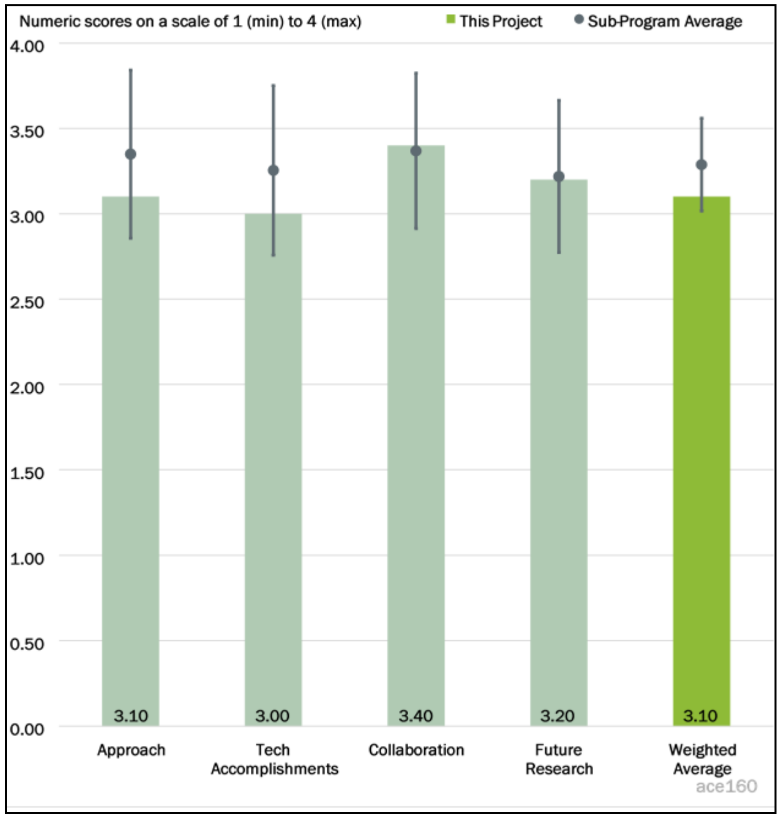


Figure 1-33 - Presentation Number: ace160 Presentation Title: Optimization and Evaluation of Energy Savings for Connected and Autonomous Off-Road Vehicles Principal Investigator: Zongxuan Sun (University of Minnesota)

Presenter

Zongxuan Sun, University of Minnesota

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked the way the project team presented the technical barriers of the engine's interaction with the propulsion and hydraulics. It is important to tie these together in the model. The reviewer believed the project is well defined and laid out, which should lead to success.

Reviewer 2:

The approach seemed good to the reviewer based on the initial outline, but the reviewer noted that it is a little difficult to understand what the approach will result as a deliverable. This may be due to the early nature of the project, and the validity of the approach should become clearer as the optimization controls ideas are fleshed out and clearly defined. The ability to validate the controls and automation on a hardware-in-the-loop (HIL) bench should be good enough to demonstrate the performance potential.

Reviewer 3:

Overall, the reviewer commented that this project does address two key points—fuel consumption optimization of autonomous, off-road vehicle, power system management; and driver optimization. Regarding the latter area, the reviewer asked whether the team plans to use global positioning system (GPS) for forward-looking vehicle control purposes. The reviewer noticed light detection and ranging (LIDAR) and cameras though did not see any reference to GPS. Also, for attempting to quantify overall fuel savings versus current product, it is not clear how soft soil effects (cone index of some nature) are incorporated into the model. One challenge with taking off-road vehicle performance and correlating it with a good vehicle model is the soft soil portion of the analysis.

Planned HIL testing will be valuable using representative vehicle load data from field measurements along with eventual actual field testing. The reviewer called this a very good project that should deliver quite a bit of understanding in both power system optimization and current state of the art (SOA) in off-road autonomous vehicles.

Reviewer 4:

The reviewer's synopsis of the project was that the development team is modeling a machine and some worksite and work cycle with the goal of figuring out a sequence of command inputs to perform the required work at the lowest energy and best productivity. After that, the development team will use HIL to evaluate energy savings. It was not clear to the reviewer how the tool part of the machine will be evaluated in the HIL. Based on that, is the reviewer questioned if the HIL is needed at all when there is not a tool portion.

Additionally, there is not much information provided on the worksite model. The reviewer assumed that this would include modeling the digging, but it is not called out explicitly. There is no mention of validating the worksite model. The reviewer assumed that this would be critical to trusting any productivity and efficiency improvements. Accurately replicating the powertrain and implement loads with a hydrostatic dynamometer might be a significant challenge.

Reviewer 5:

More information would be useful on what the optimization opportunities are for off-road applications. The reviewer asked if the idea is to put the primary powertrain in a maximum efficiency region by coordinating vehicle motion and work-tool usage. Some examples of typical usage and how this could be improved would be useful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project team has made good progress developing and validating the models. The team has used data from 11 different cycles provided by CNH and has also collected around 70 channels of data to develop the models. The project only started last November but has already made good progress.

Reviewer 2:

The reviewer stated that the project is in its early stages and initial work is addressing milestones of the project, which has a predominate simulation focus.

Reviewer 3:

Machine modeling looks promising, and the accuracy looks good for the basic subsystems. Total plan model order reduction is good, but it was still not clear to the reviewer how much computation time is being saved.

The worksite simulation model and its validation need to be completed. The reviewer wanted to know what the variability of this model is, how that is going to impact the validity of efficiency improvements, and whether the team is going to model several different autonomous machines at the work site. These activities may be a significant undertaking.

Reviewer 4:

It looked to the reviewer like the accomplishments to date are satisfactory. The reviewer had a difficult time really understanding what the model is and what has been done beyond the starting point. and asked if the model is a Simulink model, a one-dimensional (1-D) code of some sort, or something based on script programming. The milestones seem to be achieved on time, but there is just detail lacking on the model to really understand if this is beyond satisfactory. Additionally, the reviewer asked the team to please describe the model order precisely, what was done to reduce the order, what assumptions were simplified, and how this impacts the ability for the model to be transferred to different operating cycles or different off-road architectures. The diversity of off-road applications and load cycles makes modular capability in autonomy and optimization very important.

The reviewer asked two questions. Firstly, can the team describe how this optimization will interact with the machine operator? Secondly, will the controls detect what is desired and dampen, limit, or alter the operator input somehow or will there be periods of automation that the operator can choose to enable somehow? How this really gets implemented in an operator and dynamic work environment was not yet clear to the reviewer.

Reviewer 5:

It was not clear to the reviewer if a diverse selection of worksites is envisioned.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer observed an excellent team, including the vehicle OEM that will oversee field testing.

Reviewer 2:

The reviewer commented that it was good to see that all parties are contributing and meeting every other week with the two universities and the entire team on a monthly basis.

Reviewer 3:

According to the reviewer, there is a good mix of university and industrial partners.

Reviewer 4:

The collaboration seemed good to the reviewer to get the initial model built with critical machine work cycles. The reviewer thought that once the HIL work begins, there will be opportunity for much more collaboration.

Reviewer 5:

It looked to the reviewer like the two universities are meeting bi-weekly, and the OEM is getting involved once a month. Caution needs to be made in model transfers and interfaces as different tasks will be performed at different 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. Note: if the project has ended, please state project ended.

Reviewer 1:

It appeared to the reviewer that everything is on schedule, and the plan is to have the HIL simulation up and running soon. It would be good to identify some potential problems and plan how to overcome them if they happen. A quote from one of reviewer's colleagues when his project was behind schedule was that "There were more unknowns than we knew about." The point is to give some thought to what could go wrong and how to overcome that.

Reviewer 2:

The impact of remote communication and variability might significantly affect efficiency and productivity. The benefit the reviewer saw from the proposed research is the development of the optimization technique, which should be robust enough to produce projected efficiency.

Reviewer 3:

The reviewer suggested encouraging the team to consider a diverse set of worksites to ensure this concept works across a range of use cases. Also, more definition is needed on what the opportunity is to better coordinate vehicle and work-tool functions via connectivity.

Reviewer 4:

The plan to finish the optimization and automation development and then transition to the HIL work is clear and what is required for the program goals and objectives. The reviewer proposed that the team please consider how it needs to interface with the machine operator in the HIL work.

Reviewer 5:

The future research plan is logical and focused on project goals. One suggestion from the reviewer is to consider a transient cooling model to better address possible fuel savings though this is dependent on vehicle OEM measurements concerning parasitic losses in thermal management systems. Also, closer attention to soil mechanics could be very helpful, too.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, there is the potential for a 30%-40% efficiency gain in material handling with this technology. If this is successful, it will greatly reduce the fuel consumptions for these applications where this can be applied. Also, going all the way to autonomous would save on labor costs.

Reviewer 2:

The reviewer noted that connectivity is a good fit to off-road applications.

Reviewer 3:

The reviewer responded that, yes, reducing fuel consumption in off-road machines directly goes to the DOE's energy security and emissions reduction objectives.

Reviewer 4:

The reviewer commented that the proposed technology is aiming to increase the energy efficiency of the wheel loader. The amount will heavily depend on the baseline model and variability of the cycle.

Reviewer 5:

The reviewer observed a good project that combines power management optimization with autonomy improvements in energy use. One concern is that the latter autonomy pieces may inhibit the findings of this project, e.g., barriers in latency and sensing could limit vehicle capability at high work-site operating speeds. Nevertheless, combining both thrusts in a reasonable approach.

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

Reviewer 1:

Resources seem to be about right. The reviewer expected much of the work is modeling so that requires supporting one or two graduate students and plans to do HIL, which is cost effective. The project seems to be a good value.

Reviewer 2:

It seemed to the reviewer that all parties in this project have sufficient resources for the proposed future work and the engagement of OEM, and the two universities are good.

Reviewer 3:

To date, the reviewer commented that the resources seem to be sufficient to complete the milestones on target. The HIL work may take more resources, but that will develop in the next budget period.

Reviewer 4:

Resources are in place to complete this project, according to the reviewer.

Reviewer 5:

No comment was indicated by this reviewer.

Presentation Number: ace161
Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements
Principal Investigator: Andrea Vacca (Purdue University)

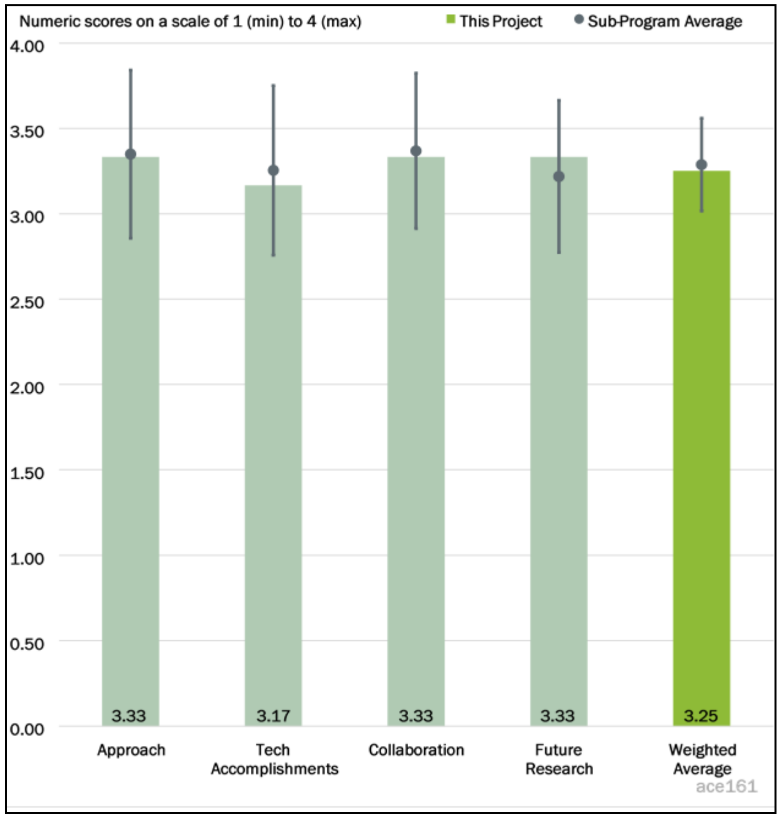


Figure 1-34 - Presentation Number: ace161 Presentation Title: New Approach for Increasing Efficiency of Agricultural Tractors and Implements Principal Investigator: Andrea Vacca (Purdue University)

Presenter

Andrea Vacca, Purdue University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found this to be a very interesting concept and approach for converting from flow control to pressure control with the multi-pressure rail (MPR) system optimization. It has great potential, and the reviewer would like to see this project move forward.

Reviewer 2:

According to the reviewer, the approach of getting the baseline data is good, and the results show a good match between the model and the measured data.

Reviewer 3:

The technical approach is quite interesting. It was not clear to the reviewer how all the efficiency gains will be achieved but the reviewer would be interested to see the future developments

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that fantastic progress is being made toward achieving the defined project milestones and encouraged the project team to keep it up.

Reviewer 2:

The project just started in the past fiscal year so the results to date are hard to evaluate. The reviewer hoped that progress is accelerating.

Reviewer 3:

This project seemed to the reviewer to be making good progress. There is a potential to achieve predicted efficiency with the increase in circuit complexity. However, the market may be reluctant to take on the cost increase, which needs to be followed on. Eventually, the project team should explain how the pressure levels for High, Medium, and Low-pressure rails are chosen. It seems that the planter application has the most opportunity for potential savings, but the reviewer suggested that an aggregate cycle be studied.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found excellent collaboration across the project team, which is leveraging expertise from university, national laboratory, critical component supplier, and OEM staff. The reviewer called the effort well done.

Reviewer 2:

The communication level is good among all the partners. It seemed to the reviewer that the partners are sharing data well, and having the machine available at the principal investigator's (PI) location is also a big plus for this project.

One point of concern and a suggestion is related to making sure that the communication of requirements for controls development (as part of the future work) stays strong as the National Renewable Energy Laboratory (NREL), Purdue, and Case are all involved.

Reviewer 3:

It was hard for the reviewer to tell how much interaction there is between the partners so far.

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 state project ended.

Reviewer 1:

The reviewer commented that fluid power efficiency needs to improve, and the project goal is well aligned with this need.

Reviewer 2:

According to the reviewer, the proposed future research is effectively planned. However, there are some key barriers with regard to commercialization and customer acceptance that should be addressed, such as the packaging plan as well as implementation challenges for customers with mixed tractor-implement fleets.

The implement is self regulating and will get what it needs, and peak demands often drive system design and optimization. The reviewer asked how the project team could ensure that the MPR system will be optimal for a given production system when the system is operating below the peak for most of its duty cycle.

Reviewer 3:

Future technical work looked appropriate to the reviewer. There is a need to emphasize again that the market analysis and ability to create enough customer value with the proposed approach is well understood and that the proposed solution is realistic. The reviewer wanted to know what the assumptions are for the payback period.

Space claim is a challenge on agricultural tractors. The reviewer asked if a packaging study is planned to help downselect from the various concepts.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

By targeting technologies and concepts that will double the energy efficiency of the overall hydraulic transmission system of tractors and their implements through the reduction of throttling losses, this project supports the DOE objectives to de-carbonize the agricultural sector while providing savings to farmers as well as a transition to a clean energy economy.

Reviewer 2:

The reviewer found good alignment.

Reviewer 3:

The proposed technology seems to increase the energy efficiency of the tractor-implement hydraulic system. The reviewer was not sure that it will "double it," and that is yet to be proven in an aggregate tractor cycle.

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

Reviewer 1:

Resources seemed good to the reviewer.

Reviewer 2:

The reviewer noted that the project spend is on track.

Reviewer 3:

It seemed to the reviewer that all parties in this project have sufficient resources for the proposed future work.

Presentation Number: ace162
Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification
Principal Investigator: Jeremy Worm (MTU)

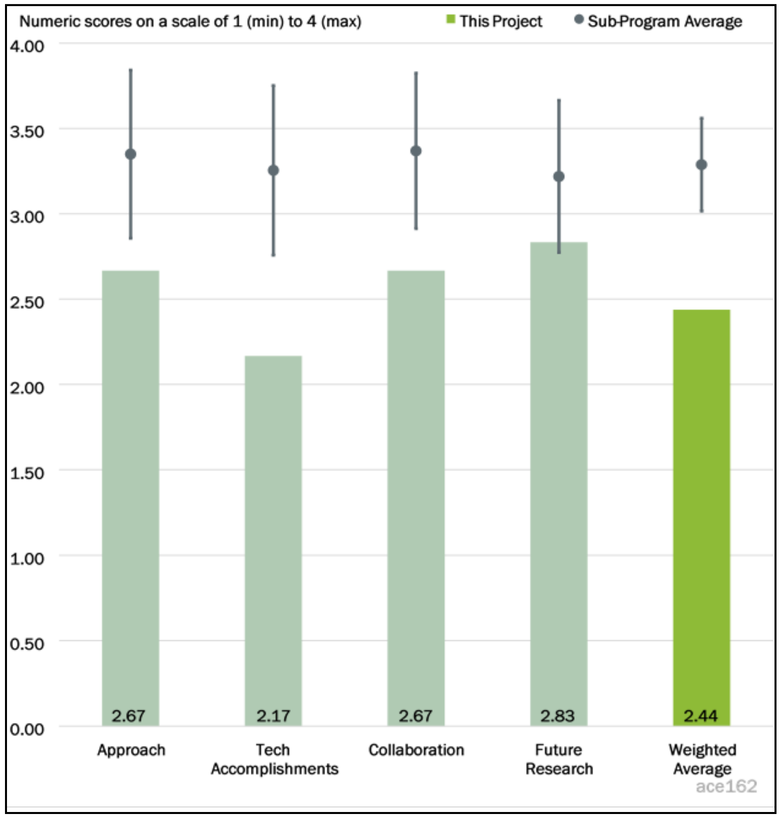


Figure 1-35 - Presentation Number: ace162 Presentation Title: Improved Efficiency of Off-Road Material Handling Equipment through Electrification Principal Investigator: Jeremy Worm (MTU)

Presenter

Jeremy Worm, MTU

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project is reasonably well defined and has some potential due to the criticality of material handling.

Reviewer 2:

The reviewer remarked that the hydraulic system modeling data are not available, which will cause the PI to struggle to get accurate baseline models, which in turn will not provide good machine baseline performance. Additionally, lack of the machine application data may yield an incomplete understanding of the machine and component requirements. It was surprising to the reviewer to see that the OEM does not have any machine application data that would be useful for this project.

Reviewer 3:

The reviewer indicated that some discussion on the type of electrification envisioned (full battery electric versus hybrid) would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that not much progress has been made on this project due to some understandable delays and encouraged the project team to please keep working through the challenges.

Reviewer 2:

The reviewer stated that the project is off to a slow start but agreed this is a good application to consider electrification.

Reviewer 3:

The reviewer said that this project has had significant delays and indicated that the uncertainty of project completion is very high. The reviewer was concerned that subcontracts are not yet complete and that the partner has not re-created the technical documentation for the machine hydraulic system. The project is stating that the improvements will be done "through electrification," so the reviewer inquired about some of the electrical architecture concepts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that a strong project team has been assembled with partners representing all relevant subsystems.

Reviewer 2:

According to the reviewer, more work needs to be done across the project team, especially with the OEM partner on key project inputs such as obtaining real-world duty cycle information instead of developing representative duty cycles based on a video of a working machine. The duty cycle is a critical input for designing an optimal electrification architecture.

Reviewer 3:

It looked to the reviewer like the OEM is not providing enough support and the PI needs to send the machine to an end-user to collect the baseline data, which will further slow down this development. In addition, this is the only one of the possible applications. The conclusion obtained from this site may not be sufficient to understand the full picture of the machine 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The plan outlined for the project was reasonable to the reviewer, who expressed interest in getting some confidence that the project team can effectively execute in a collaborative manner. The reviewer encouraged the team to please keep working through the challenges.

Reviewer 2:

The reviewer inquired whether the project team should consider applications other than material handling so that the electrification system developed has the broadest possible application.

Reviewer 3:

It looked to the reviewer like the future challenges with modeling will continue. Again, there are no details about electrification circuits and components. The reviewer commented that the percent complete for the project does not line up with the milestones or the content provided in the overview.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the demonstration of 20% reduction in fuel economy for a critical application like material handing will support the overall DOE objectives to de-carbonize the industrial sector and transition to a clean energy economy.

Reviewer 2:

In general, the reviewer noted that these types of applications (intermittent usage, high potential energy) should be studied for best form of electrification and hybridization.

Reviewer 3:

The reviewer stated that the project supports the general idea of energy saving and seems like an interesting project but one lacking in detail and progress.

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

Reviewer 1:

Team assembled looked appropriate to the reviewer to get the job done.

Reviewer 2:

With little progress made so far in this project, the reviewer indicated that there are sufficient funds left to execute the project.

Reviewer 3:

The reviewer remarked that it looks like the OEM is not providing sufficient support and adequate data.

Presentation Number: ace163
Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines
Principal Investigator: Adam Klingbel (Wabtec)

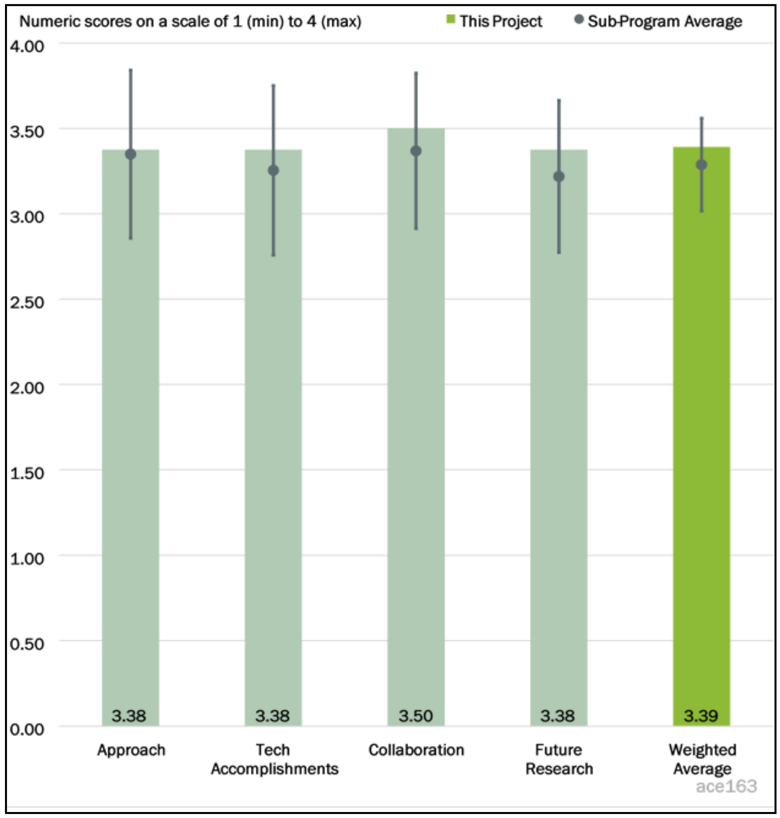


Figure 1-36 - Presentation Number: ace163 Presentation Title: Ducted Fuel Injection and Cooled Spray Technologies for Particulate Control in Heavy-Duty Diesel Engines Principal Investigator: Adam Klingbel (Wabtec)

Presenter

Adam Klingbel, Wabtec

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the approach to use both optical engine work and metal engine work is outstanding to help bring the strengths of each toolset together. The reviewer believed there will be great power in taking the surprises from the metal engine and trying to replicate and understand them better in the optical engine. The timeline and scope all seem well designed and feasible within the project timeline and budget.

Reviewer 2:

The reviewer remarked that the approach is to utilize similar technologies in-cylinder to enhance premixing of fuel and air to reduce PM production. The approach, if successful, should result in a substantially altered soot and NO_x tradeoff, allowing for use of more EGR to control NO_x while not penalizing the engine on PM. The project looks to be studying the relevant scientific principles, and the proposed work should go a long way in establishing the viability of these technologies. However, some off-road vehicles sometimes struggle with high levels of EGR due to the general lack of ram-air cooling for EGR coolers. These proposed technologies may be significantly less effective in those applications.

Reviewer 3:

The reviewer stated that the overall approach is very good: evaluate metal engine and optical engine results sharing similar combustion system designs and iterate on possible additional solutions based on these results.

One element that is missing and might be useful is spray modeling as an aid in choosing duct length and diameter design options. There are possibly good reasons for not including this element.

Reviewer 4:

The reviewer found very limited detail provided on the approach to the work, or even the justification, outside of the reduction in PM claimed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that two of the scheduled milestones were completed with the only other milestone having a 1-month delay, which is very good for a newly launched project still dealing with the residual effects of the COVID-19 pandemic. Evidence of excellent progress is that many of the new designs are complete, with some components already purchased and procured. The new fiber optic alignment technique is also excellent as it may be critical for both successful lab experiments and for production manufacturing.

Reviewer 2:

Since the project initiated in October 2020, it was difficult for the reviewer to accurately assess project progress. However, there does appear to be a significant amount of technical progress even in the limited time the project has been active. There are already hardware pieces and test cells prepped for testing engines using these technologies.

Reviewer 3:

In all fairness, the reviewer commented that this project has recently begun and that is why just a good rating was chosen. It is too early to make a fair judgment right now.

Reviewer 4:

The reviewer noted that the project progression is in its very early days.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The different partners on this project appeared to the reviewer to be very well coordinated, and close collaboration has allowed for the substantial progress even to date. Southwest Research Institute (SwRI), SNL, and Wabtec all look to be on the same page.

Reviewer 2:

Being that there are three core teams working on this project (Wabtec, SNL, and SwRI) the collaboration seemed excellent thus far to the reviewer. The plan to coordinate metal and optical engine work will necessitate excellent collaboration as data and learning progress with the future work.

Reviewer 3:

The reviewer found the team to be a good mix of metal and optical engine expertise. Collaboration could be extended to another entity such as possibly a university if CFD were added to this work effort for further iterating on various duct designs.

Reviewer 4:

The reviewer noted that there was limited information on what other team members have actually achieved. The plans are clear, but progress is early.

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 state project ended.

Reviewer 1:

The reviewer pronounced as outstanding the metal and optical engine approach toward future convergence of the optimal duct design. One suggestion as mentioned above is to include CFD analysis for aiding duct design iterations.

Reviewer 2:

The reviewer noted that this work looks to address both scientific understanding and commercial application, which is an excellent combination. The decision to try to understand the "scaling" of DFI and cooled spray (CS) was a very good one since this will allow for a broader evaluation and application of these technologies in the future. However, it remains to be seen how easy it will be to manufacture either of these technologies on a large scale. Even if the project is successful, it will be necessary to chart a course on how to take either or both of these technologies out of the lab and into the factory.

Reviewer 3:

The proposed future work all seemed very logical to the reviewer, with no gaps in real areas. Obviously as the preliminary data on CS from the metal engine emerge, there will need to be adjustments in the future research.

There was a question about the difference between CS and ducted fuel injection (DFI). DFI is widely discussed in the literature as generally just a duct placed near the injector nozzle exit. The reviewer inquired as to whether the project team could describe what the CS concept is doing that is inherently different in the near nozzle region from DFI. It seems like Wabtec has had good success with soot reductions with the present form of CS, but to achieve the goals of scaling laws for various engine sizes the physics of this concept needs to be elucidated clearly. the reviewer did not know how this CS physics description can be disclosed sufficiently while retaining the confidentiality that Wabtec would clearly want to protect. The reviewer suggested that the team please think about how to best make the information useful for this publicly funded project.

Reviewer 4:

The justification for the spray ducting is apparent, but the justification for CS was less so to the reviewer, who asked why that was important.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that there is significant benefit in reducing the emissions level for off-road vehicles by using potentially inexpensive technologies. Many off-road vehicles are not easy to electrify, so engine technology advances are needed in this area.

Reviewer 2:

Providing reduced cost emissions reductions technology is clearly aligned with DOE's objectives for off-road power systems, according to the reviewer.

Reviewer 3:

The reviewer remarked that this project is a very straightforward hardware design and evaluation effort focusing on PM reduction based on past demonstrated experimental efforts. This project should provide an excellent assessment of ducted fuel injection and its capability to dramatically reduce PM.

Reviewer 4:

The reviewer commented that improving the IC engine remains an important part of energy efficiency in the automotive 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 stated that the budget seems sufficient as the project goals are fairly modest.

Reviewer 2:

The resources allocated to this project appeared to the reviewer to be satisfactory to allow for success in a timely fashion.

Reviewer 3:

The work scope and plan seemed to be feasible to the reviewer with the given budget and collaborator resources.

Reviewer 4:

No comment was indicated by this reviewer.

Presentation Number: ace164
Presentation Title: Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines
Principal Investigator: Sage Kokjohn (University of Wisconsin)

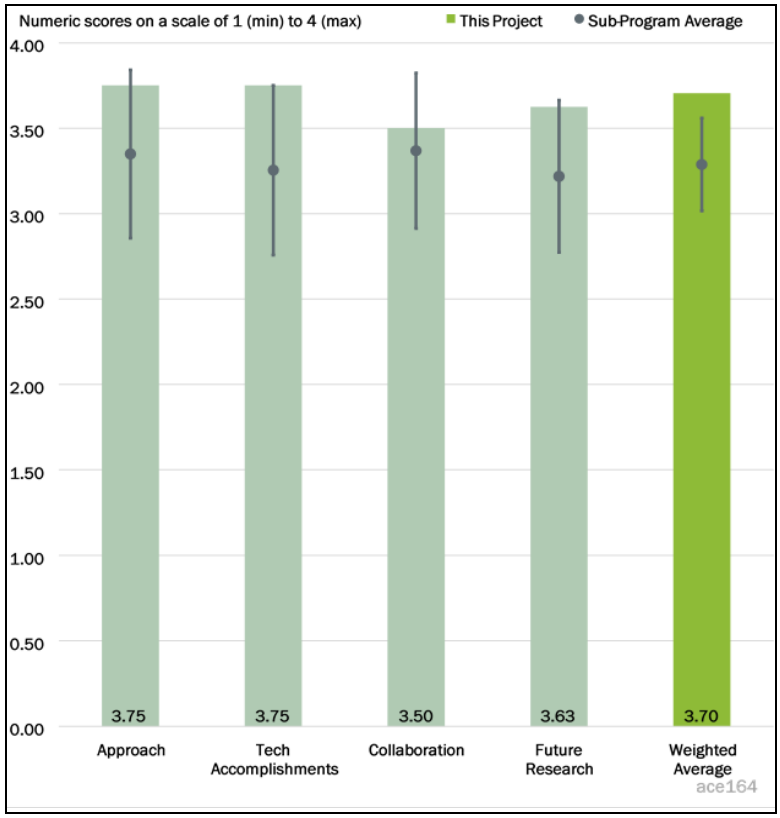


Figure 1-37 - Presentation Number: ace164 Presentation Title: Improving Efficiency of Off-Road Vehicles by Novel Integration of Electric Machines and Advanced Combustion Engines Principal Investigator: Sage Kokjohn (University of Wisconsin)

Presenter

Sage Kokjohn, University of Wisconsin

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project concerns a strategy for improving fuel efficiency of off-road vehicles—tractors, farm equipment, etc. The importance of this undertaking is that this transportation is as high as high as 8% of the total energy consumed in the U.S. transportation sector. The primary piston engine employed in this sector is the diesel engine with its concomitant potential for creating harmful emissions during operation that include greenhouse gases, particulate matter (i.e., soot), oxides of nitrogen and other toxic gases. The obvious approach to mitigate these concerns is full electrification. However, the PI has considered that this approach is unlikely to be viable, likely due to concerns over battery development and the loads expected on the machinery from the typically harsh environment of operation. The PI's approach is to hybridize the off-road frame with the goal of downsizing the engine and optimizing combustion. This project was started in 2019, and this is apparently the first year for its review.

The PI's approach includes modeling, engine experiments, and vehicle testing. A specific platform was selected with an engine size of 6.8 L (the baseline), which the PI is downsizing to 4.5L.vThe reviewer stated that the approach is well conceived and has good promise.

Reviewer 2:

To date, there has not been much research into electrification into off-road vehicles, and the reviewer thought that it is important to support work in this area. One barrier not discussed was that the project team is using light- and medium- duty on-road parts for the off-highway environment. In the future, the reviewer suggested that the team may need to address the reliability and durability of these parts for the off-road vehicles, even though the reviewer knows that this is beyond the scope of this initial investigation. Overall, the approach looks good and is well laid out and very feasible.

Reviewer 3:

The reviewer called the approach to this project very solid: developing a vehicle-level model; validating the model against data; modifying the drivetrain to evaluate different hardware, including turbo geometries and hybridization schemes; narrowing the testing matrix; and testing the resulting systems for efficiency and cost effectiveness. The work performed to date has been well done and evaluated through several industrial partners to ensure success in real-world applications.

Reviewer 4:

This reviewer inquired whether hybrid systems should be considered, such as parallel hybrid in addition to series hybrid. This could allow for downsizing of the electrical system as the engine contributes directly to drive shaft power.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project just started in October 2019, and the baseline modeling and simulations have been completed. The project team has shown that it is possible to downsize from the 6.8L to the 4.5L engine. So far, the results look promising. The team is scheduled to have a front-end loader provided to the project so it looks not only like there will be good progress on the next milestone but also a demonstration during the final budget period.

Reviewer 2:

The project team's progress is up to date and on target, according to the reviewer. The team has an impressive and aggressive set of goals that are currently on target and achieving a high degree of success. A potential 17.6% efficiency increase is impressive.

Reviewer 3:

Optimizing engine displacement is an important consideration. It seemed to the reviewer that the project settled on a 4.5L displacement, and the reviewer asked if there had been a study done to show this is optimal from an overall efficiency standpoint. As the eBooster and eTurbo consume electrical power, the reviewer wanted to know if this is the best usage of that electricity or should it be better used for shaft work.

Reviewer 4:

According to the reviewer, the PI and the project team have done a lot in a short amount of time. The work has already shown a significant reduction of soot with the eBooster.

There are a number of questions the reviewer posed that should be considered as the project advances:

- The modeling will need to be better explained. Considerations of the model inputs— kinetic mechanism, soot model, and how these elements were validated along with predictions of in-cylinder transport— should be discussed in future modeling. With a system as complex as the vehicle considered, it was not clear to the reviewer how a system-level model would be able to provide quantitative predictions, given the significant complexity of in-cylinder transport. This should be explained.

- The PI notes "machine learning" for the soot model. This needs clarification.
- The Gaussian process regression (GPR) model should be discussed.
- Presumably, a diesel surrogate is being used, correct? There should be discussions of how it was formulated and validated.

This project work has employed a lot of testing and simulation over the past year, and the results have shown some promising trends (e.g., 21% reduction of particulate emissions). The project team should consider how to generalize work to not only address the specific engine system being developed but also to provide results on mechanisms and processes that could guide performance evaluation for other designs. In the absence of attempting to understand the processes, the results of the project could be overly narrow and not extendable to other off-road systems. The ability to do this could rest on the efficacy of the CFD modeling work. Validation is also key, and that too should be discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team has monthly calls. Initially, the reviewer had the impression that the University of Wisconsin and John Deere are heavily involved in the first part of the project and Purdue will be collaborating more in the near future when that university will be responsible for the handling the supervisory controls and software for demonstrating in a vehicle. Overall, there is good collaboration.

Reviewer 2:

The reviewer commented that the really good progress for the first year of this project is evidence of a highly functional cross-organization team.

Reviewer 3:

The presenter listed four team members, two of them at University of Wisconsin (UW)-Madison (UW-Madison) (Mechanical and Electrical departments), which the reviewer indicated can have the potential to lead to good collaboration on the project as proximity is not an issue. John Deere is an excellent source for cost and operational data. Purdue's participation is also a good partner for controls work. The only collaboration that is missing is a powertrain parts manufacturer for a more direct pipeline for parts needed for testing. This can be overcome due to the project's use of John Deere. All in all, this is an excellent group, which by all accounts looks to be working well together.

Reviewer 4:

The lead for the project is UW-Madison. The university is responsible for the electric machine and combustion system analysis. Collaborators are John Deere and Purdue. The John Deere collaboration is good, especially because they have provided some data against which the PI could compare their system-level simulations. In fact, Slide 6 shows some impressive comparisons. The reviewer suggested that further details should be provided regarding what is needed for the solution to be carried out (e.g., turbulent transport, detailed combustion chemistry, a surrogate model, soot model, and how the various inputs were separately validated).

The reviewer requested that the PI should provide some details of the Purdue component, which is stated to be "powertrain control." The reviewer wanted to know. specifically, what that will involve. UW-Madison has extensive engine testing facilities; the reviewer asked what unique elements the Purdue component provides to the project.

The project team is well conceived. However, it was not evident to the reviewer that the collaborators cover issues related to matters related to the battery. This is a crucial element that could impact the overall success of developing hybrid off-road vehicles. A recommendation would be to bring on a collaborator with expertise in battery 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. Note: if the project has ended, please state project ended.

Reviewer 1: .

The reviewer noted that this is the first year of the project, which has made significant progress and accomplished significant results. Looking at the progress and results, the goals and pathway of the research are logical and well planned out. The only missing piece (which could be follow-on research) is the effect of hybridization on cold-start emissions and aftertreatment effectiveness. Data from this study could enable an excellent investigation into the emissions effects of this work.

Reviewer 2:

According to the reviewer, the researchers have a good plan and schedule to meet the final vehicle demonstration. Most of the work will be in simulating the system and eventually validating with an actual engine in the test cell with the eBooster. One barrier that will be addressed is cost. The technology needs to be cost effective before OEMs will consider pursuing for production. This will have to be weighed against the competing technologies. There may be other technologies that can deliver more than an 8% fuel economy benefit.

Reviewer 3:

This is a very relevant project, and the reviewer asked that the project team should please ensure that the vehicle is tested over a full range of usage profiles so the hybrid system. power level, and battery size settled on are relevant to a range of applications.

Reviewer 4:

The reviewer commented that the future plans are well conceived and make sense, though they are rather broadly conceived. The proposed plan for continuation includes validating simulations about which the PI has already provided some results (e.g., Slide 6). As noted previously, validation should also include some aspect related to inputs to the simulation, such as the soot model, kinetic mechanism, surrogate, etc.

The success of the project, as likely with development of any hybrid vehicle, may be impacted by the available battery technology and associated issues (e.g., charging rate, battery size and capacity, safety [e.g., risk of explosions, battery thermal management]), etc. The reviewer remarked that off-road vehicles of the type considered in the project will be subjected to potentially harsher environment than on-road vehicles. The work plan does not seem to consider this potential concern. The PI's perspective (Slide 3) that "energy storage is expected to be available" might be oversimplistic. For that reason, a collaborator with expertise in the battery development community might be a worthwhile addition to the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project supports DOE's broad objectives of improving fuel and engine efficiency and reducing consumption of petroleum-based fuels. Hybridization of off-road systems is an important and not well studied technology. The goal of improved fuel efficiency of this sector is thus highly relevant to DOE's mission.

Reviewer 2:

The reviewer indicated that this is exactly the type of work that needs to be done: vehicle-level demonstrations to determine best level of hybridization from a cost-benefit standpoint.

Reviewer 3:

The reviewer remarked that the main objective of the project is to improve vehicle fuel economy and reduce greenhouse gas emissions. The goal is to reduce fuel consumption by 10% with no or improved vehicle operation.

Reviewer 4:

The reviewer said that off-road vehicles and equipment use 8% of U.S. energy in the U.S. transportation sector and cannot be fully converted to electric drivetrains due to their operational requirements. Implements used by these vehicles are, however, becoming more electrified. It would make sense to hybridize these vehicles to allow for 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 thought that the dollar amount and the personnel resources are sufficient. A good portion of the work is simulation; in the near future the project team will be validating the models with engine testing and finally a vehicle demonstration. The vehicle demonstration will take considerable support from John Deere, but that company has been known to provide good support on past projects.

Reviewer 2:

According to the reviewer, the resources appear to be sufficient.

Reviewer 3:

The reviewer noted that there had been great progress by the team this past year.

Reviewer 4:

The resources seem adequate, though without more details (e.g., overhead rate, scientist and technician salaries, equipment costs, etc.) beyond the bottom-line costs for the project provided in the presentation, the reviewer is not qualified to adequately score this category. An ultimate judgment would have to come from a cost-benefit analysis based on DOE’s investment relative to the commercialization potential of what the PIs are pursuing.

Presentation Number: ace165
Presentation Title: Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics
Principal Investigator: Gina Magnotti (Argonne National Laboratory)

Presenter

Gina Magnotti, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

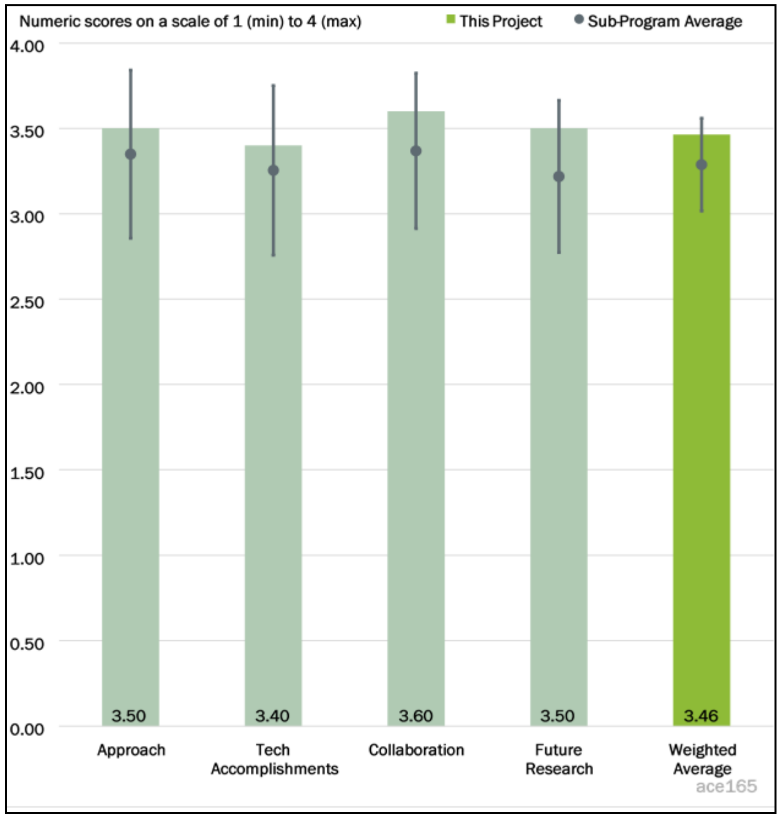


Figure 1-38 - Presentation Number: ace165 Presentation Title: Advancing Simulation Tools for Heavy Duty Engine Combustion Using X-ray Diagnostics Principal Investigator: Gina Magnotti (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a major fuel injection program that has been on-going since 2017, and the project team keeps expanding the scope of the program. The reviewer liked the idea that they “Develop, Apply, and Share” with others. For the Development part, they are investigating the fundamental spray parameters that need to be known to improve the spray and combustion models. The Apply part is to apply the information to create cleaner and more efficient engines. Finally, they are working with Converge to incorporate their models into commercial software that will be available to all. The reviewer liked the overall theme.

Reviewer 2:

The reviewer noted that the overall approach to provide simulation tools for accurate prediction of heavy-duty engine spray-combustion seems reasonable, which is supported by unique X-ray spray diagnostics and advanced combustion solvers.

Reviewer 3:

The reviewer commented that the joint simulation and experimental effort is the correct methodology for predictive spray model development. The Develop, Apply, and Share tag line hits well.

Reviewer 4:

According to the reviewer, the very clear approach to Develop, Apply, and Share is outstanding. It is very evident that the approach is intended to transfer the knowledge and the simulation tools to the industry end-users.

Reviewer 5:

It looked like the approach is reasonable to the reviewer. However, the injector nozzle erosion is highly stochastic, with a lot of parameters from operating conditions. The approach seems to be limited with predictivity. A consideration of stochastic erosion pattern would help the industry better.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Over the years, the reviewer pointed out that great accomplishments have been made in spray and combustion modeling. The models are well received by industry, and many in industry are following your progress. The collaboration with Cummins and Converge and their use of the software is evidence of its importance.

The reviewer also thought that the erosion rig and erosion modeling are important to understand how emissions may change over time.

Reviewer 2:

Progress was made with a new injector cavitation rig and the ANL flamelet solver. The reviewer said that it will be exciting to see the link between erosion and combustion and emission behavior.

Reviewer 3:

The accomplishments seemed solid to the reviewer, who offered the following points:

- Referencing Slide 6, it would have been better to show how the cavitation-induced erosion risk assessment (CIERA) tool correlates against the measurement. The CIERA tool has been around for a few years, so the reviewer wanted to know what the plan is for further validation and development of the tool (second bullet).
- Referencing Slides 9-11, the measured nozzle erosion pattern is a decisive factor of the result. The whole process needs to be extended upstream to take into account the random erosion in the real world over broad operating conditions.

Reviewer 4:

It was rather surprising to the reviewer that the most advanced combustion model with large eddy simulation (LES) cannot predict in-cylinder heat release rate reasonably. It will be an issue for very low fidelity in engine performance prediction if this is the case for a real engine simulation.

Reviewer 5:

This reviewer observed excellent progress that is clearly demonstrated by the new erosion facility build at ANL; unsteady flamelet progress variable (UFPV) flamelet solver simulation producing approximately 25% reduced central processing unit (CPU) over well-stirred reactor multi-zone (WSR-MZ) models; end-to-end spray-to-combustion simulation toolchain development; volume of fluid (VOF) and Euler-Lagrange spray atomization (ELSA) validation with direct numerical simulation (DNS); and initiation of the new four-way CRADA.

It was clear to the reviewer that, with the CRADA, there is an industry first adopter for the end-to-end simulation toolchain, but the reviewer wondered how the adoption of this will be seen for others than Cummins. Industry has simulation plus experiment solutions today that vary based on need and desired simulation output, which may be cheaper or easier. Maybe the project team can plan to show how the end-to-end toolchain can be adopted or how it can provide clear benefits. The reviewer asked about how the injector design and operation gets integrated into the injector flow simulation. These are typically done with 1-D type tools or with injector design experience. The reviewer also wondered about the need for including cavitation damage in this simulation toolchain, being that the goal of the injector design is to not have cavitation damage. It seems that this is a useful tool to help get the injector design right, but it is not necessarily needed to predict the spray and combustion of damaged nozzles. Maybe there is a real need or use here that can be highlighted more clearly.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the project team showed that the collaboration and coordination with various other organizations were done well.

Reviewer 2:

The reviewer commented that a well-coordinated collaboration of ANL, Lawrence Livermore National Laboratory (LLNL), SNL, Converge, and university partners is combined with industrial partner involvement.

Reviewer 3:

The reviewer stated that there is very clear collaboration and coordination among the national laboratories, industry, academia, and CRADAs.

Reviewer 4:

The reviewer remarked that the collaboration part is great and had nothing to point out.

Reviewer 5:

The reviewer said that there is a fairly long list of collaborators over the years from other national laboratories to engine OEMs and software suppliers. The reviewer thought that it is essential to work with Converge to improve the models that will eventually be available to all OEMs that use the Converge 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that the PI and the project team continue to improve models and develop new ones that are applicable to the industry. There is a long list of future barriers that can still be addressed and plans to make progress on all of them. Overall, it is a vast project, but the project team is making good progress in all areas.

Reviewer 2:

The reviewer commented that the goal is solid: link cavitation, erosion, combustion, and emissions. Specifically, the link to soot formation will be crucial.

Reviewer 3:

All the proposed research picks up on the current accomplishments and progress, and it was clear to the reviewer that it is subject to future funding. The reviewer encouraged the teams to orient toward off-road, marine, and rail with low GHG fuels, per the VTO's new funding statements.

Reviewer 4:

The reviewer noted that the ELSA model was developed more than 20 years ago, and it has been implemented in several commercial computational fluid dynamics (CFD) codes, including CONVERGE. An elaboration of the model development and improvement is needed (on Slide 15).

Reviewer 5:

Although further studies on injector nozzle cavitation and erosion seem necessary, the reviewer was not convinced that injector nozzle cavitation and erosion should be the most critical area of this project. From a heavy-duty engine maker point of view, spray-wall interaction, air-fuel mixing, and accurate prediction of NO_x-soot trade-off are far more important than the nozzle internal flow simulation or soot modeling.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer the final goal is to be able to take the models developed and collaborate with Converge to incorporate them into their commercial software. If successful, the efforts from the DOE supporting the work will be well received via the industry.

Reviewer 2:

The reviewer found this project to be helpful for relevant industries to access advanced modeling tools and practices and utilize them for their engines with better emissions and engine efficiency, which should be relevant to DOE also.

Reviewer 3:

The reviewer commented that the project targets DOE barriers in spray fundamentals, aids advanced low-temperature combustion strategies, and contributes to soot modeling.

Reviewer 4:

The reviewer remarked that this supports increased understanding, physics modeling, and simulation of higher efficiency internal combustion engines (ICEs) for reduced fuel consumption and emissions.

Reviewer 5:

The reviewer indicated that the project supports the DOE objectives in a way to enable a predictive tool development for more durable and efficiency engine development.

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

Reviewer 1:

It seems sufficient by looking at the good progress in the key milestones, according to the reviewer.

Reviewer 2:

The reviewer commented that the team appears well supported to conduct the investigation.

Reviewer 3:

The funding looked sufficient to the reviewer.

Reviewer 4:

It was clear to the reviewer there are sufficient experimental capabilities and high-performance computing (HPC) resources. Having a CFD vendor tightly incorporated should really help the simulation development and project deliverables.

Reviewer 5:

The reviewer thought that there could be more funds allocated to this program. There are minimal funds to support the computer modeling, and the reviewer expected that a good portion of the overall funds are going toward the Erosion Spray Rig (which is important and recommends continuing to move forward). However, an additional modeler would speed up the overall results.

Presentation Number: ace166
Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine
Principal Investigator: Fabien Redon (Achates Power, Inc.)

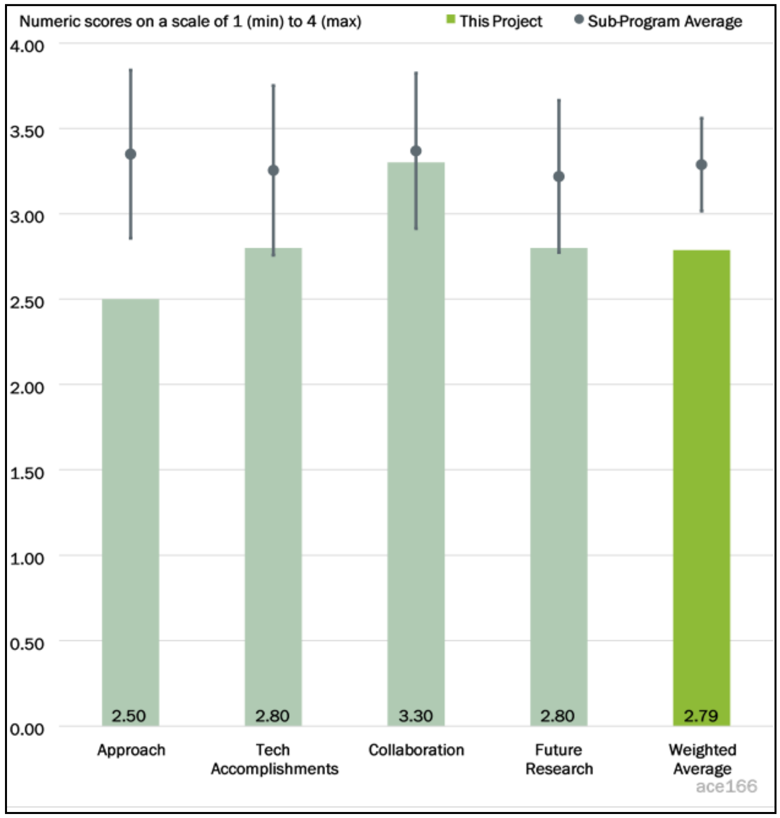


Figure 1-39 - Presentation Number: ace166 Presentation Title: New Two-Cylinder Prototype Demonstration and Concept Design of a Next Generation Class 3-6 Opposed Piston Engine Principal Investigator: Fabien Redon (Achates Power, Inc.)

Presenter

Fabien Redon, Achates Power, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

60% of reviewers felt that the project was relevant to current DOE objectives, 40% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that the program plan is comprehensive and that the project benefits from Achates experience of having had a number of DOE-funded projects.

Reviewer 2:

The approach is well matched to the specific barriers noted in the presentation. However, the reviewer indicated that specific barriers related to the DOE VTO mission are not clearly linked to the work or the approach. The project design and teaming are well matched for the project objectives. It could be made clearer how this effort builds on previous work and what lessons and improvement are being applied here for this specific application.

Reviewer 3:

According to the reviewer, the project approach does not adequately address the challenges of meeting ultra-low emission requirements. Efficiency gains made in this project will not be transferable to the automotive commercial sector unless emissions are adequately addressed, and there is insufficient emphasis or concern for emissions as this project is currently constructed. If the approach is to move this engine design toward meeting efficiency goals in this project and then meeting emission requirements in some future effort, then that should be stated in the presentation.

Reviewer 4:

The overall approach of specifying engine requirements, simulation, testing was sensible to the reviewer. A key flaw is targeting high-level barriers (challenges) of conventional diesel engines whereas the more appropriate barriers would be the persisting technical barriers facing this particular engine architecture. The specific approach to the important, relevant barriers is not really complete. It would be constructive to show the technical issues that have been resolved for the Achates design over 17 years of research and show the few issues that still need more work.

The reviewer indicated that the target of 10% efficiency gain over standard engines is too conservative for the relatively high risk of an unconventional engine. The demonstration of emissions target is unclear whether by hardware, vehicle, or simulation. This question came up in question and answer (Q&A) and was not clearly answered.

Reviewer 5:

The reviewer stated that there is significant overlap with other federally funded projects. The market for this engine design is decreasing as states are requiring that zero emission Class 3-6 vehicles be purchased in the next 10-15 years. Larger (Class 8) engine research should be completed prior to starting more research in this area. A 10% fuel economy increase target is low compared to risks associated with this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the project is in its early days, but good progress has been made to date.

Reviewer 2:

The reviewer indicated that good progress has been made early into the project. The milestones on system profile and updating the CFD model and 1-D model for opposed piston architecture are in line with ensuring progress.

Reviewer 3:

Although early in the project, the reviewer stated that the effort made to date is in accordance with the statement of project objectives (SOPO) and indicates that the project is just about where it should be now.

Reviewer 4:

This is a new project the reviewer remarked so accomplishments are in early stages for this specific application of a two-stroke engine. The project team has installed a test engine at Clemson. Simulation and design of a two-cylinder engine is in progress.

Reviewer 5:

The reviewer pointed out that no hardware progress has been accomplished (was not a milestone, but for this amount of funding, some brass board testing should have been started based on the Class 8 research). Limited background research and modeling (which should have been accomplished prior to the project) was accomplished in year 1.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Great teaming and application of partner strengths to overall goals, according to the reviewer.

Reviewer 2:

The reviewer commented that the overall project team is strengthened by the participation of a major engine manufacturer. The university partners are traditionally strong in engine research. The reviewer noted capabilities in thermal barriers as well.

Reviewer 3:

The reviewer asserted that coordination with other project members is adequate for this project to achieve the stated goals and be successful.

Reviewer 4:

The reviewer stated that there are well-defined roles for the partners. although Isuzu's engine design capability. Is being underutilized. There is good use of the university partners' supporting modeling efforts.

Reviewer 5:

It is too early to tell if the collaboration and coordination work. The comment about Clemson possibly not being able to perform the model predictive control (MPC) work was concerning to the reviewer. This would allow the test matrix to be expanded and optimized; the absence of this aspect of the work will increase the testing required at reduced overall benefit.

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 state project ended.

Reviewer 1:

The reviewer commented that the team understands the complexities and difficulties of engine development and has laid out a comprehensive SOPO.

Reviewer 2:

The reviewer found the project has a very good future research plan aligned well to overall goals.

Reviewer 3:

The reviewer asked that the research to achieve a commercial-ready technology should be described. The low-emissions achievement should be clarified as either a vehicle demonstration or partly done by simulation. This section of the project and presentation needs improvement to address these issues.

Reviewer 4:

The reviewer remarked that this project does not give adequate weight to the difficultly that will most likely be encountered in meeting emission requirements, even though engine-out data rather than tailpipe-out are what are being measured. More emphasis needs to be directed toward meeting ultra-low emissions because this is a major challenge for all engine development efforts and particularly for two-stroke engines. The PI for this project does not seem to recognize the challenge that lies ahead in terms of meeting the emission standards set for this project.

Reviewer 5:

The reviewer suggested using funding for other purposes, such as Class 8 research and engine development, demonstration, and deployment before modeling and developing new engine designs for alternative vehicle applications. Alternative fuels should be incorporated into the Class 8 testing scheme to improve engine-out emissions (question was asked about this topic but was never answered).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the investigation of improvements to IC engine efficiency and reduced emissions is still an essential part of automotive development. The use of low-carbon or zero-carbon fuels in a highly efficient engine architecture is another area worth pursuing.

Reviewer 2:

The reviewer proposed that investigating and developing an alternative engine design to the commercially available diesel engine is needed for increased diversification of the DOE research portfolio. This project meets that need.

Reviewer 3:

The reviewer said that this project does support the overall DOE goals of improving efficiency and reducing emissions in the MD and heavy-duty (HD) vehicle sector using advanced engine technologies. The project uses advanced tools, such as CFD, machine learning, and lower-order models, to accelerate the implementation of the designs. The project could be better linked to published DOE and industry partnership goals, such as noted in the 21 Century Truck Partnership.

Reviewer 4:

The reviewer found that relevance is a weak spot for this project. The projected benefits of this engine (10%) for DOE's mission are not large enough to justify investment at this time of emerging electric vehicles and continuing improvements being seen in "conventional" ICE vehicles that are moving the needle much more than 10%. If the engine showed a vastly superior applicability of low-carbon fuels, its relevance could be re-argued. Similarly, there are already efforts to exploit hybrid systems with this engine. The emissions from the engine are only as good as conventional engines, apparently not targeting lower levels.

Reviewer 5:

No, this project does not support the DOE objectives toward zero-emission vehicle 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 engine development is very expensive, but Achates has developed a number of variants, which ensures that they know what the true costs are or will be.

Reviewer 2:

This is a large project with significant goals. The resources seemed to the reviewer to be well matched to deliver in a timely fashion.

Reviewer 3:

Resources for this effort are sufficient; however, it seems that Achates should be providing greater cost share than they are at present. Achates has been developing this engine for quite some time and the opposed piston configuration is a known quantity so the reviewer proposed that the usual 50% cost share would be more appropriate.

Reviewer 4:

Many parts of government have made investments in this engine architecture and company, and some are still in progress. The cost share by industry for this project is lower than the typical 50% for DOE industry product development programs. The presenter noted various development programs ongoing for 17 years since

Achates was formed. The engine may be well suited for military or other applications. The resources are okay for the tasks being pursued, but the reviewer questioned the overall relevance and benefits of the project.

Reviewer 5:

The reviewer indicated that this project overlaps with other federally funded research on a slightly larger engine design. That work should be completed and assessed prior to investing more funds into this engine design.

Presentation Number: ace167
Presentation Title: Spray/Flow Interaction in Engines
Principal Investigator: Roberto Torelli (Argonne National Laboratory)

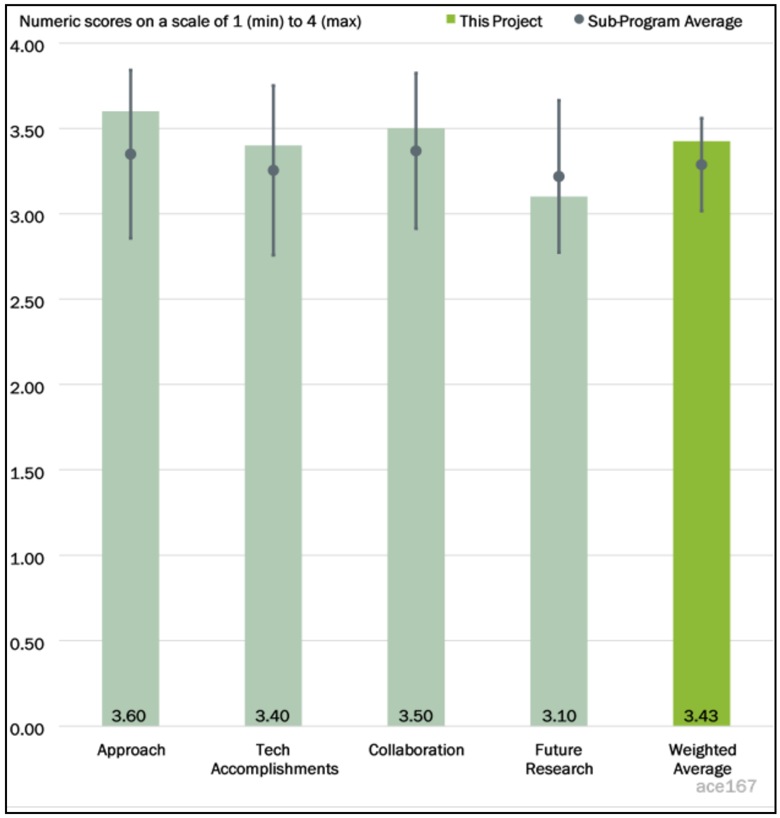


Figure 1-40 - Presentation Number: ace167 Presentation Title: Spray/Flow Interaction in Engines Principal Investigator: Roberto Torelli (Argonne National Laboratory)

Presenter

Roberto Torelli, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project investigates free sprays and spray-wall interaction along with mixture formation for high-efficiency combustion regimes. Spray modeling is something for which improvements need to be done on a continuous basis, and this effort achieves that. There is very high quality CFD work to match experimental observations.

Reviewer 2:

The project is focusing on both free spray and wall impinging jet through numeral and experiment work. The reviewer noted that very informative data from the experiments are fed to CFD so that the spray wall interaction model can be improved.

Reviewer 3:

The reviewer pronounced the connections between the various modeling-experimental approaches to be excellent.

Reviewer 4:

It looked to the reviewer like the approach is great.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that the Slide 3 results are excellent. While the fundamental understanding behind GDI cold-start issues is paramount, the practical solutions are also incredibly helpful. The various experimental-modeling connections are excellent.

Reviewer 2:

The reviewer made several observations: multi-hole spray collapse in engine conditions seems to be very useful information, flash-boiling breakup and one-way coupling of injection are proven to be important, the necessity of setting up spray-cone included-angle seems to be limited in CFD modeling, and a new spray-wall interaction model has been made available to other users.

Reviewer 3:

The reviewer found the project to be a very nice combination work of experiment and simulation while asking if the new spray-wall interaction (SWI) model is more predictive than "postdictive,", negating calibration needs. The reviewer commented that it looks like the new SWI model needs improvement on the side-wall side.

Reviewer 4:

According to the reviewer, technical accomplishments are in line with what was proposed. Perhaps something lacking in the effort is the droplet-size quantification and comparison with some fundamental experiments (e.g., phase Doppler particle analyzer [PDPA] or other) along with qualitative assessment of the spray. The droplet-size measurement is important for equivalence ratio distribution as well as combustion and emissions formation, of course. Wall film development and some validation with experiments will also be beneficial for understanding soot formation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

From the three spray talks, the collaboration appeared excellent to the reviewer.

Reviewer 2:

Again, the collaboration looked excellent to the reviewer.

Reviewer 3:

The reviewer observed good collaboration and stated that this is an effort applicable to pretty much all advanced combustion CFD work.

Reviewer 4:

The reviewer said that collaborations with project partners among national laboratories seem well coordinated. For spray modeling, more involvement with industry would be helpful to hear their needs also, maybe first through DOE Advanced Engine Combustion (AEC) members, either CFD software vendors, or 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the research appears to be fine. It sounds like Eco-boost engine experiments will be pursued. These engines use a side-mounted injector (spraying orthogonally to the cylinder axis). A comparison of cylinder axial injection versus side injection would be helpful.

Reviewer 2:

This reviewer remarked that fuel film formation on the cold wall is difficult to simulate accurately, let alone for free spray before reaching to the wall. The reviewer suggested that some other factor like wall roughness can be considered in simulations.

Reviewer 3:

-It looked to the reviewer like the spray-wall (SW) model needs some fundamental improvement than trying more validation cases. The reviewer did not see a clear benefit of implementing the Huh-Gosman model to CONVERGE. The reviewer wanted to know what the purpose of it is in the context of the project, what is new with the CHT model, and what is it going to bring into the project. Overall, the return seems a bit diminishing.

Reviewer 4:

If possible, the reviewer suggested that a wide variety of validation should be done compared to experiments. Droplet-size distribution may be important for predicting mixture formation (due by September 2021).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer found that this project supports the PACE DOE objectives in understanding spray mixing behavior in engine and overcoming technical barriers.

Reviewer 2:

According to the reviewer, the project supports the DOE objectives. It will contribute to understanding the spray physics better and improve prediction capabilities of simulation tools.

Reviewer 3:

The reviewer asserted that this is exactly the kind of work national laboratories should be conducting and feeding to industry. There is perfect alignment with DOE goals.

Reviewer 4:

It would have been nice to see emissions results from the engine experiments in order to get a sense of the baseline as well as other approaches applied. The reviewer indicated that connecting back (even briefly) to the end goal would be useful.

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

Reviewer 1:

The reviewer pronounced the resources as excellent and appearing to be fine.

Reviewer 2:

The resources looked sufficient to the reviewer.

Reviewer 3:

The reviewer deemed the resources as sufficient.

Reviewer 4:

The reviewer observed that there are many tasks to be done in FY 2021 and FY 2022, but the resources seem just right to move along and achieve the milestones in time.

Presentation Number: ace168
Presentation Title: Soot Modeling and Experiments
Principal Investigator: Julien Manin (Sandia National Laboratories)

Presenter

Julien Manin, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

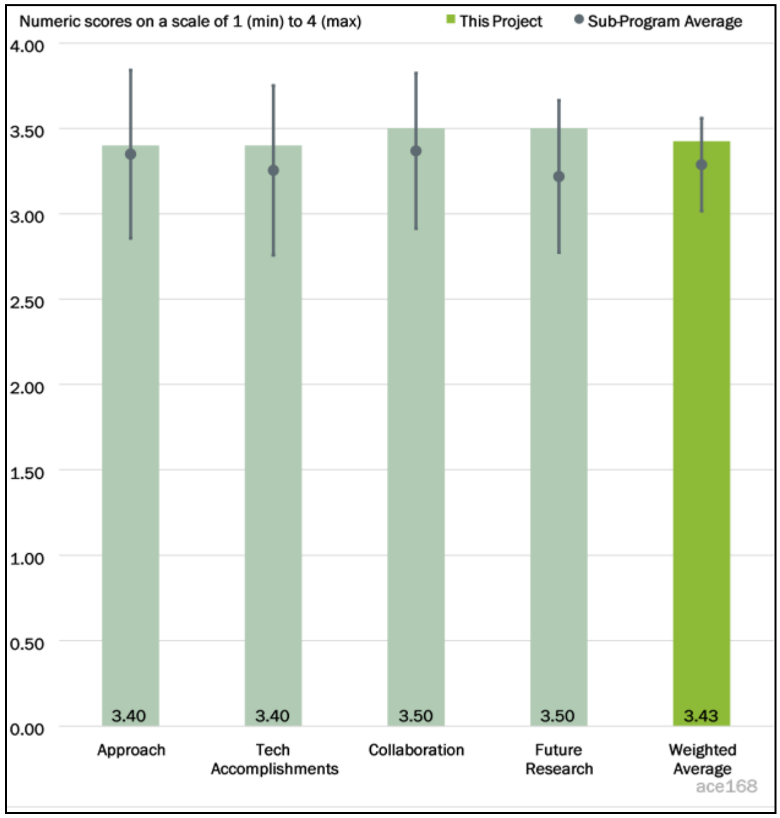


Figure 1-41 - Presentation Number: ace168 Presentation Title: Soot Modeling and Experiments Principal Investigator: Julien Manin (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of this program is very well designed. The more fundamental chemistry development is happening on the right levels and is well connected, leading to computationally efficient soot models for industry use. The experiments are tied in with the modeling effort, and it looked to the reviewer like future work will have more high-fidelity simulation to see if the chemical models are matching the experiments. This is going to be an important step, and so it will be good to see those results next year. It was unclear to the reviewer if the simulations will be able to capture the wall-impingement work; it would be good to clarify that. Otherwise, the program structure and approach are appropriate and yielding very interesting and useful results.

Reviewer 2:

Soot modeling is one of the most difficult tasks in any engine modeling area. According to the reviewer, the project team seems to understand the issues and tasks to resolve to develop a reliable soot model for engine cold start.

Reviewer 3:

The reviewer asserted that the approach is excellent as good models need to first be in place.

Reviewer 4:

The reviewer called the approach excellent, based on the use of the multiple types of experimental data sources feeding the high-fidelity simulation work that then will be distilled to the CFD-ready deliverables. Soot is an incredibly challenging topic regarding accuracy. Major Outcome 8 of PACE has a less than 20% relative error on cold-start emissions, which includes soot. The reviewer asked the project team to think about how to tie this ACE168 to the less than 20% error at the current status. Where is the team relative to this less than 20% error today?

Reviewer 5:

This reviewer commented that organizing a soot working group and focusing on the cold start is good. The entire period while the engine is below operating temperature is critical for soot research, not just the 20-30 seconds of catalyst heating, which is critical for HC, NO_x, and CO.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer called all the technical accomplishments of the many different aspects of the program excellent. There are five that stand out at this point as particularly high impact. First, the pyrolyzing spray experiments are really interesting, and the combined diagnostics provide important information on PAH and soot together, which will be critical for comparison to simulation. Second, the improved PAH chemistry is really nicely done, and it is good to see that one of the outcomes of this will be publication of the updated mechanism online. Third, the initial comparison of the new chemistry in CONVERGE with experiments is promising; continuing to benchmark these improvements will be important. The 0-D model is quite clever, and it is nice to see the lab working with early-career academics on this effort. Finally, the wall-film experiments are yielding very interesting results. It might be good to coordinate with the experiments presented by Lyle Pickett on their wall-impingement studies. It is also encouraging to see that despite the challenges, the PIs are working toward understanding these processes in an engine experiment.

Reviewer 2:

The reviewer asserted that the accomplishments and progress are excellent, based on four of seven deliverables being complete and three of seven are on track. The cold-start engine experiments seem to be very valuable to highlight the importance of the thermal state of the engine regarding the sooting similarity between the RD5-87 and PACE-20 fuels. Similarly, the spray vessel pyrolysis experiments help to corroborate the surrogate fuel similarities for sooting.

To achieve the goals of the PACE Output 8, the kinetics and simulation work is key, and it looks to be making good progress. The reduced PAH mechanism looks to be validated sufficiently, but a reference-reduced PAH mechanism would be nice to compare. The Reynolds-averaged Navier-Stokes (RANS) CFD of the pyrolysis is excellent in that it clearly illuminates the gap and where to focus efforts on the kinetics leading to soot formation. This seems to be critical area, and it looks like the team is making very good progress on it.

Reviewer 3:

The reviewer said there was excellent progress.

Reviewer 4:

The reviewer suggested that the project team please seek to connect the current work to the end goal and how the current work will ultimately allow for cleaning GDI cold start from the particulate perspective.

Reviewer 5:

The reviewer said that the team identified soot sources during engine cold start, but no explanation was given on the finding, which could be explained through CFD with currently available soot models or other parameters. Zero-dimensional (0-D) simulation of soot model seems to be a good approach for model parameter studies. Transitions from polycyclic aromatic hydrocarbons (PAHs) to soot were identified from wall-film experiments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Between the alignment to PACE and the involvement of SNL, LLNL, ANL, ORNL, and multiple universities, the reviewer remarked that this project demonstrates excellent collaboration.

Reviewer 2:

By definition, PACE has drastically improved collaboration across labs and with industry. The reviewer encouraged the project team to keep it up.

Reviewer 3:

The reviewer stated that collaboration was excellent.

Reviewer 4:

So far, there has been good collaboration across the different aspects of the project. It would be nice to see tighter integration with more CONVERGE simulations of the experimental configuration now that some of the new models have been developed and tested against simpler target flames. It looked to the reviewer like this is in the plan, which is good. There is also good collaboration with universities and other researchers through the Engine Combustion Network (ECN) and the International Energy Agency (IEA) working groups.

Reviewer 5:

The reviewer stated that the project team showed active collaboration with many universities and national laboratories. No interaction with industry was mentioned, but it could be done with AEC 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer affirmed that the future research plan put forth on Slide 18 has clear and sufficient detail in six areas. It can be logically seen that these are the right next steps toward the goal of soot understanding, soot model development, and delivery.

Reviewer 2:

The reviewer encouraged the project team to continue to pursue experimentation and simulation to achieve predictability.

Reviewer 3:

The reviewer wondered how the models will perform during the expansion stroke as soot oxidation is likely to continue through engine expansion after combustion. This is important in diesels, so the reviewer was curious if that was also equally important in GDI during cold start.

Reviewer 4:

All the future paths for the research looked really good. As the reviewer had mentioned above, it would be interesting to see some simulation of the wall-wetting work, since this was identified as a particular problem at cold start. Otherwise, it is a good lineup for the next year. It would be helpful if the PIs included target dates for the tasks or a timeline.

Reviewer 5:

There were a couple of challenges and barriers identified for each of five different areas related to soot modeling and experiments. Each PI laid out items for further research, which seem quite reasonable. Soot formation can be a main source of soot during cold-start engine operation, so it is right to focus on it. However, the reviewer noted that how to suppress soot formation and accelerate soot oxidation seems to be missing in the whole picture of PACE.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that this project is an important part of the DOE PACE objectives to minimize engine-out and vehicle tailpipe emissions.

Reviewer 2:

The reviewer responded affirmatively and said that this project is clearly aligned with the DOE's PACE consortium and Major Output 8.

Reviewer 3:

Improved prediction and reduction of soot is critical for cost-effective ICE applications, according to the reviewer.

Reviewer 4:

The reviewer commented that this project is highly relevant to the goals of PACE and hence the DOE objectives. It also integrates well with several other DOE-supported initiatives, like the ECN, which support better understanding and modeling of sprays, combustion, and emissions.

Reviewer 5:

The reviewer found the project to be very relevant to the GDI cold-start challenge, but only wondered about how the newer port fuel-injected (PFI)-GDI approaches may help the situation.

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

Reviewer 1:

The resources looked sufficient to the reviewer as all five PIs are involved actively, and research has progressed fine.

Reviewer 2:

Resources appeared fine to the reviewer.

Reviewer 3:

The resources seemed sufficient to the reviewer, and the PIs are executing the tasks in a timely manner.

Reviewer 4:

The reviewer expressed concern over FY 2022 spending cuts and their impact on this relevant and needed research.

Reviewer 5:

The experimental resources and computation resources seem to be in place. However, the reviewer did not understand how the new VTO budget, with the 57% reduction in Engine & Fuels funding, will or will not impact the PACE projects. Clearly, if it does, this project has insufficient funding resources.

Presentation Number: ace169
Presentation Title: Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts
Principal Investigator: Yong Wang (Washington State University)

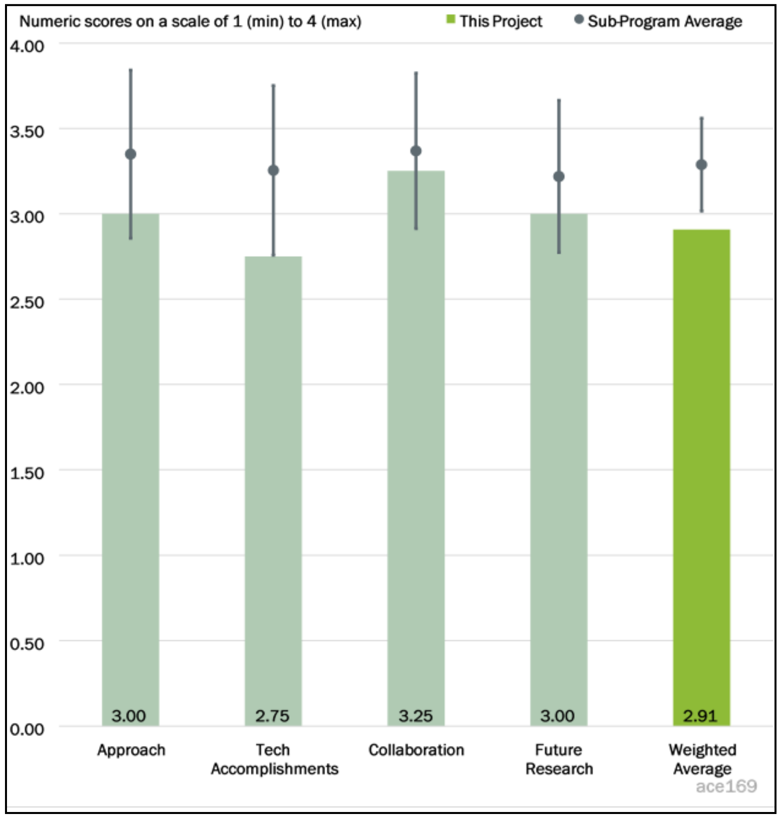


Figure 1-42 - Presentation Number: ace169 Presentation Title: Greatly Reduced Vehicle Platinum Group Metals (PGM) Contant Using Engineered, Highly Dispersed Precious Metal Catalysts Principal Investigator: Yong Wang (Washington State University)

Presenter

Yong Wang, Washington State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This is a very well thought out project, and the reviewer appreciated the matrix of catalyst combinations that will be tested. Also, it is good to see hydrothermal aging and sulfur resistance included in the scope. It is not clear if the final optimized catalysts will be tested on a vehicle (the goal is super ultra-low emission vehicle [SULEV20/30] compliance), but that would be good to include if possible. The reviewer suggested it will be useful to identify any barriers for commercialization as early as possible to either address them here or serve as motivation for future research.

Reviewer 2:

The reviewer opined that the approach of using SAC to reduce PGM content (if successful) would go a long way to overcoming the barrier related to sustainability and cost. However, no further information was provided on the approach other than to say researchers will use the U.S. DRIVE protocol to see if the SACs work, yet the current catalyst data presented by the researchers did not use conditions listed in the protocol. In order to understand and compare data from the proposed SAC with currently available catalysts, it is imperative that the protocol conditions be used to support positive SAC results.

Reviewer 3:

Researchers indicated several times that SACs were going to be the focus of their advanced materials that were synthesized using atom trapping. This approach has been clearly described during the review and in the literature. However, the literature has also indicated that the SAC materials do not necessarily result in the highest reactivity, especially for hydrocarbons. In fact, it is clusters that have better reactivity. The reviewer thought that it will be important for the researchers to clarify whether it is SAC or stable clusters as the project moves forward. If less than approximately 1nanometer(nm), all of the metals will be exposed to the surface, and this may be the true goal of the project. It seems that the tailored oxygen storage capacity (OSC) phase will be the most important aspect of the study, and the reviewer was looking forward to more discussion on that in the coming years.

The reviewer was a little concerned that the two projects have different starting points for the PGM content, as the percentage improvement will be very different.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the progress made so far is promising.

Reviewer 2:

Relevant simulated exhaust compositions were not used to evaluate the baseline catalyst presented. The baseline catalyst will need to be retested with the U.S. DRIVE protocol conditions in order to validate future results of new SACs. It was unclear to the reviewer if the researchers understand the parameters provided in the U.S. DRIVE protocol that was mentioned in the approach; during Q&A, the project team claimed to have followed the protocol, yet its figures clearly indicate different conditions. Additionally, the current gas hourly space velocity (GHSV) and gas compositions listed as being used are not relevant to stoichiometric gasoline exhaust and thus, do not provide useful catalyst information related to the TWC application.

Reviewer 3:

Having some data at this point was nice to see, and the team deserves credit for showing progress already. However, it was troubling to the reviewer that the evaluations were not performed under stoichiometric conditions and not while flowing all the criteria pollutants at the same time, which of course is the definition of TWC. If the researchers are looking for one material to do CO and NO, while another material does HC conversion, then it should be stated explicitly. In the end, there was a lot of confusion as to what the results indicated. Additionally, it is not clear why hydrothermal aging (HTA) was performed in air rather than lean-rich cycling or at least under neutral conditions. It almost seemed like these results were not directly intended for this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that this is an excellent team with a track record of fundamental emissions control research and characterization and good industry partners.

Reviewer 2:

It looked like a well-coordinated effort to the reviewer.

Reviewer 3:

The project team includes a diverse team that crosses all research sectors. Tasks seemed appropriate to the reviewer for assigned partners’ 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed future research is good, especially since it lists experimental conditions that are more relevant than the initial ones shown in the results section. It will be good to see the approach proposed scaled up to larger sizes for washcoating.

Reviewer 2:

The reviewer asserted that it was good to see sulfur tolerance in the plan. It would be worth doing at least a couple of experiments at varying space velocities to examine any impact of pore diffusion effects.

While aiming to show similar conversion with low PGM, it would be useful to also show how much improvement in conversion could be achieved using similar PGM levels with the SACs (or if there is an upper bound on the loadings achievable).

Reviewer 3:

The only details given were to state that new SAC would be tested according to protocol and scale up. The lack of detail related to future work made it difficult for the reviewer to evaluate; future work does not include decision points or possible barriers. The lack of this information makes it difficult to discern if the project team will be making new catalysts or just going to retest catalysts presented under appropriate exhaust conditions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer emphasized that reducing PGM content is very critical, given the high prices. Also, this will help with improved conversion of pollutants.

Reviewer 2:

The reviewer noted that the target of showing that SACs are more active than state-of -the-art, commercial TWCs at relevant temperatures would support DOE’s objective of reducing PGM use.

Reviewer 3:

The reviewer said that PGM research is clearly important due to the expected deficit in supply in the near future. This research has the potential to alleviant this in a short time period.

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 to do the intended tasks considering the increased cost of on-vehicle testing that will occur in the later stages, according to the reviewer.

Reviewer 2:

Resources look sufficient. It was not clear to the reviewer whether atomic modeling is included to help facilitate catalyst development— maybe it has already been done in the past— but it is worth clarifying the plans for this project.

Reviewer 3:

DOE resources are sufficient for this project, although the reviewer opined that it would have been nice to see additional funding coming from industry to support this research.

Acronyms and Abbreviations

°C	Degrees Celsius
0-D	Zero-dimensional
1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
3PL	Third-party logistics
A/F	Air/fuel
ACE	Advanced Combustion Engines
ACEC	Advanced Combustion and Emissions Control
AEC	Advanced Engine Combustion
Ag	Silver
AI	Artificial intelligence
AMOX	Ammonia oxidation
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ASC	Ammonia slip catalyst
BEA	Zeolite beta
BES	Basic Energy Sciences
BEV	Battery-electric vehicle
BP	Budget Period
BTE	Brake thermal efficiency
CA10	Crank angle at 10% mass fraction burned
CAFE	Corporate Average Fuel Economy
cc	Close coupled
CCV	Cycle-to-cycle variation
Ce	Cerium
CFD	Computational fluid dynamics
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression-ignition

CLEERS	Crosscut Lean Exhaust Emissions Reduction Simulations
CIERA	Cavitation-induced erosion risk assessment
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
COTS	Commercial-off-the-shelf
CR	Compression ratio
CRADA	Cooperative research and development agreement
CS	Cold start
CS	Cooled spray
CT	Computerized tomography
Cu	Copper
CUC	Clean up catalyst
DFI	Ducted fuel injection
DFP	Diesel particulate filter
DI	Direct injection
DMTV	Discharge molecular tagging velocimetry
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOC-F	Combined diesel oxidation catalyst and diesel particulate filter
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
E10	10% ethanol, 90% gasoline blend
EAT	Exhaust aftertreatment
ECFM	Extended coherent flame model
ECN	Engine Combustion Network
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EHC	Electrically heated catalyst
ELSA	Euler-Lagrange spray atomization
EMSL	Environmental Molecular Sciences Laboratory

EPA	U.S. Environmental Protection Agency
EPR	Electron paramagnetic resonance spectroscopy
Fe	Iron
FTE	Freight-ton efficiency
FTIR	Fourier-transform infrared spectroscopy
FTP	Federal Test Procedure
FY	Fiscal Year
g/hp-hr	Gram per horsepower-hour
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GHG	Greenhouse gas
GHSV	Gas hourly space velocity
GM	General Motors
GPCF	Gallon per cubic foot
GPF	Gasoline particulate filter
GPR	Gaussian process regression
GPS	Global positioning system
GVWR	Gross vehicle weight rating
H_2	Hydrogen
H_2O	Water
HC	Hydrocarbon
HCT	Hydrocarbon trap
HD	Heavy-duty
HFET	Highway Fuel Economy Test
HFS	High fuel stratification
HIL	Hardware-in-the-loop
HPC	High performance computing
HTA	Hydrothermally aged
HVAC	Heating, ventilation, and air conditioning
IC	Internal combustion
ICE	Internal combustion engine
ITE	Indicated thermal efficiency

L	Liter
lb	Pound
LD	Light-duty
LES	Large eddy simulation
LIDAR	Light detection and ranging
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LVF	Liquid volume fraction
MCCI	Mixing-controlled compression ignition
MCE	Multi-cylinder engine
MD	Medium-duty
MER	Molar expansion ratio
MIT	Massachusetts Institute of Technology
ML	Machine learning
Mn	Manganese
MnCe	Manganese cerium
MOU	Memorandum of Understanding
MPC	Model predictive control
MPR	Multi-pressure rail
MY	Model Year
N_2O	Nitrous oxide
nm	Nanometer
NM	Non-methane
NMHC	Non-methane hydrocarbon
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NREL	National Renewable Energy Laboratory
NTC	Negative temperature coefficient
NYCC	New York City Cycle

OEM	Original equipment manufacturer
OHC	Oxidation half cycles
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity/component
P	Pressure
PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
PC	Pre-chamber
PCI	Precision Combustion Inc.
PCP	Peak cylinder pressure
Pd	Palladium
PDPA	Phase Doppler particle analyzer
PFI	Port fuel injection
PFS	Partial fuel stratification
PGM	Platinum group metals
PI	Principal Investigator
PIV	Particle image velocimetry
PM	Particulate matter
PNA	Polynuclear aromatics
PNNL	Pacific Northwest National Laboratory
ppm	Parts per million
Pt	Platinum
Q&A	Question and answer
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes
Rb	Rubidium
RCM	Rapid compression machine
RD5-87	Research-grade regular E10 gasoline
RDD&D	Research, development, deployment, and demonstration
Rh	Rhodium
RHC	Reduction half cycle
rpm	Revolutions per minute

Ru	Ruthenium
S	Flame speed
S	Sulfur
SAC	Single-atom catalyst (catalysis)
SAE	Society of Automotive Engineers
SCE	Single-cylinder engine
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SI	Spark ignition
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
SOA	State of the art
SOPO	Statement of project objectives
Spaci-MS	Spatially resolved capillary inlet - mass spectroscopy
SPI	Stochastic pre-ignition
SULEV	Super Ultra-Low Emissions Vehicle
SW	Spray wall
SWI	Spray-wall interaction
SwRI	Southwest Research Institute
t	Time
TCC-III	Transparent combustion chamber
TCO	Total cost of ownership
TPD	Temperature programmed desorption
TPR	Temperature programmed reduction
TPRF	Toluene primary reference fuel
TRL	Technology Readiness Level
TWC	Three-way catalyst
UDF	Undefined user files
UFPV	Unsteady flamelet progress variable
UH	University of Houston
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability

UVA	University of Virginia
UW-Madison	University of Wisconsin at Madison
V	Volt
VMT	Vehicle-miles traveled
VOF	Volume of fluid
VTO	Vehicle Technologies Office
WHR	Waste heat recovery
WSR-MZ	Well-stirred reactor multi-zone
wt.%	Weight percent
Zero-RK	Zero-Order Reaction Kinetics
Zr	Zirconium
ZSM-5	Zeolite Sacony Mobil5

2. Battery R&D

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Battery R&D subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and distinct crosscuts. The Energy Storage Grand Challenge encompasses R&D across energy storage including the discovery of alternative lithium battery materials, processing for raw materials, development of advanced battery cells, discovery of innovative cell manufacturing techniques, and battery recycling. The Critical Minerals crosscut aims to reduce or eliminate cobalt and nickel in lithium battery cathode materials, develop substitutes for graphite such as silicon composite anodes and lithium metal anodes, and develop advanced recycling and processing through scale up of bench-scale recycling processes and innovative separation processes seedlings. The Advanced Manufacturing crosscut is focused on coordination with the Advanced Manufacturing Office for joint projects scaling up solid state battery materials and lithium metal electrode processing technologies addressing critical materials for batteries.

The Battery R&D activity supports early-stage R&D of high-energy and high-power battery materials, cells, and battery development that can enable industry to significantly reduce the cost, weight, volume, and charge time of PEV batteries. This activity is organized into sub-activities: advanced battery materials research, advanced battery cell R&D, and battery recycling R&D. Advanced battery materials research is coordinated with the Critical Minerals Initiative and includes: early-stage research of new lithium-ion cathode, anode, and electrolyte materials (currently accounting for 50-70 percent of PEV battery cost) and the development of "beyond lithium-ion" technologies, such as lithium metal anodes, solid-state electrolytes, and sulfur-based cathodes, that have the potential to significantly reduce weight, volume, and cost by three times, with a target of $60/kWh. Advanced battery cell R&D includes: early-stage R&D of new battery cell technology that contains new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast charging; and high-fidelity battery performance, life, fast charging, and safety testing of innovative battery technologies including recycled material and cells. Battery recycling R&D includes the development of innovative battery materials recycling and reuse technologies, and the Lithium-Ion Battery Recycling Prize, both to assure sustainability and domestic supplies of key battery materials and minerals.

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
bat028	Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility	Wenquan Lu (ANL)	2-11	2.88	3.00	3.13	3.13	**3.00**
bat030	Electrode Prototyping Activities in ANL's Cell Analysis, Modeling and Prototyping (CAMP) Facility	Andrew Jansen (ANL)	2-16	3.50	3.33	3.33	3.17	**3.35**
bat164	Thick, Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing	Jianlin Li (ORNL)	2-20	3.25	3.25	3.13	3.00	**3.20**
bat167	Process Development and Scale-Up of Advanced Active Battery Materials	Ozge Kahvecioglu (ANL)	2-25	3.50	3.75	3.75	3.42	**3.65**
bat168	Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials	Krzysztof Pupek (ANL)	2-31	3.63	3.50	3.63	3.38	**3.53**
bat183	In Situ Spectroscopies of Processing Next-Generation Cathode Materials	Feng Wang (BNL)	2-34	3.75	3.88	3.63	3.63	**3.78**
bat232	High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions	Vincent Battaglia (LBNL)	2-38	3.00	3.00	2.63	3.00	**2.95**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat240	High-Energy Anode Material Development for Lithium-Ion Batteries	Cary Hayner (Sinode Systems/ NanoGraf)	2-43	3.30	3.00	3.40	3.20	**3.15**
bat247	Fast-Charge and Low-Cost Lithium-Ion Batteries for Electric Vehicles	Herman Lopez (Zenlabs Energy, Inc./ Envia Systems)	2-47	3.40	3.40	3.40	3.50	**3.41**
bat269	An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials	Chad Xing (University of Missouri)	2-51	3.00	2.67	3.17	2.67	**2.81**
bat293	A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries	Yan Wang (Worcester Polytechnic Institute)	2-55	3.13	3.38	3.25	3.50	**3.31**
bat315	Process R&D for Droplet-Produced Powdered Materials	Joe Libera (ANL)	2-59	3.38	3.25	3.00	3.25	**3.25**
bat355	Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications	Madhuri Thakur (Farasis Energy)	2-64	3.25	3.13	3.38	3.00	**3.17**
bat356	Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials	Madhuri Thakur (Farasis Energy)	2-67	3.38	3.13	2.88	3.00	**3.14**
bat377	ReCell–Overview and Update	Jeffrey Spangen-berger (ANL)	2-70	3.25	3.25	3.50	3.33	**3.29**
bat382	ReCell–Modeling and Analysis for Recycling	Qaing Dai (ANL)	2-74	3.36	3.36	3.36	2.92	**3.30**
bat386	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update	Venkat Srinivasan (ANL)	2-79	3.50	3.30	3.50	2.88	**3.32**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat402	Improving Battery Performance through Structure-Morphology Optimization	Venkat Srinivasan (ANL)	2-83	3.75	3.50	3.75	3.63	**3.61**
bat441	High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LMNO)/Lithium-Titanate (LTO) Batteries	Jennifer Hoffman (Gotion)	2-87	3.30	2.70	3.20	3.00	**2.95**
bat442	Behind-the-Meter-Storage (BTMS)–Overview and Update	Anthony Burrell (NREL)	2-91	3.63	3.50	3.50	3.50	**3.53**
bat456	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Anode Structures that Enhance Fast Charge	Andrew Jansen (ANL)	2-95	3.58	3.42	3.58	3.17	**3.45**
bat457	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Methods for the Detection and Quantification of Lithium Plating	Johanna Nelson-Weker (SLAC)	2-100	3.58	3.58	3.50	3.60	**3.58**
bat459	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Heat-Generation Concerns Associated with Extreme Fast Charging	Matthew Keyser (NREL)	2-104	3.58	3.42	3.33	3.10	**3.41**
bat461	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Quantifying Heterogeneities/Degradation During Fast Charge	Andrew Colclasure (NREL)	2-108	3.25	3.00	3.38	3.00	**3.11**
bat462	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Aging and the Role of Fast-Charge Protocol	Eric Dufek (INL)	2-111	3.58	3.25	3.58	3.42	**3.40**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat463	eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Effects of Extreme Fast Charging on Lithium-Ion Battery Cathode	Tanvir Tanim (INL)	2-115	3.50	3.25	3.75	2.50	**3.28**
bat464	ReCell–Direct Cathode Recycling: Material Separation and Preparation	Albert Lipson (ANL)	2-119	3.67	3.33	3.17	3.17	**3.38**
bat465	ReCell–Direct Cathode Recycling: Relithiation and Upcycling	Jack Vaughey (ANL)	2-121	3.25	3.50	3.33	3.08	**3.36**
bat467	ReCell–Battery Design for Recycling	Jianlin Li (ORNL)	2-126	3.14	2.86	2.71	2.71	**2.89**
bat470	Process R&D Using Supercritical Fluid Reactors	Youngho Shin (ANL)	2-132	3.40	3.40	3.40	2.90	**3.34**
bat472	Behind-the-Meter-Storage (BTMS)–Materials	Kyusung Park (NREL)	2-137	3.00	3.17	3.33	2.92	**3.11**
bat473	Behind-the-Meter-Storage (BTMS)–Analysis	Margaret Mann (NREL)	2-142	3.56	3.31	3.38	3.25	**3.38**
bat475	Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes	David Wood (ORNL)	2-148	3.42	3.17	3.25	3.25	**3.25**
bat478	Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes for Solid State Lithium Batteries	Steve Martin (Iowa State University of Science and Technology)	2-154	3.38	3.38	2.13	3.50	**3.23**
bat479	Composite Solid Ion Conductor with Engineered Lithium Interface	Kyler Carroll (Wildcat Discovery Technologies)	2-158	3.33	3.00	1.83	2.83	**2.92**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat480	Physical and Mechano-Electrochemical Phenomena of Thin Film Li-Ceramic Electrolyte Constructs	Jeff Sakamoto (University of Michigan)	2-163	3.63	3.63	3.38	3.50	**3.58**
bat481	Li Dendrite-Free Li7N2I-LiOH Solid Electrolytes for High Energy Lithium Batteries	Chunsheng Wang (University of Maryland, College Park)	2-167	3.38	3.50	3.38	3.25	**3.42**
bat482	Hot Pressing of Reinforced Lithium Nickel Manganese Cobalt Oxide (Li-NMC) All-Solid-State Batteries with Sulfide Glass Electrolyte	Thomas Yersak (General Motors, LLC)	2-171	3.50	3.42	3.00	3.08	**3.34**
bat483	Low Impedance Cathode/Electrolyte Interfaces for High Energy Density Solid-State Batteries	Eric Wachsman (University of Maryland, College Park)	2-176	3.38	3.50	3.75	3.50	**3.50**
bat484	Developing an In-Situ Formed Dynamic Protection Layer to Mitigate Lithium Interface Shifting: Preventing Dendrite Formation on Metallic Lithium Surface to Facilitate Long Cycle Life of Lithium Solid State Batteries	Deyang Qu (The University of Wisconsin-Milwaukee)	2-180	3.38	3.38	3.50	3.38	**3.39**
bat485	Molecular Ionic Composites: A New Class of Polymer Electrolytes to Enable All Solid-State and High Voltage Lithium Batteries	Louis Madsen (Virginia Polytechnic Institute and State University)	2-185	3.42	3.25	3.50	3.33	**3.33**
bat486	All Solid State Batteries Enabled by Multifunctional Electrolyte Materials	Pu Zhang (Solid Power, Inc)	2-190	3.33	3.50	2.83	3.33	**3.35**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat487	Developing Materials for High-Energy-Density Solid State Lithium-Sulfur Batteries	Donghai Wang (Penn State University Park)	2-194	3.40	3.40	2.80	3.40	**3.33**
bat488	Fundamental Understanding of Interfacial Phenomena in Solid State Batteries	Xingcheng Xiao (General Motors, LLC)	2-198	3.50	3.33	3.83	2.83	**3.38**
bat489	Multidimensional Diagnostics of the Interface Evolutions in Solid-State Lithium Batteries	Yan Yao (University of Houston)	2-202	3.64	3.71	3.71	3.50	**3.67**
bat490	First-Principals Modeling of Cluster-Based Solid Electrolytes	Puru Jena (Virginia Common-wealth University)	2-207	3.50	2.83	2.83	3.00	**3.02**
bat491	Predictive Engineering of Interfaces and Cathodes for High-Performance All Solid-State Lithium-Sulfur Batteries	Badri Narayanan (University of Louisville)	2-210	3.17	3.00	3.08	3.00	**3.05**
bat492	Machine Learning for Accelerated Life Prediction and Cell Design	Eric Dufek (INL)	2-215	3.50	3.50	3.67	3.50	**3.52**
bat493	WPI USABC LCFC Project	Yan Wang (WPI)	2-217	3.50	3.40	3.60	3.40	**3.45**
bat494	Microvast USABC LCFC Project	Wenjuan Mattis (Microvast)	2-221	3.67	3.67	3.50	3.67	**3.65**
bat495	AMO/VTO FOA Award Applied Materials	Ajey M. Joshi (Applied Materials)	2-224	3.50	3.40	3.50	3.30	**3.43**
bat496	Silicon Consortium Project: Advanced Characterization of Silicon Electrodes	Robert Kostecki (LBNL)	2-228	3.75	3.50	3.50	3.75	**3.59**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat497	Silicon Consortium Project: Electrochemistry of Silicon Electrodes	Christopher Johnson (ANL)	2-231	3.63	3.63	3.63	3.50	**3.61**
bat498	Silicon Consortium Project: Next-Gen Materials for Silicon Anodes	Nathan Neale (NREL)	2-234	3.63	3.25	3.63	3.25	**3.39**
bat499	Silicon Consortium Project: Mechanical Properties of Silicon Anodes	Katherine Harrison (SNL)	2-237	3.38	3.13	3.38	3.25	**3.23**
bat500	Silicon Consortium Project: Science of Manufacturing for Silicon Anodes	Gabe Veith (ORNL)	2-240	3.63	3.25	3.75	3.25	**3.41**
bat501	Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode	Kristin Persson (LBNL)	2-243	3.50	3.38	3.75	3.38	**3.45**
bat502	Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Si Anode (Si-HPC)	Andrew Colclasure (NREL)	2-246	3.75	3.63	3.88	3.75	**3.70**
bat503	Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicone Anode	Jean-Luc Fattebert (ORNL)	2-249	3.63	3.38	3.50	3.25	**3.44**
bat504	3D Printed, Low Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries	Eric Wachsman (University of Maryland)	2-252	3.63	3.38	3.13	3.50	**3.42**
bat505	Advanced Electrolyte Supporting 500 Wh/Kg Li-C/NMC Batteries	Chunsheng Wang (University of Maryland)	2-256	3.38	3.38	3.50	3.13	**3.36**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat506	Composite Cathode Architectures Made by Freeze-Casting for All Solid State Lithium Batteries	Marca Doeff (LBNL)	2-259	3.50	3.38	3.50		**3.43**
bat507	Controlled Interfacial Phenomena for Extended Battery Life	Perla Balbuena (Texas A&M)	2-263	3.33	3.33	3.33	3.00	**3.29**
bat508	Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries	Mei Cai (General Motors, LLC)	2-266	3.25	3.25	3.17	3.08	**3.22**
bat510	Electrochemically Stable High Energy Density Lithium-Sulfur Batteries	Prashant Kumta (University of Pittsburgh)	2-270	3.25	3.25	3.13	3.25	**3.23**
bat511	High-Energy Solid-State Lithium Batteries with Organic Cathode Materials	Yan Yao (University of Houston)	2-274	3.50	3.25	3.50	3.17	**3.33**
bat512	Highly Loaded Sulfur Cathode, Coated Separator and Gel Electrolyte for High Rate Li-Sulfur	Yong Joo (Cornell University)	2-278	3.08	2.92	3.00	3.00	**2.98**
bat513	Multifunctional Li-ion Conducting Interfacial Materials for Lithium Metal Batteries	Donghai Wang (Penn State University)	2-282	3.63	3.63	3.38	3.38	**3.56**
bat518	Solvent-free and Non-sintered 500 Wh/kg All Solid State Battery	Mike Wixom (Navitas Advanced Solutions Group)	2-286	3.00	2.63	3.25	2.88	**2.83**
bat519	Synthesis, Screening, and Characterization of Novel Low Temperature Electrolyte for Lithium-Ion Batteries	Xiao-Qing Yang (LBNL)	2-289	3.17	3.00	3.17	3.00	**3.06**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat520	Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-Ion Batteries	Zhengcheng Zhang (ANL)	2-292	3.17	3.00	3.17	3.33	**3.10**
bat521	Ethylene Carbonate-Lean Electrolytes for Low-Temperature, Safe, Lithium-Ion Batteries	Bryan McCloskey (University of California, Berkeley)	2-295	3.33	3.33	3.33	3.50	**3.35**
bat522	Thin-film Lithium Metal Manufacture by Room Temperature Electrodeposition	Alirio Liscano (Albemarle)	2-299	3.13	2.88	3.00	2.88	**2.95**
Overall Average				**3.41**	**3.29**	**3.32**	**3.22**	**3.32**

Presentation Number: bat028
Presentation Title: Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility
Principal Investigator: Wenquan Lu (Argonne National Laboratory)

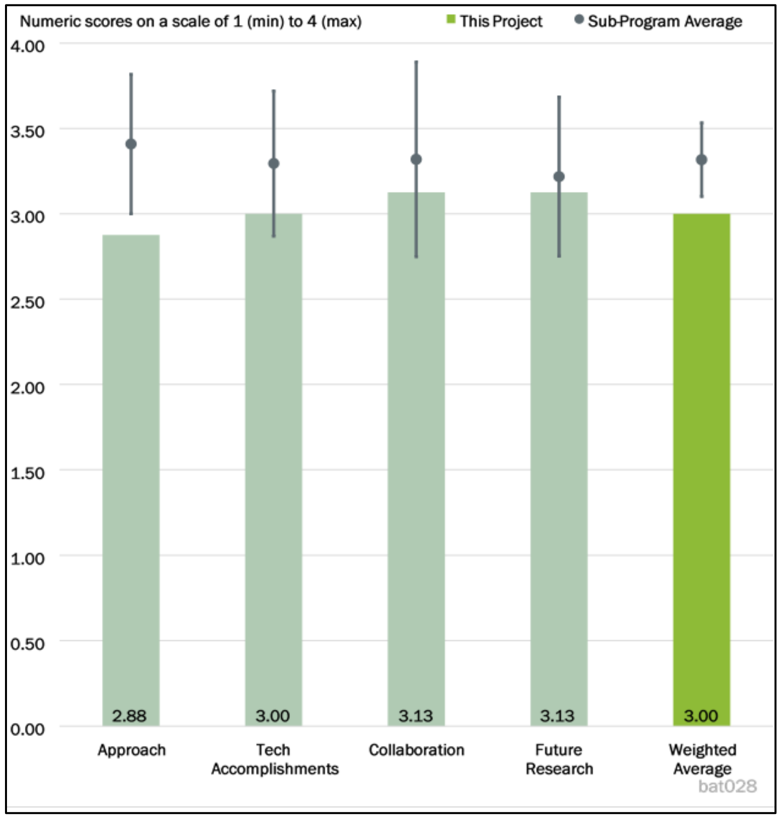


Figure 2-1 - Presentation Number: bat028 Presentation Title: Materials Benchmarking Activities for Cell Analysis, Modeling, and Prototyping (CAMP) Facility Principal Investigator: Wenquan Lu (Argonne National Laboratory)

Presenter

Wenquan Lu, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Based on the slide deck, it was not clear to the reviewer what the benchmark is and what the selection protocol is for screening materials. It also appears that the new materials development was undertaken as part of this project. The work presented is very interesting and very encouraging and is covering a wide range of topics definitely supporting some of the objectives. The reviewer asked for the project team to please comment on cost reduction opportunities for each project undertaken.

Reviewer 2:

According to the reviewer, the project's approach is generally effective but could be improved with a little more focus on evaluating more relevant cathode and anode materials and developing processes for electrolytes. It does contribute to overcoming the barriers in the development of electric vehicle (EV) batteries that can meet DOE and United States Advanced Battery Consortium (USABC) goals both in cost and performance by performing the evaluation of high energy active martials. This is part of a larger activity (the reviewer was not sure why this should be a separate project) related to the materials benchmarking activities for Cell Analysis, Modeling, and Prototyping (CAMP). It is no doubt important to have standardization in the materials evaluation, especially because of the wide category of materials being pursued by DOE, which are continuing to evolve.

The reviewer identified two weaknesses. Firstly, and despite the on-going work on the development of solid polymer electrolyte membrane and the assessment of holey graphene, this project does not seem to be well connected with the material development in other (DOE) laboratories. Secondly, benchmarking needs to be done on the materials currently used in or rapidly emerging from industry, either in liquid electrolyte or solid electrolyte (SE) systems, but the project does not seem to have established any such connections. Getting access to such materials may be challenging, but efforts should be made in that direction.

Reviewer 3:

The question the reviewer had relates to the focus of the work. It was clear to the reviewer that benchmarking of new battery materials is a critical task in terms of sorting out whether new materials have any favorable comparison (or not) to existing established materials. To that end, the benchmarking aspect of the project is certainly important. What was not clear to the reviewer is whether the project goal is to develop new materials or to evaluate proposed materials from developers to provide feedback as to commercial relevance. There seems to be a mix of activities along this front, and the reviewer assumed that this issue has been discussed; however, the reviewer found the charter of the project a little confusing. That is not to say that the work is not well planned or executed, the reviewer was just unsure whether the goals are sufficiently clear.

Reviewer 4:

The reviewer commended the multiple methods developed to produce both cast and stand-alone separator films. However, it would have been good to understand more about the degree of challenges that were overcome; for example, ran X experiments with Y outcomes and required Z cycles of data to achieve results. In addition, it would be good to discuss next steps, or challenges, even if out of scope for the current effort.

For solid electrolyte approaches, it would have been good to map out properties in terms of thickness and operating temperature. In addition, the reviewer asked the project team to please highlight the technical gaps in performance that might limit or enable further development or scale-up.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that good progress has been made: developing methods for standalone and direct casting solid-state electrolyte (SSE) thin films on a lithium (Li) anode by incorporating solid electrolytes, which showed good performance in cells with lithium iron phosphate (LFP) cathode; evaluating silicon that is made from halloysite preserves high specific capacity; and evaluating binder and solvent-free nickel manganese cobalt oxide (NMC) cathodes holey graphene, which showed decent performance at high loadings. The results with a solid electrolyte membrane are particularly interesting, though details are missing on LFP cathode (if the same solid electrolyte or some other ionic conductor is dispersed in the composite cathode).

This reviewer also identified one weakness—among the three activities, the first one has greater relevance to the project, but the latter two tasks do not have as much relevance and the results are not noteworthy. This underlines the need for better coordination for bringing relevant tasks into this project.

Reviewer 2:

All experimental work is of high quality and results are very encouraging, according to the reviewer. Clear performance/benchmarking targets for each material/component would be helpful. in the slide deck as the performance indicators are only shown at a cell level.

The reviewer inquired about the form of silicon (Si) with respect to the 1,800 milliampere-hours per gram (mAh/g) specific capacity on Slide 13.

Reviewer 3:

The milestones for the time period were stated as developing coating methods to produce solid-state ceramic separators. It was not clear to the reviewer whether any commercial solid-state ceramic systems were benchmarked in order to establish the state of the art. Several activities were presented that were not part of milestones for this time period.

Reviewer 4:

Although the information and progress demonstrated is impressive, the reviewer was disappointed that the stated goal to "benchmark state of the art material from partners" seemed disjointed from the progress and data achieved. However, this was clearly not an issue with the project owner(s), but more a symptom of not having access to those materials. In light of this, maybe the whole project goals should be reevaluated. For example, it was difficult for the reviewer to connect the overall project objectives with the year's accomplishments and how they link to the USABC objectives. The reviewer suggested that, in a future request to properly review progress, a section be added to the project on how the milestones were chosen and how they tie to the overall project goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that technical collaboration is commendable and shows in the great use of the characterization techniques.

Reviewer 2:

The reviewer mentioned several on-going collaborations: U.S. Department of Energy (DOE) laboratories (Argonne National Laboratory [ANL], Brookhaven National Laboratory [BNL], Oak Ridge National Laboratory [ORNL], and Pacific Northwest National Laboratory [PNNL]), National Aeronautics and Space Administration (NASA), universities (Indiana University – Purdue University Indianapolis [IUPUI], University of Missouri, University of Arkansas, The George Washington University, Western Michigan University, Brigham Young University, and University of Louisville), and industrial partners (Applied Minerals, Jolt Energy Storage Technologies, Koura, Lubrizol, NEI, Osaka Titanium Corp., OSiAlC , Paraclete Energy, Phillips 66, Superior Graphite Co., Targray, and Toda Kogyo).

The reviewer brought up two weaknesses: (1) it is not clear what the specific activities and materials are in these collaborations as it would be helpful if the activity is mentioned for each of the collaborations and (2) collaboration with any battery company manufacturer would be beneficial.

Reviewer 3:

As the PI stated, it would have been helpful to the reviewer to find more state-of-the-art partners who could take advantage of the project and help advance the science. The reviewer wanted to know if there should be more effort made to market this project or find other collaboration models that can bring in partners, especially those from industry.

Reviewer 4:

No issues were noted 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer mentioned that the proposed future work is effectively and logically planned by continuing the development of solid-state electrolyte (SSE) effort, especially focusing on the fabrication scalability of oxide and sulfide SSE (lithium lanthanum zirconium oxide [LLZO], Li_6PS_5Cl) and integration into prototype cells will be quite useful and relevant. Additionally, there are plans to acquire and characterize high-energy anode and cathode materials from domestic vendors, including thermal properties. Overall, the future plans are to continue to work closely with research institutions and industrial suppliers to enable the lithium-ion battery (LIB) technology for EV applications.

Reviewer 2:

The reviewer thought that the future effort outlined makes sense in the context of the barriers to obtaining new, state-of-the-art materials.

Reviewer 3:

The future goals are broad but relevant, according to the reviewer.

Reviewer 4:

As the team has suggested, it is important to balance research and validation activities. The reviewer stated that the work on solid electrolytes is outlined very well.

The comment on the ability to source advanced materials is valid, and the project team might consider creating a model that will allow industry to collaborate with the national laboratories while protecting the background and resulting intellectual property (IP).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the project supports the overall DOE objectives by validating the rapidly emerging electrode and electrolyte materials being marketed and reported to improve lithium-ion batteries. A centralized facility is required for a consistent and correct assessment of these materials, either for material development or material benchmarking, which this project is intended to do. This project has therefore a dual role of interacting with universities and national laboratories for material development and industry for material assessment and benchmarking. Overall, this is quite relevant to the DOE VTO battery programs.

Reviewer 2:

The reviewer remarked that third-party validation of the new materials and their compatibility with other cell components is critical for the industry as a whole. Developing processes to support the scale-up of the new materials should be the CAMP facility’s focus.

Reviewer 3:

Material benchmarking of advanced materials in battery systems is critically important. The reviewer said that focusing on the scope of the project should continue.

Reviewer 4:

The reviewer responded affirmatively and said that the projects described encompass potentially low-cost methods to form solid electrolytes, to find straightforward techniques to generate Si nanomaterials, and to find methods to form binder and solvent-free cathode electrode; these are important and relevant. However, the reviewer would like to have more analysis presented. For example, the reviewer wanted to know how much cost is saved versus how much is potentially added as part of the cathode project, whether that makes it a relevant project, and what its importance is.

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, resources are commensurate with the scope of the project and adequate to achieve the stated milestones.

Reviewer 2:

Given that the objectives are on track to be achieved, or have already been achieved, the reviewer asserted that it would be a good assumption that the goals are properly resourced.

Reviewer 3:

The reviewer found the resources to be sufficient. However, there might need to be some legal or project management support to improve access to the new materials.

Reviewer 4:

This reviewer noted no issues.

Presentation Number: bat030
Presentation Title: Electrode Prototyping Activities in ANL's Cell Analysis, Modeling and Prototyping (CAMP) Facility
Principal Investigator: Andrew Jansen (Argonne National Laboratory)

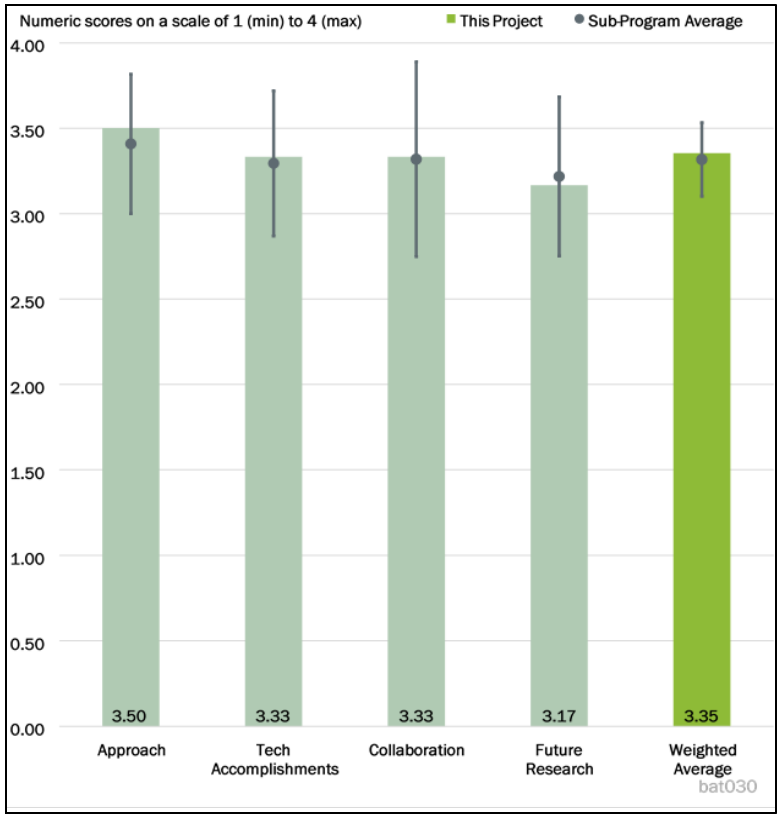


Figure 2-2 - Presentation Number: bat030 Presentation Title: Electrode Prototyping Activities in ANL's Cell Analysis, Modeling and Prototyping (CAMP) Facility Principal Investigator: Andrew Jansen (Argonne National Laboratory)

Presenter

Andrew Jansen, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, this is a superb project for the development of new technologies for electrodes. It is a great service to other labs and universities. This project addresses very carefully the major barrier, which is to increase the energy density that is very limited in present commercial batteries as well as focus on using materials that guaranteed safety, good cost, and long cycle life. A great advantage of this project is the testing of small-scale electrodes before going to large and commercial scale.

Reviewer 2:

The reviewer asserted that the project aims to scale up a material evaluation from bench-top to pre-pilot or pilot level. The PI has demonstrated that the project’s capability of scale-up evaluation for the materials is building up. The project is well designed and feasible; for example, a multi-functional coater has been designed and optimized and therefore materials of different kinds can be tried at pilot level.

Reviewer 3:

The reviewer observed that the proposal is generally effective but needs a little more focus on evaluating more relevant and newer cathode and anode materials and electrolytes. This is a fairly big project and is the only DOE project that provides independent validation within DOE for new materials being developed under VTO projects. It helps to overcome the barriers to the development of advanced EV batteries by assisting in the development of new materials that will provide performance enhancement and/or reduced cost. It is crucial to have standardization in the assessment of the materials, particularly in bigger pouch cells (instead of coin cells), especially because of the wide category of materials continuing to evolve under the VTO projects.

The reviewer mentioned three weaknesses: (1) there is little material assessment being done on "Beyond Li-ion battery" technologies, i.e., either Si-NMC or Li-sulfur (S) technologies. Even for Li-ion technologies, this project has not really caught up with the new materials (high Ni), high-voltage electrolyte, etc. (2) The PIs should be encouraged (or even mandated by DOE) to utilize the CAMP faciality as a pathway toward scale-up and commercialization of their technologies. (3) Benchmarking needs to be done on the materials currently used in or rapidly emerging from industry, but the project does not seem to have established any such connections yet. Getting access to such materials may be challenging, but efforts should be made in that direction.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that multiple instruments, e.g., multi-functional coater, were set up and tested. The capability of manufacturing a large electrode web was demonstrated. The facility has served many customers.

Reviewer 2:

The reviewer stated that progress goes as planned with some constraints due to coronavirus disease 2019 (COVID-19). Major breakthroughs are coming together with the BAT028 project. The scheduled milestones so far have been concluded successfully, and those in progress are providing the expected results.

Perhaps the PIs should report more extensive tables comparing the coatings and cathode materials. These comparisons should include such factors as safety, cycling life, and cost as well the other, already reported factors as cobalt mass per energy and energy per mass (g-density). For both cathodes and coatings materials, the reviewers may have a better idea of the big picture behind these prospective materials. Also, except for the baseline anode (graphite) and silicon monoxide reports in virtual conferences, all the effort in anodes has been limited to the baseline (graphite).

Reviewer 3:

The reviewer found that good progress has been made in supporting several DOE projects by providing advanced prototype electrodes (baseline and novel materials), which is one of the main objectives of this project. Likewise, the process for coating hybrid ceramic polymer composites and electrode ceramic structures using the roll-to-roll (R2R) reverse comma coater has been optimized (also listed in another project, which may be a sub to this). A multi-functional coater is being installed that may benefit many projects. Finally, radiography and energy dispersive X-ray diffraction are being explored to probe electrode heterogeneity in thick electrodes. Overall, the progress is fair and generally effective and helps in alleviating the problems of variability in electrode assessment and problems related to coating polymer electrolyte and solid electrolyte films on a Li anode.

Regarding weaknesses, the reviewer commented that two of the project activities—supplying electrodes to the other PIs and installing a new multi-functional coater—have greater relevance to the project and are beneficial to other on-going projects. However, the project has yet to address the more current materials for Li-ion batteries and also new materials for beyond Li-ion technologies. This underlies the need for better coordination with DOE for bringing relevant tasks into this project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that this project has extraordinary collaborations, providing electrodes and cells to several first-tier universities, to leading industrial companies in the battery business, and to several of the major national laboratories.

Reviewer 2:

The reviewer remarked that there are several on-going collaborations listed here, within and outside DOE, several universities, and industrial partners. The majority of these collaborations over the past several years are related to the CAMP Facility providing electrodes and cells.

According to the reviewer, one weakness in the project is that it is probably useful to provide further description of the materials and cells supplied to the collaborators to assess the scope and benefits of such collaborations.

Reviewer 3:

The reviewer indicated that the CAMP Facility has provided electrode and cells to universities, national laboratories, and industry. The reviewer suggested that the PI should consider reaching out to collaborate with either academics or industry to gain knowledge of scale-up processing of materials with different properties in addition to different chemistries.

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 state project ended.

Reviewer 1:

The reviewer found that the proposed future work is effectively and logically planned: demonstrate the functionality of new multi-functional coated with hybrid ceramic polymer composite coatings; explore new electrode formulations with reduced binder; and expand the electrode library by adding new materials of various NMC formulations such as high Ni, NMC, and SiO_x etc. Overall, the future plans are to continue to work closely with research institutions and industrial suppliers to enable the LIB technology for EV applications.

Reviewer 2:

All seemed very well planned to the reviewer, who commented that the development of better anodes should have a stronger emphasis in this project, such that development of electrolytes and cathodes are in full balance with the development of anodes.

Reviewer 3:

The reviewer remarked that the proposed research in the next budget period is to demonstrate hybrid ceramic-polymer coating capability for the coater and enhance the electrode library. The research aligns well with the objective. However, the reviewer suggested that the PI enhance the diagnosis so the impact of properties on the processability can be better understood.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the project supports the overall DOE objectives by validating the rapidly emerging electrode and electrolyte materials being marketed and reported to improve lithium-ion batteries. A centralized facility is required for an independent verification and validation of these materials, either for material development or materials benchmarking, which this project is intended to do. This will be essential for subsequent implementation (and commercialization) of these materials in EV cells. This project also provides good baseline electrodes (in the electrode library) to other battery projects as a way of standardization. This project has a dual role of interacting with other DOE-VTO PIs at universities and national laboratories for material development and industry for material assessment and benchmarking. Overall, this is quite relevant to the DOE VTO battery programs.

Reviewer 2:

The reviewer agreed that the project supports the DOE objectives. The project aims to facilitate evaluation of new electrode materials from tens of grams scale to kilogram scale. The CAMP facility would assist the material development and scale-up investigations.

Reviewer 3:

This project is fully relevant to all aspects of DOE objectives, according 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 stated that resources are commensurate (even slightly higher) with the scope of the project and adequate to achieve the stated milestones.

Reviewer 2:

The reviewer commented that the resources are really more than sufficient, except that some new sophisticated measurement equipment may be needed.

Reviewer 3:

The reviewer remarked that ANL has excessive resources in engineering design and advanced diagnosis.

Presentation Number: bat164
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 four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

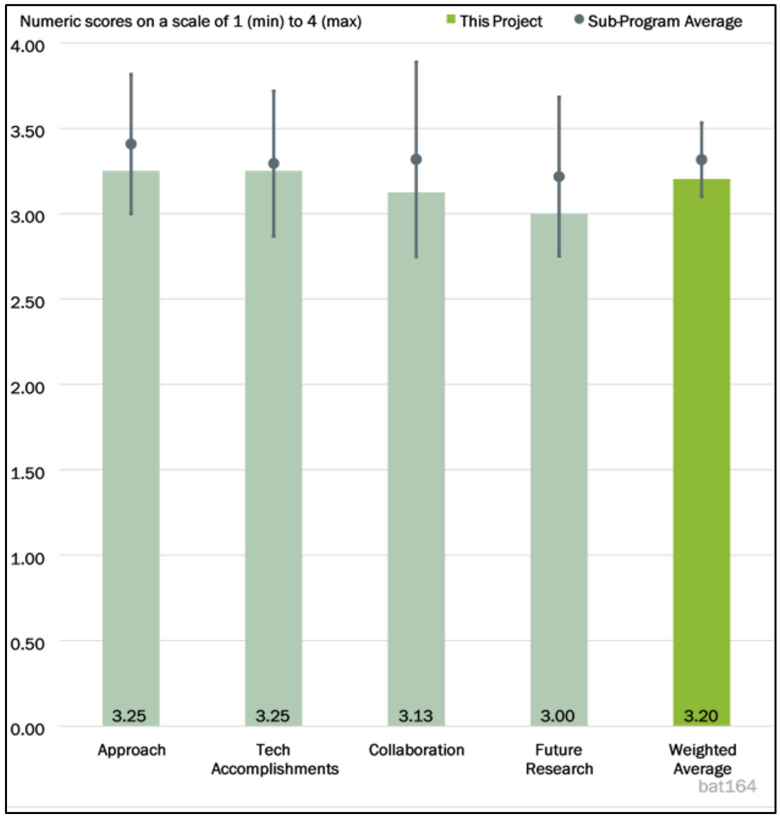


Figure 2-3 - Presentation Number: bat164 Presentation Title: Thick, Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that there is a well-defined approach toward achieving project milestones and direct relevance to solving barriers addressed in the project. The technical barrier of achieving high loading, crack-free electrodes has been addressed with double pass and mixed particle size coating techniques. The path to improving high resistance on aqueous-processed nickel manganese aluminum oxide (NCA) has been identified. A freeze tape cast, hybrid electrode structure for improving rate capability has been developed.

Reviewer 2:

The reviewer found that the project is generally effective and contributes to overcoming barriers in the development of crack-free dense cathodes using low-cost and environmentally compatible aqueous slurries for EV batteries that can meet both DOE and USABC cost goal. The main objective of improving cell energy and power density and reducing battery pack cost by manufacturing thick electrodes with tailored electrode architecture is consistent with the VTO program goals. Cathode fabrication is a crucial step in defining both the performance and cost, and aqueous processing methods for high-energy cathodes (NMC 811) are superior to conventional N-methyl-2-pyrrolidone (NMP)--based method for cost and environmental reasons.

There are no serious weaknesses here, according to the reviewer. However, it would be interesting to see how this aqueous processing method compares with recently emerged "dry fabrication" methods. Apart from cost, the reviewer asked whether there had been a cost comparison among these three methods (NMP, aqueous, and dry). The development of a composite cathode with co-sintered solid electrolyte, though interesting, is not relevant to the theme of the project for improving Li-ion batteries, but only to solid-state batteries, which are now part of the future study. The reviewer inquired about how the co-sintered composite cathode compares against the composite cathode obtained by mechanically mixing of cathode and well characterized solid electrolyte powder and whether it is possible to work with lower proportions of solid electrolytes in co-sintered cathodes. Finally, it would be more appropriate to extend this aqueous processing to the "Beyond Li-ion" technologies (Si-NMC and Li-S, which will possibly achieve technology maturation sooner than solid-state batteries).

Reviewer 3:

The reviewer asserted that the project aims to develop thick electrode with tailored electrode architectures. The water-based cathode process was explored, and a freeze tape casting technique was investigated to construct layer structures. Fundamental studies, including modeling, were conducted to understand mass transport in a thick electrode.

The reviewer opined that there were two issues the PI should have addressed: (1) whether NMC811 was stable in the aqueous condition and (2) the cost and impact of line speed of the freeze tape casting.

Reviewer 4:

The reviewer noted that the project is focused on the production of thick (6-8 mAh/square centimeter [$cm^{2]}$) Li-ion electrodes for EVs at $80/kilowatt-hour (kWh) by 2022 and for architectures for hybrid and EV battery systems. Another goal is to achieve a discharge cycling of 1,000 for EVs by 2022. This is done using an aqueous processing to Ni-rich layered oxides, including the demonstration of a solid-state battery (SSB) of at least 350 watt-hour per kilogram (Wh/kg). The PI reported a delay of 3 months for these goals due to COVID-19. Still, the PI reported major problems for which a technical approach and strategy has been planned. Perhaps the few alternatives on fabrication based on transition metal oxides as cathode electrodes are not enough to reach ambitious goals.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Given the circumstances (COVID-19), the reviewer believed that the group has made a strong effort to keep up in the best way possible with the scheduled research.

Reviewer 2:

The reviewer saw good progress having been made toward the stated goals to date. Some delays due to restricted lab access due to COVID-19 delayed a milestone. Thick cathode processing with double pass coating to improve rate performance was shown, and cyclability of these electrodes needs to be demonstrated. Cost reduction efforts using aqueous, thick electrode processing are clearly defined. Progress toward other key metrics of greater than 250 Wh/kg and 1,000-cycle milestones were not clearly articulated. It was unclear to the reviewer how the solid-state battery effort is related to the overall high-level goals of cost reduction, thick electrodes, and overall project goals of low-cost manufacturing.

Reviewer 3:

According to the reviewer, good progress has been made in developing aqueous processing for new cathode materials including NCA and the high-Ni NMC (811) and demonstrating rate and cycling performance in thick cathodes with high areal capacity (6-8 mAh/cm^2). The high-rate performance (greater than a C-rate (C) of 1C) seems to be further improved with architectures having small particles combined with large particles, either randomly mixed or arranged in a layered structure. The reviewer inquired as to whether this is entirely due to the increased surface area or due to any enhanced electrolyte penetration and/or wetting with the "layered" arrangement of smaller particles over larger particles. An interesting method and analysis have been developed to probe electrolyte wettability in thick electrodes. The reviewer asked if this can be extended to the discharge condition at high rates to assess electrolyte permeability into the porous cathode. Finally, the possibility of co-sintering solid electrolyte together with the cathode material for intimate mixing has been demonstrated. It would be interesting, however, to verify if this provides any enhanced ion conduction to the cathode compared to conventional (mechanical) mixing of cathode and solid electrolyte.

Reviewer 4:

The reviewer stated that the project team made a thick NMC811 cathode using the aqueous process. Improved rate performance of the thick electrode was demonstrated in a two-layer structure electrode. The capability of freeze tape casting was also demonstrated. The reviewer suggested that the PI should be more focused on the stability of the cathode material in an aqueous environment and optimization of both electron and ion transfer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that there are several useful and on-going collaborations stated here with the DOE laboratories (ANL, Sandia National Laboratories [SNL], and Idaho National Laboratory [INL]), academia (Karlsruhe Institute of Technology [KIT], State University of New York at Binghamton [SUNY Binghamton], University of Picardy Jules Verne, and University of Arkansas), and battery manufacturers. This project requires good interactions to develop processing methods for the relevant materials.

The reviewer noted two weaknesses. Firstly, it was unclear what the specific activities and/or materials are in these collaborations. It would be helpful if the activity is mentioned for each of the collaborations. Secondly, collaboration with any battery company manufacturer to demonstrate the aqueous electrode fabrication methodology for dense cathodes in a production environment (pilot plant) would be beneficial and will facilitate commercialization.

Reviewer 2:

The reviewer remarked that the cross-functional project team was good and coordination across partners was impressive. There is a good cross section of university, national laboratories, and industry partners in the project. The reviewer stated that an overall summary of how these different partnerships are working in concert toward solving the key barriers identified in the project would be helpful.

Reviewer 3:

It seemed to the reviewer that there was collaborative research at the PI's institution, but it was not clear how outside collaborators contributed to the project.

Reviewer 4:

The reviewer commented that this project has very good active collaborations with Binghamton University, but much less frequently with the University of Picardy (France) and others, such as ANL, JSR, and Navitas.

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 state project ended.

Reviewer 1:

The proposed future studies focusing on the fabrication of composite NMC cathode with 3 mAh/cm^2 for solid-state batteries and polymer electrolytes and to optimize the freeze tape casting method for the NMC cathode for solid state batteries looks good no doubt, but this is a long-term solution. For the immediate needs, the reviewer said that it would be better if the aqueous processing methodology were extended to the "Beyond Li-ion" technologies (Si-NMC and Li-S), which may be able to attain technical readiness and maturity earlier than solid-state batteries.

Reviewer 2:

Future work looked to the reviewer to be primarily focused on solid-state batteries. It was unclear how the thick electrode work and the solid-state battery work are connected. The project milestones and objectives need to be re-written if this is the case.

Reviewer 3:

The PI proposed to continue and extend the process development into cathode and solid-state electrolyte and polymer electrolyte. The project team will take the advantage of freeze tape casting and apply it to a making solid-state battery. The reviewer encouraged the project team to take into consideration the significant difference of solid-state electrolyte processing.

Reviewer 4:

The proposed research is very challenging, and the group is working hard on it; however, the reviewer asserted that an effort should be done to correct toward other technologies.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that the project supports the overall DOE objectives by developing low-cost and environmentally friendly fabrication methods for dense and high areal capacity electrodes for lithium-ion cells. The conventional method is expensive and involves environmentally incompatible solvents (NMP). Overall, this is quite relevant to the DOE VTO battery program.

Reviewer 2:

Low-cost manufacturing of batteries by using aqueous processing and enabling thick electrodes for both cost and energy density reasons is directly related to the DOE objectives, according to the reviewer.

Reviewer 3:

The reviewer commented that making high energy density, e.g., thick, electrodes and exploring low-cost options for electrode making are relevant to the overall DOE objectives.

Reviewer 4:

The reviewer affirmed that, in general, 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:

The reviewer noted that resources are commensurate with the scope of the project and adequate to achieve the stated milestones.

Reviewer 2:

Except for additional highly sophisticated equipment, the reviewer said that the resources are enough.

Reviewer 3:

Resource breakdown was not provided. The reviewer assumed resources are sufficient based on project milestones tracking.

Reviewer 4:

The reviewer said that Oak Ridge National Laboratory has more than sufficient resources to conduct the proposed research.

Presentation Number: bat167
Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials
Principal Investigator: Ozge Kahvecioglu (Argonne National Laboratory)

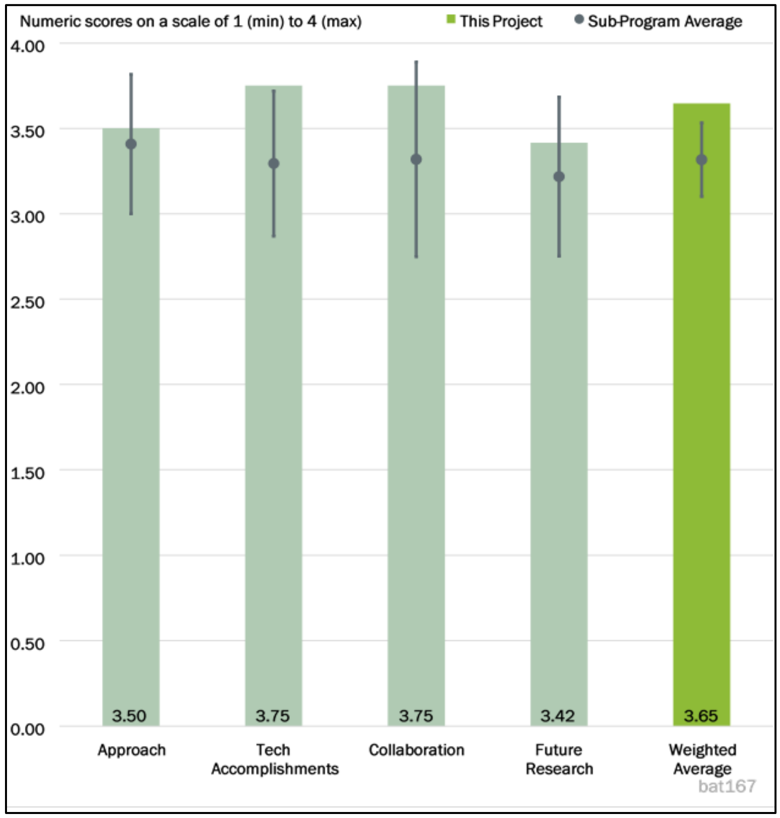


Figure 2-4 - Presentation Number: bat167 Presentation Title: Process Development and Scale-Up of Advanced Active Battery Materials Principal Investigator: Ozge Kahvecioglu (Argonne National Laboratory)

Presenter

Ozge Kahvecioglu, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Overall, this is a novel approach to synthesize materials at a scale that bridges the needs of academia and industry-scale research and development (R&D). The project team has made strong progress in a short amount of time. The reviewer thought that the approach and strategy are strong.

Reviewer 2:

The reviewer commented that the project has established a range of synthetic capabilities to support a variety of requests for high--quality cathode material. The establishment of Taylor Vortex Reactor (TVR) coprecipitation synthesis at 10-liter (L)-scale is important. The project appears to have established a reasonable feedback loop between customers and the project so that the necessary capabilities are in place to allow the project to address customers' needs. There may be room for new chemistries to be introduced (e.g., different coprecipitation chemistry or the introduction of alloying that was mentioned in the presentation) to be better prepared to provide customer requests beyond the lithium-nickel dioxide ($LiNiO_2$) (LNO) materials being provided now. But, given the mission to provide high quality cathode material in prototyping quantities to the battery community at large, the approach is excellent, the team is in communication with the community, and the team appears ready to be able to address most requests.

Reviewer 3:

The reviewer asserted that this project utilizes the mid-scale production facility at ANL to synthesize large quantities of non-commercial LNO-based cathode materials. The team has been successful in supporting the broad DOE battery research community by supplying cathode materials that are not commercially available to many projects for large-format cell testing, which fills a gap between bench-scale and high-volume production. It also demonstrates that the Taylor Vortex Reactor could manufacture cathodes with improved properties over the traditional co-precipitation method, which holds promise as a cost-effective, scalable process.

Reviewer 4:

The reviewer said that the ability to provide different formulations of high-Ni cathodes in a systematic way in meaningful volumes is important. Extensive use of the resources available was demonstrated by looking at combinations of formulations and processing conditions to produce a variety of results. However, one of the key objectives was to produce enough quantities to be meaningful to associated research projects. It would have been good to show some metrics of what the goals were and how much of this was in fact achieved.

Reviewer 5:

The goals were clearly defined, but the reviewer stated that the technical approach was not. For example, Slide 5 discusses the approach, but no technical details are given as to what the synthesis approach is and why it is a cost-effective scalable process, which is one of the key goals. There should be a slide or brief text in the presentation regarding the Taylor Vortex Reactor and what this approach is (yes, in the oral presentation this was described a bit), but more importantly why this is a scalable process that is cost effective. The reviewer wanted to know where the cost comparisons are that define this approach as novel and cost effective and scalable versus today’s state of the art. This needs to be laid out in the beginning to justify this work. Otherwise, it still has value in supplying partners with hard-to-obtain compositions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that the project team has made significant progress in several fronts. It successfully scaled up the production of NMC precursors with high-Ni contents using the TVR method and explored the effects of processing conditions (power of hydrogen [pH], calcination temperature, and oxygen partial pressure) on the electrode performance. It compares the morphology and performance of NMC precursors synthesized by the TVR versus the co-precipitation method and reveals that the former produces more spherical particles with a broader particle size distribution and improved rate capability. The team also supplies cathode materials to many collaborators and facilitates a wide range of research studies from new electrode design to characterization and battery recycling.

Reviewer 2:

It was clear to the reviewer that the PI has been successfully fabricating materials to supply DOE partners. The reviewer would have liked to see more benchmark results of materials made by this process versus commercially obtained materials. The reviewer realized that one of the purposes of this project is to supply novel hard-to-find materials, but maybe just a side effort to use this process. Also, there should be some discussion and data about particle-size distribution and how this is controlled and optimized using this process. Some data regarding scaling and cost effectiveness should be shown. However, it seems the PI has made really excellent progress in the relatively short time the project has been active and hit a large number of the milestones.

Reviewer 3:

Overall, for the short time duration of the project (October 2020 start date), the results are both interesting and promising for the battery community. The reviewer was Interested to see longer term results with LNO and nickel cobalt manganese oxide (NCM) and the further box furnace optimizations. For the box furnace optimizations, it is not clear what the PI has planned, but perhaps some basic thermal or gas flow models can give insight if experimental iterations hit roadblocks. It would also be helpful to know time scales for synthesis and estimated D10, D50, and D90 numbers for all materials created. While the d50 is the nominal metric used, the full PSA is also helpful to know for the materials. The PSA was given on Slide 7, but not on all the slides.

Reviewer 4:

The project overall appeared to the reviewer to be on track with both its process and chemistry development goals as well as its related mission to provide high-quality materials to various customers. The project is responsible for developing new capabilities, presumably to stay at or near the state of the art. It was not exactly clear what the near-term targets were for capability development, so it is hard to judge how well the project team is doing against expectations. But, some of the presentation touched on materials beyond LNO and chemistries such as alloying during the coprecipitation stage to avoid a costly alloying step later, so the project appears to be moving forward reasonably well with capability development. The progress on meeting customers' requests looks excellent in terms of material delivered; it is clear that many customers, especially in VTO-funded projects, are getting high-quality material in a large enough quantity to complete their research. What was not clear was the timeline for fulfilling a request: that is, the time on average from the first discussion of the need to the delivery of a kilogram of high-quality cathode material. Perhaps the project could establish a measure for the time between request and delivery and report that measure in the future to help understand if this aspect of the project is meeting its performance expectations.

Reviewer 5:

Given the short duration of the project to date and the difficulties associated with completing lab-based work in the COVID-19 environment, the reviewer found that the progress demonstrated was outstanding. It would be, however, helpful in the future for each of the sub-projects to better define the goals of the optimization projects. For example, parameters such as primary and secondary particle size, key surface and bulk characteristics, etc. It would also be helpful to show if those initial goals were adjusted based on feedback from partners. In addition, since one of the key objectives is to deliver sufficient amounts of specific materials, it would be helpful to set those goals ahead of time and measure their progress (as opposed to "scaled up to 10 L TVR"). In addition, the reviewer asked if there should be metrics on reproducibility, as that is a key component of the scale-up process.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project team collaborates extensively with the subgroups in the Deep-Dive into Next-Generation Cathode Materials effort and supplies many high-Ni NMC precursors to different projects. It also supports other VTO-funded projects and university research. Overall, the reviewer called the collaborative element of the project outstanding.

Reviewer 2:

This reviewer referenced Slides 4 and 17 and the oral presentation, which clearly described a number of material deliverables to the overall team. Clearly there seemed to the reviewer to be great communication among the local team and the larger DOE community. Many samples have been fabricated, and the PI and team seem to be very active and proactive with communication.

Reviewer 3:

According to the reviewer, the results of the collaboration efforts are clearly demonstrated. What would be helpful is if feedback (if any) were included in the effort on next steps on how to improve results from a material perspective.

Reviewer 4:

The reviewer had no doubt from the presentation that the project is working very closely and in good collaboration with a large number of VTO-funded projects and has been integral to the success of those projects. Collaborations with non-VTO funded projects, such as start-up companies (there seemed to be only one, Volexion), was far more limited. Perhaps this simply reflects a low demand from outside the VTO-funded community, but if this is important, then some progress needs to be made in developing such collaborations with industry and academia. Nevertheless, the level of collaboration and coordination within the VTO-funded community is outstanding and a clear strength of the project.

Reviewer 5:

Given the project is trying to fill a niche for industry or companies that are not able to take on the financial risk of process development and scale-up of multiple new materials, the reviewer thought that it is prudent to have another company or industry research lab involved as an additional collaborator or at least advisor of general material needs and requirements.

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 state project ended.

Reviewer 1:

The proposed future research would optimize the calcination processes, scale up the production of new cathode chemistries, and continue to provide commercially unavailable cathode materials to the battery research community. The plan appeared reasonable to the reviewer.

Reviewer 2:

The reviewer stated that the future research efforts outlined make sense and build upon the current status and results.

Reviewer 3:

Given that the project must respond to the ever-changing needs of the research community, it certainly can be difficult to look ahead and plan for the chemistries and processes that the cathode community will need. It seemed to the reviewer that the team is knowledgeable about the state of the art and has likely developed plans for the future that will allow them to continue to meet the needs of customers and to contribute to the development of advanced cathode manufacturing processes. Having said that, it probably would be useful for the project to clearly identify a short list of those new chemistries and processes that are the highest priority to establish in the near term to be able to continually meet their mission. Some of that was implied in the presentation; it would have been better for it to have been more explicit.

Reviewer 4:

The reviewer gave a good rating as it is clear the PI has the fabrication and delivery of the samples under control but lacks a bit on plans (or articulated plans) to achieve the goal of a cost-effective scalable process. The reviewer wanted to know what the hurdles are and what the cost projects are to scale relative to the state of the art (SOA) for the equipment development and fabrications. More benchmarking of the materials produced by this process should be established relative to a commercially obtained high-quality material. The reviewer inquired about what the differentiating wins are with respect to cost and scalability and whether this process can be commercialized.

Reviewer 5:

Proposed future work plan seemed reasonable to the reviewer and follows the workflow outlined in the presentation. For what was identified as a "remaining challenge," the reviewer asked whether there are sensitivities of the LNO-based NMCs to calcination conditions and storage conditions. It was not directly clear how or if some of these challenges identified are part of the proposed future research plan.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project supports the overall DOE objectives by supplying large quantities of non-commercial NMC chemistries to the DOE battery research community and developing a new, cost-effective, scalable process for electrode manufacturing.

Reviewer 2:

The reviewer commented that this project (if successful at scale-up with consistent materials) fills an important need in the battery community for research labs (academic, corporate, government): the ability to provide meaningful and large quantities of new materials for testing with a low financial and time burden to outside labs.

Reviewer 3:

The reviewed viewed the project as clearly integral to the VTO program and the DOE objective to enable technology development for the electrification of vehicles. The project represents a key element in the VTO strategy and is playing a significant role in the broader success of the VTO program through the numerous collaborations that have been established.

Reviewer 4:

According to the reviewer, reducing cobalt (Co) content and increasing capacity are key pathways to reach the DOE goals.

Reviewer 5:

This project is important as a resource for custom materials not readily available in the community, which could benefit other projects. The reviewer liked the PI's involvement in other, broader projects, such as ReCell. The end game plans for commercialization and/or impact of this scalable process to impact the position of the country are a bit ambiguous.

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 allocated resources are appropriate for the scope of the project.

Reviewer 2:

Funding seemed appropriate to the reviewer for the scale of work being done.

Reviewer 3:

Given the current number of requests for materials, the resources allotted to the project appeared to be sufficient to the reviewer. However, the resource needs will scale with the number of requests for cathode materials so if the project is more successful in its interactions with start-ups, established industrial companies, and/or academia, then greater resources will be needed, or some sort of prioritization process will have to be established. But for now, the resources are judged to be sufficient.

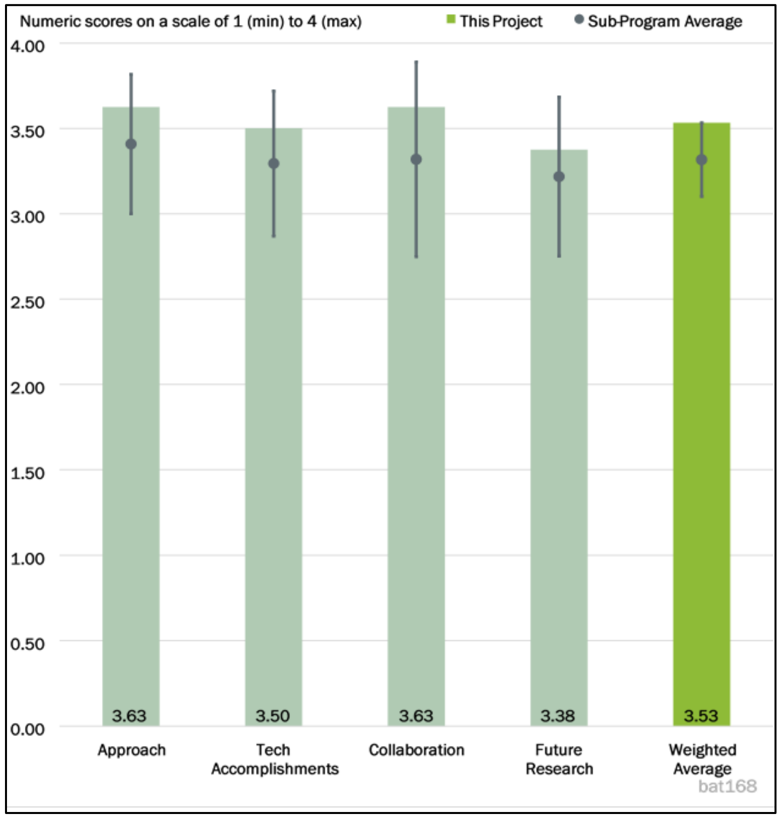
Reviewer 4:

The reviewer could not make a clear judgment based on information presented whether there is sufficient funding and resources in place. The reviewer assumed for purposes of this review that the resources are sufficient.

Reviewer 5:

This project should state what major equipment was developed in the project with respect to expense. The reviewer wanted to know whether this Taylor Vortex Reactor pre-existed or has been purchased and/or modified heavily with DOE funds.

Presentation Number: bat168
Presentation Title: Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials
Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)



F Figure 2-5 - Presentation Number: bat168 Presentation Title: Process Development and Scale-Up of Critical Battery Materials - Continuous Flow-Produced Materials Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)

Presenter

Krzysztof Pupek, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the synthesis of materials that are new electrolyte candidates is greatly needed. This is an area that may not have been sufficiently emphasized historically. The material targets that the group has selected are reasonable. Further, the project team's approaches to preparing the materials are sound and well considered. The team is handling hazardous materials and the appropriate precautions are taken in order for them to do this successfully and without incident. At this scale, the purification is batch level. This is appropriate as the materials are still made on a modest scale, but enough for the R&D community.

Reviewer 2:

The reviewer remarked that the continuous flow reactor technology has been developed and has a number of outstanding benefits, especially with respect to developing various electrolytes. Also the PI, the Materials Engineering Research Facility (MERF), seems to have a very well designed flow process for selection and downselection of electrolyte candidates that are of interest.

Reviewer 3:

MERF has state-of-the-art equipment for designing continuous flow processes for synthesizing electrolytes and solvents. The facility produces kilogram quantities of materials that facilitate property evaluation and testing in different locations using different instrumentation. This is a valuable asset for the battery community, according to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that this project has been active for 11 years but has really shown results both in the development and continuous improvement of the continuous flow reactor technology (both in process equipment and in-situ characterization, such Fourier-transform infrared spectroscopy [FTIR]). The PI has demonstrated that this process works by fabricating and delivering an extremely wide variety of high-purity solvents to the community.

Reviewer 2:

The reviewer was impressed by the variety of salts and solvents that have been produced by the facility (Slide 30). The facility appears to have flexibility for synthesizing a wide variety of electrolytic compounds.

Reviewer 3:

The reviewer commented that the target materials were successfully prepared at a good purity level. Continuous processing was demonstrated for the material targets. Appropriate safety measures were used in the planning and the execution of the synthetic schemes.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that collaboration is intrinsically outstanding in this project as that is the basis for the decisions for fabricating novel electrolyte materials that are not easily obtained commercially. MERF has a mechanism to share these materials with the general United States (U.S.) research community and is a very highly collaborative resource.

Reviewer 2:

There is good synergy between the synthesis and characterization team members. The reviewer was impressed by the quality of the characterization data (Slide 17, for example).

Reviewer 3:

The reviewer stated that collaboration among the project teams is appropriate.

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 state project ended.

Reviewer 1:

The future plans are based on excellent accomplishments and well within the instruments set up and the expertise of the PIs, according to the reviewer.

Reviewer 2:

On the excellent side, the reviewer acknowledged future electrolyte development and scaling, especially with the focus on ionic liquids (ILs).

In the good or less than good side, the reviewer suggested that the: PI needs to give more details about equipment development, hurdles, and direction to achieve a true continuous fabrication. There are not enough specifics in Slide 23 (Future Work) as much of it is written ambiguously.

Reviewer 3:

The reviewer stated that the future targets are appropriate. One suggestion for modification is that the most value from this effort is obtained when the group is focused on materials synthesis, purification, and characterization. Testing the materials in batteries would be better left to collaborators or partners.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that this project has tremendous current and future impact on the U.S. battery research community. It is much more difficult to obtain high-quality electrolytes than active electrode materials. If the reviewer were to continue funding one of the projects being reviewed, this would be it. It is a great example of highly practical, impactful work of the national laboratories and DOE to the U.S. battery research community. The reviewer would like to have seen more electrolyte projects and maybe fewer layered active material projects. It is also commendable that this project is supplying electrolytes at the same time as it is developing a somewhat novel and scalable synthesis approach for electrolytes with a number of positive attributes.

Reviewer 2:

The reviewer said that this is a unique and important facility for the battery community as it focuses on the electrolyte. Much of the synthetic focus is on the electrode materials.

Reviewer 3:

The reviewer indicated that new materials, including electrolytes, are needed. The detailed research explorations can only take place if the appropriate materials are available. This effort prepares the needed materials.

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, this is a generously funded program that delivers excellent results.

Reviewer 2:

The reviewer stated that the group is well funded and at an appropriate level for the objectives put forward.

Reviewer 3:

The reviewer could not comment on resources as the burn rate and LOE of the project are not given. However, the project seems to be adequately funded over a long period of time, and funding should be continued.

Presentation Number: bat183
Presentation Title: In Situ Spectroscopies of Processing Next-Generation Cathode Materials
Principal Investigator: Feng Wang (Brookhaven National Laboratory)

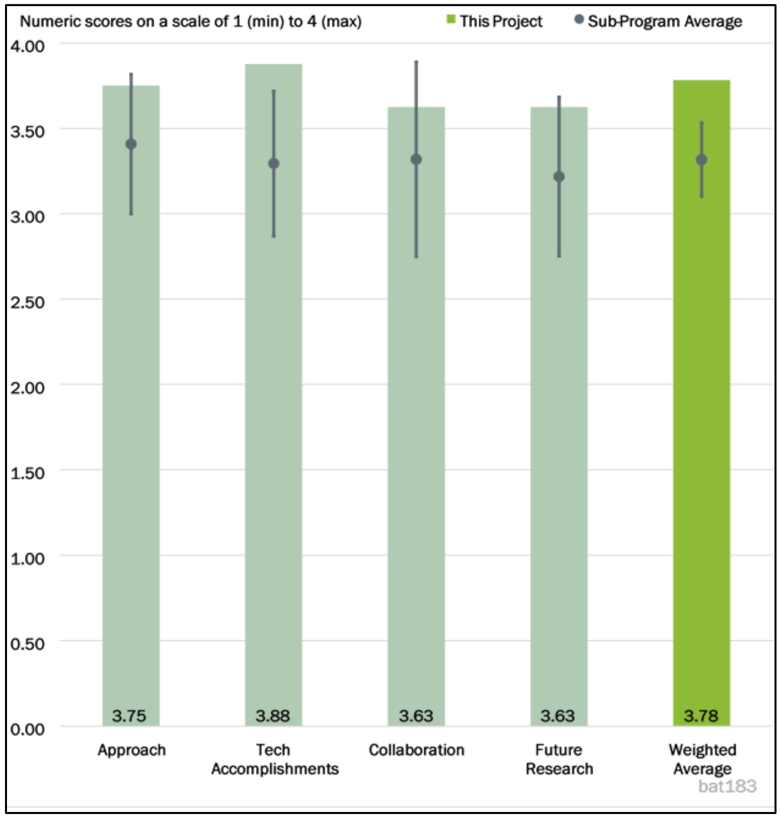


Figure 2-6 - Presentation Number: bat183 Presentation Title: In Situ Spectroscopies of Processing Next-Generation Cathode Materials Principal Investigator: Feng Wang (Brookhaven National Laboratory)

Presenter

Feng Wang, Brookhaven National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the approach used thorough and complete. The PIs use synchrotron methods (diffraction and spectroscopy) in addition to electron microscopy to study the complex processes that are necessary for synthesizing high-Ni cathode materials. In situ measurements indicate that the sluggish kinetics of formation of NMC811 is due to slow oxidation of Ni. This is an important insight into an increasingly important material.

Reviewer 2:

The reviewer said that is a well-structured project that aims to understand some of the most challenging aspects of NMC cathode materials both from processing and cost standpoints with the right collaborative team. Developing protocols for the synthesis of high-Ni cathodes are extremely critical for commercial realization of this class of cathode materials in the next generation LIBs, which is one of the main objectives of this project.

Reviewer 3:

In situ synchrotron X-ray spectroscopies, such as in situ X-ray diffraction (XRD), pair-distribution function (PDF), transmission X-ray microscopy (TXM), X-ray absorption near edge structure spectroscopy (XANES), and real-time tracking of elemental distribution, were conducted to study the processing of cathode materials in multiple length scales by the team, which is promising, according to the reviewer.

Reviewer 4:

The reviewer asserted that very nice work has been completed on this topic. The barriers listed mentioned low-energy density and cycle life, yet very limited amounts of performance data were included in the poster. To ensure that methods taken to improve cycle life were being mitigated, some performance data could have been included. Overall, the reviewer praised the project as very nice work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the PIs have accomplished their goals by obtaining precise data that allow for understanding the reaction pathways of interest. The publication record of the PIs is outstanding.

Reviewer 2:

The reviewer stated that significant progress was achieved in various issues of high-Ni cathode materials, such as long-range, local structural change and elemental distribution during synthesis, kinetics of single-crystal and polycrystalline high-Ni materials during charge and discharge processes, etc. These issues are highly related to the electrochemical performance of high-Ni materials. The microwave synthesis of NMC materials is also promising, which is fast with low heat dissipation.

Reviewer 3:

The objectives of this project have been well addressed, and the results give clear guidance on the specific reasons for the structural evolution of high-Ni NMC cathode materials. The reviewer had a few questions to further clarify the methodology followed:

- When the in situ measurements are performed, what is the atmosphere for high-Ni NMC?
- Is microwave (MW) driven synthesis commercially viable at an industrial scale manufacturing of hundreds of MegaTons (MT) per year?
- Is the understanding of the structural aspects from a fast MW assisted synthesis transferrable to other methods of synthesis? If not, why not?

Reviewer 4:

The reviewer said that there was very nice work completed during this technical study. For the local redox, in situ TXM study, accepting the data is a bit doubtful because the entire color spectrum is not present. This reviewer explained that in a lot of Ni-rich NMC materials, there is some Ni^{2+} on the surface of most of the material. Here, the TXM data do not illustrate that. Additionally, during the live presentations, there was some discussion regarding the quality of the single-crystal material. The reviewer wanted to know whether an aggregate of single-crystal particles behaves similarly to polycrystalline material. More uniform, single-crystal material must be analyzed to ensure that the data are representative.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The work involved extensive coordination between BNL and ANL. The synergy between the partners was clear to the reviewer, as indicated by the wide variety of methods employed and the presence of several collaborators listed as authors on publications.

Reviewer 2:

According to the reviewer, the collaborative team is very well aligned to meet the project objectives.

Reviewer 3:

Collaborations were very clear to the reviewer. During the live presentation, it was a team effort, suggesting great collaboration between all the scientists involved in tackling the challenges and barriers listed.

Reviewer 4:

The reviewer asserted that the collaboration is excellent, and the duty of each team member is 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that the proposed future research is well planned and strongly related to the objectives from two perspectives: (1) improvement of high-Ni, low-Co, and Co-free materials, including morphology control, coating, doping, etc., and (2) development of new characterization methods.

Reviewer 2:

The reviewer commented that future work follows logically from the accomplishments. The focus on development of new, in situ approaches is noteworthy.

Reviewer 3:

The proposed work envisions understanding the low-Co and Co-free cathode materials during the next year synthesized via a TVR reactor. According to the reviewer, this is extremely important as industry is moving in the direction of reducing Co in the cathode material and eventually eliminating any Co.

Reviewer 4:

All the proposed future work is reasonable toward the goal. The reviewer indicated that the project team should ensure that there is a strategic approach toward understanding morphological control of the particles. If lithiation drives the morphology change, the reviewer wanted to know why and cautioned to be sure to have future work that aligns with answering this question.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that high-Ni content electrodes are of great importance in the quest for clean energy through rechargeable batteries. The fundamental knowledge obtained by the PIs will inform production of these materials.

Reviewer 2:

The reviewer noted that the project is highly relevant as it targets DOE's important objectives of both high-Ni NMC and low or no Co.

Reviewer 3:

The reviewer remarked that the work supports the overall DOE objectives. It advances energy while promoting scientific and technological innovation. Low-Co and Co-free materials are at the frontier of research, and this work supports those efforts.

Reviewer 4:

The reviewer indicated that this work is clearly relevant toward the goal. Studying the properties of high-Ni NMC materials in detail using advanced characterization methods is instructive for the improvement of electrochemical 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 found that the resources available for the project, particularly the access to synchrotron-based instrumentation, enable accomplishing milestones in a timely manner.

Reviewer 2:

The resources are sufficient to meet the project objectives, according to the reviewer.

Reviewer 3:

The reviewer said that the resources provided seem sufficient for completing the milestones listed.

Reviewer 4:

The reviewer noted that sufficient work has been conducted to achieve the milestones.

Presentation Number: bat232
Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions
Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

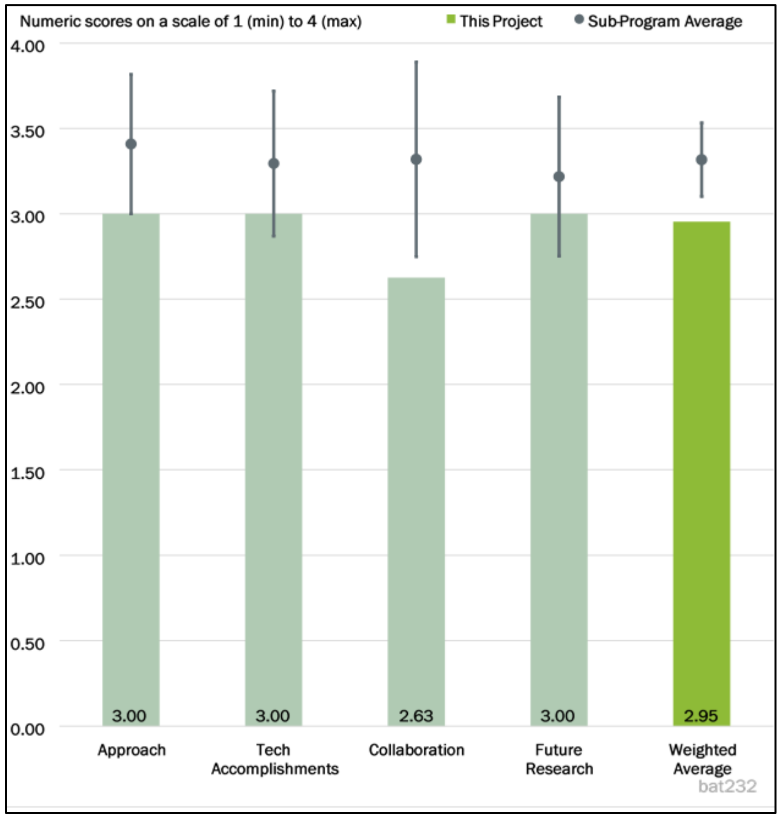


Figure 2-7 - Presentation Number: bat232 Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

Presenter

Vincent Battaglia, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the PI and the project team use standard methods to investigate the roles of inactive components and their processing conditions in determining the performance of high-energy cathodes. The study is systematic. The imaging approach could be improved with some synchrotron methods, which can give much high spatial resolution and chemical sensitivity.

Reviewer 2:

The reviewer said that the PI aims to gain fundamental understanding of the relationship between the physical properties and the performance of a thick electrode. The research covered micron-scale morphology and nano-scale interaction. The interaction between carbon and binder was investigated, especially the change of binder crystallinity.

It appeared to the reviewer that the process development and investigation involve many factors, which could interfere with each other. To get better understanding of such interference, design-of-experiment would be a good tool.

Reviewer 3:

The approach toward understanding the importance of binder content, mixing, and drying on hybrid pulse power characterization (HPPC) performance and cycle life of the positive electrode is well defined and being executed well. Electrode loading levels need to be clearly defined in the current year's accomplishments since it was unclear to the reviewer what electrode loadings are being optimized with different active material (AM) contents. More clarity on how this approach directly tackles the barriers of fast charge, cycle life, higher specific energy, and specific power needs to be provided.

Reviewer 4:

The reviewer found the project to be generally effective as it contributes to overcoming the barriers in the development of cathodes with low proportions of binder and conductive diluent and a high percentage of active material that improve the areal specific capacity of cathodes and hence specific energy Li-ion batteries. A specific objective of this project is to optimize the mechanical and electrochemical properties of high-loading electrodes with area-specific capacities greater than 4.5 mAh/cm^2. The approach being adopted includes evaluating various active material proportions of 92%-98% in the dense cathodes, keeping the carbon-to-binder ratio, but varying the processing conditions for improved rheology of the slurries without aggregates and for improved electrochemical performance, i.e., high-rate capability and cycle life of the cathodes and cells. This methodology will be extended to other DOE-VTO battery programs, e.g., eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries (XCel), cation-disordered rock salt (DRX), Co-free and R2R national laboratory collaboration, etc. Since this project is aimed at improving both performance and cost, it is directly addressing the barriers of EV batteries.

The reviewer commented that one of the weakness of this project is the need and relevance of this activity in a national laboratory environment. The optimization of cathode material composition and the process conditions (speed, mixing sequence, etc.) would be useful no doubt, but are highly dependent not only on the nature of active material, binder, and even carbon diluent but also the manufacturing equipment. This is the type of work typically done by the battery company. Quite possibly, similar optimization is being done by industry and hence there would be no technology transfer to industry in this regard. Also, the reviewer as to the relevance of this project, in the context of new "binder-free" or "dry" methods of cathode fabrication that are emerging recently. Another more specific question would be the rationale in keeping the carbon-to-binder ratio the same in this study.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress is in general satisfactory. The use of confocal microscopy is quite interesting. It appeared to the reviewer that the project is on schedule.

Reviewer 2:

The reviewer commented that the accomplishments in the budget year (BY) were to better understand the roles of carbon in the Li-ion electrodes, the importance of binder crystallographic structures, and the impact of carbon and temperature on the binder crystallographic structure. This knowledge is important for the overall project goal of the development of a high-performance, thick Li-ion electrode.

The reviewer suggested that the PI investigate carbon materials with different properties, e.g., surface area, crystallography, surface functional groups, etc., along with different binder materials. Again, statistical design-of-experiment would be beneficial.

Reviewer 3:

The project is on schedule, according to the published plan. The impact of mixing conditions and drying temperatures toward making high, active material content films has been studied and is being understood. The reviewer noted that comparison toward the specific key performance indicators for this project has not been clearly presented. More emphasis and studies on key performance metrics as a function of electrode loading is needed since high loading levels contribute directly toward solving the stated barrier of higher specific energy.

Reviewer 4:

There has been fairly good progress toward the projective objectives, according to the reviewer. Specifically, project results demonstrated that the active material content can indeed by increased up to 96% without compromising the performance, Likewise, the project team showed that the drying temperature could be increased to 180°C and the drying time reduced with no adverse effects on the performance. A new technique has been developed to track the aggregates in the cathode slurry. Finally, the process conditions have been optimized for NMC811 cathode. Overall, the progress is reasonable.

The reviewer found three weaknesses:

- Despite the good optimization carried out in this project, its impact is limited based on the specificity of the method used on the cathode material properties and process equipment (scale-up). The projected 25% improvement in specific energy and power density with less than 10% increase in cathode active material percentage (industry uses greater than or equal to 90% already) is quite a stretch.
- The cells and/or batteries need to survive environmental testing (vibration and shock) to validate the robustness of the cathodes with low binder contents.
- Cost analysis needs to be done to assess the relevance and impact of this modified cathode processing on the overall VTO goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project is being conducted with collaboration with other similar groups working on electrode mixing, casting, and characterization. Collaboration is in the form of exchange of ideas and discussion.

Reviewer 2:

From the presentation, it was not clear to the reviewer whether the team currently has direct collaborations with partners. However, there is a great potential that their results can greatly benefit the understanding of the high-energy cathode design, and future collaborations could be built easily by the team.

Reviewer 3:

The PI’s group collaborated well internally and with other national laboratories. However, it is highly practical research, and the reviewer suggested that closer collaboration with Li-ion battery manufacturers would be important.

Reviewer 4:

The reviewer commented that there are on-going collaborations with other DOE Offices, for example, the Advanced Manufacturing Office (AMO) for the R2R National Laboratory Collaboration and the Hydrogen and Fuel Cell Technologies Office (HFTO) for the Million-Mile Fuel Cell Truck Consortium. There are monthly technical meetings with other programs that are involved in electrode manufacturing and understanding the particle-level interactions.

The reviewer stated that the collaboration is non-specific and suggested that a more useful partnership would be with an industrial partner (battery manufacturer), if 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that the team has identified critical areas to improve in the future research plan. The team also recognizes some of the challenges and potential issues with their assumptions. The team has a plan to expand their studies.

Reviewer 2:

The reviewer opined that the future research was well planned and aligned to the overall objective. The PI understood the barriers well and the plan would address those barriers.

Reviewer 3:

Future work is geared toward further optimization of inactive materials with the goal of making better electrodes with high AM content. The reviewer recommended that these investigations be conducted as a function of electrode loading to determine maximum possible loading levels achievable to enable higher specific energy while maintaining other key parameters.

Reviewer 4:

The reviewer stated that the proposed future studies will focus on further optimizing the active material content and cathode fabrication and performing long-term cycle-life tests on the successful electrodes implemented in cells. Other carbons and binder (polyvinylidene fluoride [PVDF]) of different molecular weights will be examined. The future work is planned well and will have minimum risk.

According to the reviewer, the future work does not seem to be very novel, i.e., trying out new carbon and another MW PVDF. It may be more appropriate to work with new cathode formulations (higher Ni).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the project supports the overall DOE objectives by developing low-cost and environmentally friendly fabrication methods for dense and high areal capacity cathodes with high proportions of active materials for Li-ion cells. Overall, this is relevant to the DOE VTO battery programs and supports its objectives.

Reviewer 2:

Understanding variables affecting electrode manufacturing is important for achieving low-cost (lower inactive material content and faster processing), high-performance (high loading leads to high specific energy; better uniformity leads to better performance) batteries for EV applications in the reviewer's opinion.

Reviewer 3:

The reviewer stated that the project is highly relevant to support the overall DOE objectives. As a matter of fact, the method developed by the team can be applied to many different cathode chemistries that DOE VTO currently supports.

Reviewer 4:

The reviewer indicated that the project supports the overall DOE objective. It is critical to increase the active material load on an electrode in order to increase the energy density of a Li-ion cell. The proposed research on fundamental understanding of controlling parameters in the electrode process will lead the way to a high energy density thick electrode with decent power density.

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

Reviewer 1:

The resources at the PI's lab are adequate to complete the task. The reviewer saw no issue of achieving the stated milestones in a timely fashion.

Reviewer 2:

The reviewer opined that resources are commensurate with the scope of the project and adequate to achieve the stated milestones.

Reviewer 3:

The reviewer commented that resources, which cover 20% of the PI's time and 33% of a research associate, are likely sufficient for the stated goals for the next project year.

Reviewer 4:

According to the reviewer, the PI has the access to more than sufficient resources to achieve the remaining milestones.

Presentation Number: bat240
Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries
Principal Investigator: Cary Hayner (Sinode Systems/NanoGraf)

Presenter

Cary Hayner, Sinode Systems/NanoGraf

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

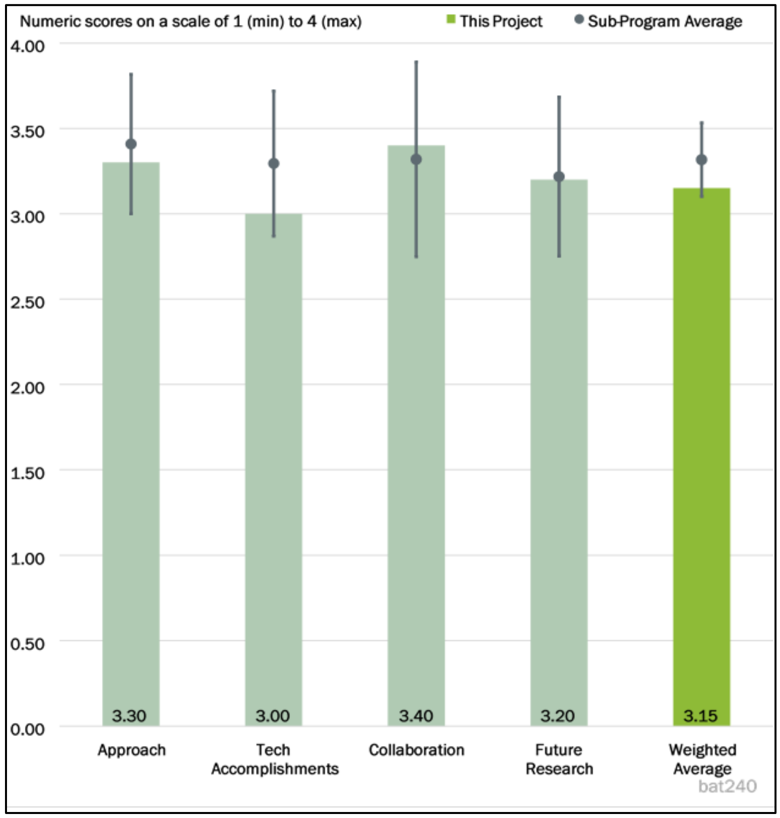


Figure 2-8 - Presentation Number: bat240 Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries Principal Investigator: Cary Hayner (Sinode Systems/NanoGraf)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Nanograf's approach for this fiscal year was to optimize synthesis conditions for oxides of silicon (SiO_x) nanoparticles, to optimize graphene coverage of Si particles, and to examine the performance of PPG binders. Overall, the reviewer noted that each of these approaches is sound, with successful development of each thrust potentially resulting in an advance over the current state of the art.

Reviewer 2:

The reviewer said that the project is well designed and addresses the technical barriers of the silicon anode.

Reviewer 3:

The reviewer noted that the project addresses major technical barriers, including battery cost and energy, by developing Si-based anode materials.

Reviewer 4:

The barriers of the technology were addressed appropriately, and the approach is sound and well structured. It is a challenge to reach the project goals, but the reviewer suggested that maybe pre-lithiation is the key to being successful.

Reviewer 5:

The reviewer remarked that, overall, the technical barriers are adequately addressed. However, it would have been better if the barriers and project goal were presented in more quantitative way.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team has made significant progress this fiscal year in each of the different thrusts. Data are provided that show optimal synthesis conditions for acid- and base-catalyzed SiO_x particles, the improvement of capacity and capacity retention of the SiO_x material with an undisclosed "Li containing surface treatment," the development of Si particles with high graphene surface coverage, and the enhanced performance and peel strength that PPG's binders provide. In the future, the reviewer looked forward to seeing how the graphene coverage impacts material electrochemical performance.

Reviewer 2:

The reviewer stated that novel progresses, such as those on novel Si-SiO_x material design, have been developed to dramatically improve performance at low cost. The project is a little bit behind the schedule. For example, barrier composition evaluation and the cost model have been completed, respectively, at only 67% and 33%.

Reviewer 3:

Progress has been made, the project seemed to be on track to the reviewer, the increase in lifetime and performance over the project time is good, and the collaboration within the project helps to solve key issues of the approach. A focus on industrialization and cost estimation is in its later stage of the project and is necessary to have a viable route to market.

Reviewer 4:

The reviewer indicated that the achieved cycle life is still far from the targeted 600 cycles. With graphene wrapping, the highest capacity is 1,500 mAh/g, which is lower than the targeted 1,800 mAh/g.

Reviewer 5:

A novel Si-SiO_x material was developed as low cost, but it was difficult for the reviewer to see cost competitiveness of the proposed synthetic route. The binder development is impressive. If a graphene coating helps volume expansion, as stated in the Approach, the reviewer would expect relevant measurement showing effectiveness of graphene coating on suppressing expansion. Also, it seems that different Si materials were used for different characterization—pre-lithiation, PPG anode binder study. The reviewer asked the PI to please label clearly which Si material was used for each test. Pre-lithiation work is confusing. If successful in developing material greater than 85% first-cycle efficiency (FCE), then the reviewer asked if pre-lithiation is necessary of it that is plan B. The reviewer also wanted to know what is unique about NanoGraf's pre-lithiation technique compared with already known methods.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found the collaborations among team members to be excellent.

Reviewer 2:

The reviewer stated that the project team works with A123 to optimize electrolyte systems and additives to form stable solid-electrolyte interfaces (SEIs) and extend cycle and calendar life.

Reviewer 3:

In the field of carbon and graphene coating, a lot of knowledge is present in the different national laboratories, especially in terms of characterization techniques. The reviewer proposed that it would be nice to see Nanograf leveraging this knowledge. The interaction with PPG and A123 helps Nanograf to industrialize the material faster and secure a path to the market.

Reviewer 4:

The PPG collaboration for novel binders appeared to the reviewer to be really beneficial and has resulted in some very nice results. A123 is also helping with cell builds and electrode design.

Reviewer 5:

The reviewer remarked that collaboration with PPG is encouraging. However, it is difficult to see A123 contribution.

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 state project ended.

Reviewer 1:

All future work appeared to the reviewer to be entirely reasonable (continuing to develop materials, put them in cells, and scale them up) and should continue to advance the technology in a reasonable direction.

Reviewer 2:

Proposed future research looked okay to the reviewer, who asked about the reference cost in a cost target of greater than 50% cost reduction.

Reviewer 3:

The reviewer said that the team plans to scale up the synthesis and improve the performance, which are very challenging tasks. Some in-depth analysis and innovative solution will be necessary to overcome these challenges.

Reviewer 4:

The pre-lithiation path will be critical for the success of the project; also the cost estimation of the material will be very important to determine the success of the approach. Additionally, the team should consider safety investigations. The reviewer wanted to know how the new material and electrolyte compares to state-of-the-art material.

Reviewer 5:

The future work illustrated is sound. It was unclear to the reviewer if the developed anode works at a relatively higher temperature. Some evaluation of the cell made with the Si anode at high temperatures may be interesting if the budget is sufficient to support it. The analysis on gassing of the Si anode during cycle and calendar life testing may ensure if the material is suitable for vehicle battery application.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Developing Si-based materials to increase battery performance and life as well to reduce costs aligns with DOE goals, according to the reviewer.

Reviewer 2:

To achieve energy density target, the reviewer indicated that a Si-containing anode with long cycle life and limited volume change should be developed and adopted. In this regard, this project supports the overall DOE objectives.

Reviewer 3:

The reviewer remarked that Si anodes are being considered as high-energy alternatives to graphite but suffer from limited capacity and calendar life. This project clearly aims at providing solutions to improve the cycling stability of Si.

Reviewer 4:

The reviewer stated that this project supports the overall DOE objectives by enabling Si anode.

Reviewer 5:

The reviewer commented that the project fully supports the 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 funding level seemed appropriate to the reviewer for this project.

Reviewer 2:

The reviewer stated that the allocated resource is sufficient to achieve the stated milestones.

Reviewer 3:

The resources seemed to be sufficient to the reviewer for the scope of the work.

Reviewer 4:

Resources appeared to be reasonable to the reviewer.

Reviewer 5:

The reviewer indicated that some aspects of the project would have benefited from working with a university.

Presentation Number: bat247
Presentation Title: Fast-Charge and Low-Cost Lithium-Ion Batteries for Electric Vehicles
Principal Investigator: Herman Lopez (Zenlabs Energy, Inc./Envia Systems)

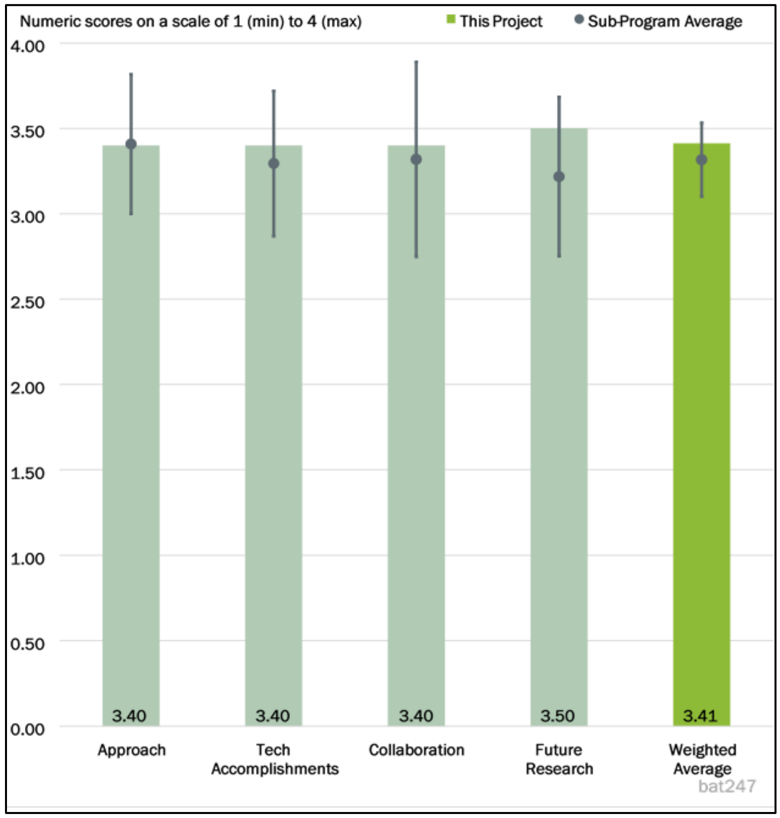


Figure 2-9 - Presentation Number: bat247 Presentation Title: Fast-Charge and Low-Cost Lithium-Ion Batteries for Electric Vehicles Principal Investigator: Herman Lopez (Zenlabs Energy, Inc./Envia Systems)

Presenter

Herman Lopez, Zenlabs Energy, Inc./Envia Systems

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that achieving high energy density, fast-charge capability, long cycle life, and low cost—all at the same time—is extremely challenging and yet must happen for wider adoption of EVs. Zenlabs' strategy to address these barriers by adopting a Si anode with pre-lithiation and developing suitable electrolytes is good.

Reviewer 2:

The reviewer said that the project is well designed and addresses the technical barriers of fast charging.

Reviewer 3:

The project addressed technical barriers to improve battery performance, cost, life, and fast charging capability by developing novel electrolyte formulations and optimized cell designs, according to the reviewer.

Reviewer 4:

The reviewer indicated that Zenlabs uses an iterative, empirically driven approach to develop electrolyte formulations and pre-lithiation techniques for SiO_x-NMC cells. The overall goal is to improve capacity retention of cells that have been repeatedly fast charged. Electrochemical analysis of capacity retention and pouch-cell thickness analysis to quantify total outgassing are used as the primary characterization techniques.

Overall, the approach is good and has yielded impressive results, but without any understanding of how electrolytes should be engineered to provide improved performance.

Reviewer 5:

The project is well designed and addresses several questions important to the future development of Li-ion batteries. The chosen path is common but poses several risks. The reviewer suggested that topics, e.g., low-temperature performance and especially swelling, should be considered. The application of a fast-charge cell needs to be heavily synchronized with the mechanical aging of the cell, i.e., gas release, loss of electrode structural stability, and expansion over lifetime.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that among the key technical accomplishments is an independently verified capacity retention of 80% after 1,000 cycles using a 4C charging rate. This is a very impressive result. Additionally, a 5C discharge capacity that is roughly 75%-80% of C/10 capacity is remarkable as well. Additional electrolyte formulations have also reduced gassing quite dramatically. Overall, the results are impressive, with the only negative being that no insight into the mode of improved performance is provided.

Reviewer 2:

The research from this project has developed cells with energy density, etc., to successfully meet the USABC cell 2023 goals, according to the reviewer.

Reviewer 3:

The performance targets are already met. However, the reviewer pointed out that the cost target is still not met, and a clear path to the target is not shown.

Reviewer 4:

The reviewer indicated that the progress made so far is good, the cycling number is impressive, and overall the project goals are within reach. However, some questions still remain open, i.e., gassing, swelling, and extreme temperature performance; a full validation over a temperature profile could provide useful insights. Also, the self-heating rate of the cell has to be considered as charging at high currents will ultimately increase the temperature of the cell and change the behavior of the load profile.

Reviewer 5:

Achieving greater than 1,000 cycles at 1C/1C cycle and greater than 800 cycles at 4C/1C cycle in a greater than 10 Ah cell form factor is very impressive. However, an increase in cell thickness by more than 200% during 65°C storage is problematic. Here are some questions from the reviewer:

- The reviewer asked whether has the project team measured cell thickness increase over the 1,000 cycles?
- The approach includes pre-lithiation development. However, pre-lithiation is not mentioned at all in the results. Was pre-lithiation applied to the 12Ah cell?
- It seems that the Zenlabs anode is Si-dominant, and the reviewer asked what the percentage of Si is in the anode.
- The reviewer understood that the cell gravimetric energy density (GED) is 315 Wh/kg at C/3 and asked what the initial GED is for the 4C/1C cycle.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the collaboration of Zenlabs with the national laboratories is very good. Overall, the team seems to be well chosen.

Reviewer 2:

The successful collaboration across the team resulted in the good research progress, according to the reviewer.

Reviewer 3:

The reviewer commented that USABC, INL, SNL, and NREL are all listed as collaborators, although the INL collaboration appears to be most valuable to this point. Many results have been independently verified by INL.

Reviewer 4:

The reviewer remarked that collaborations are mostly with national laboratories in cell testing, which is adequately structured. The reviewer wanted to know if the pre-lithiation development is a Zenlabs in-house effort.

Reviewer 5:

The reviewer stated that the project team needs to work with equipment manufacturer to scale up pre-lithiation. The electrolyte part could leverage more 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Future work—developing and applying protocols to understand calendar life, down-selecting electrolyte and electrode materials, manufacturing of pre-lithiation, and cell prototyping—is all reasonable and should allow the project to achieve stated goals, in the reviewer's opinion.

Reviewer 2:

The reviewer found the future work to be nicely planned, especially on the scale-up of pre-lithiation and electrolyte optimization to reduce degassing.

Reviewer 3:

The reviewer said that the proposed future research is well stated. However, considering the project ending date (July 31, 2021), it does not seem to be possible for the proposed future research to be done within the current project.

Reviewer 4:

The reviewer indicated that the project ended in July 2021.

Reviewer 5:

The reviewer noted that the described future study will facilitate the further development of the technology and its adoption for commercial applications. Considering the harsh working environment of electric vehicles, the high-temperature performance and cycle of the cells with the developed technology may be a concern and gassing may be potential a problem. It may be interesting if Zenlabs can weigh if the project team can leverage other projects funded by DOE, such as a shelf-life testing protocol (*https://www.nrel.gov/transportation/assets/pdfs/silicon-calendar-life-report-04012021.pdf*).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that the research is developing novel electrolyte formulations, a scalable pre-lithiation solution that enables the use of high-capacity silicon oxide anodes, and optimized cell designs that will result in LIBs capable of meeting DOE's goals on EV battery fast recharging and battery cost reduction.

Reviewer 2:

The reviewer responded positively and noted that higher energy density with fast charging rates is clearly important for car manufacturers.

Reviewer 3:

According to the reviewer, this project supports the overall DOE objectives by enabling fast charging.

Reviewer 4:

The reviewer indicated that the application of the technology fully supports the goals of DOE.

Reviewer 5:

The reviewer commented that this project supports 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 funding for the existing project seemed appropriate to the reviewer. More funding on proposed future work may warrant the optimization of the developed technology for scale-up production.

Reviewer 2:

According to the reviewer, the resources are sufficient and well spent.

Reviewer 3:

Resources appeared reasonable to the reviewer for the stated milestones.

Reviewer 4:

The reviewer said that the resources are sufficient to execute the project and to achieve the milestones.

Reviewer 5:

The reviewer opined that some aspects of the project (e.g., mechanistic understanding of the performance-limiting factor) would benefit from working with a university.

Presentation Number: bat269
Presentation Title: An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials
Principal Investigator: Chad Xing (University of Missouri)

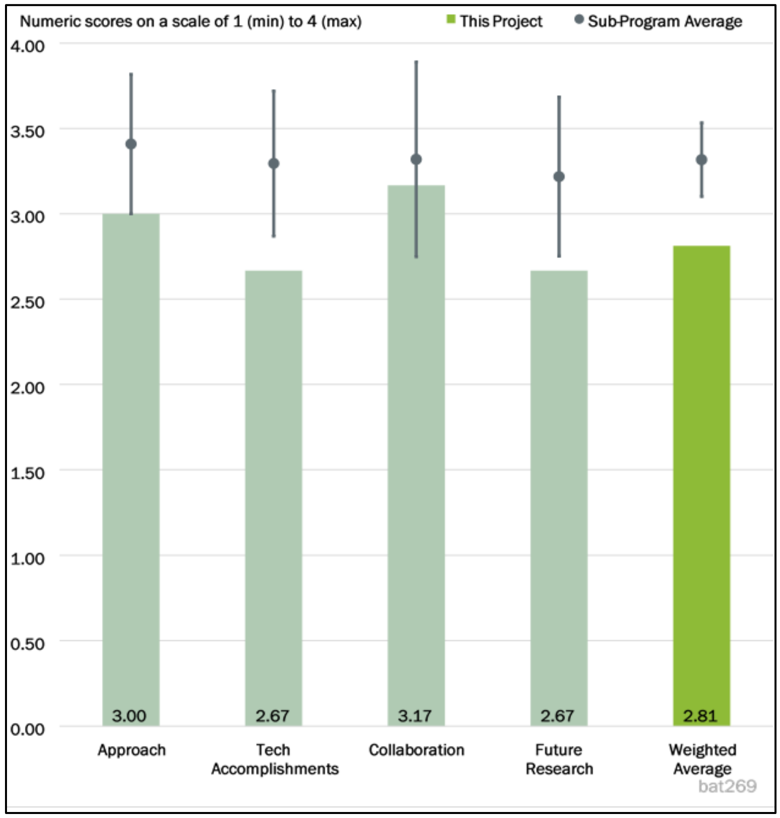


Figure 2-10 - Presentation Number: bat269 Presentation Title: An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials Principal Investigator: Chad Xing (University of Missouri)

Presenter

Chad Xing, University of Missouri

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, incorporating a new solvent for the synthesis of cathode materials is an innovative approach. The solvent that has been proposed is a byproduct from a major industrial product and using it is a novel idea. The project objectives and technical milestones are well crafted by assembling a very collaborative team.

Reviewer 2:

The reviewer indicated that the goal was to scale up a flame spray process using glycerol as the solvent and combustion process. The approach is novel and interesting although the reviewer would have liked to see an economic analysis slide giving evidence for the economic advantage versus state of the art as the entire project is based on this attribute.

Reviewer 3:

It appeared to the reviewer that this project is near conclusion, but longer term it would be productive to determine whether a path toward 250 Wh/kg energy density cells at a lab scale is possible prior to designing and fabricating parts for a pilot production line. The reviewer recognized that there may be timeline challenges that required doing both in parallel, but from the presentation, it is not clear how the pilot production line is designed relative to the lab-scale setup and whether or not challenges observed at the lab scale will carry over to pilot scale and require substantial or non-optimal equipment redesign. Also, it would be helpful to see more detail on what it would take to scale this process to NCM 811, which is of interest longer term for EVs. While NCA is a good proof of concept, the materials set is less relevant to future DOE goals.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

After $2.5 million , the reviewer expected more than 80 cycles of NCA (which look decent) demonstrated. Data should have been shown versus a benchmark. The reviewer offered the following questions and observations:

- What about rate and, elevated temperature storage?
- There are plenty of great commercial NCAs to compare to. Where are these comparisons?
- The only basis for this project is economic advantage, which could be very attractive. Where is the end-to-end analysis showing this achievement?
- Why is scale-up occurring before parity with commercial SOA established?
- Is there any other advantage to the material made by this technique versus cost?
- Particle-size distribution should be analyzed.

Reviewer 2:

In general, flame spray can be inconsistent at scale. It was not clear to the reviewer if this process can theoretically scale to at least 10 kilograms of material and how consistent the particle morphology and quality will be relative to conventional processing based on what the project team has presented. The PI mentioned that the use of an “indirect flame” was better, and it was not clear what implications that has longer term for scale up. The reviewer had more detailed questions:

- Referencing Slide 5, and for the five cells, what is the cell size in terms of Ah that the project is targeting?
- Referencing Slide 7, are these data for coin cells or pouch cells? What is the charge-discharge protocol being used? For the cells that had good capacity at approximately 200 mAh/g, why were they only run for 10 cycles versus the other data set in Figure 1(B) that was run for more than 25 cycles?

Reviewer 3:

Electrochemical properties for the NMC materials synthesized using direct and indirect flame-spray pyrolysis have been reported. The project team has shown inferior performance for the direct flame pyrolysis, which has been attributed to the high temperature the powder is experiencing during the synthesis (approximately 1500° C). However, the reviewer asked that the following needs to be clarified:

- Is there any structural difference for the NMCs synthesized via both routes? Were any XRD studies done; if so, was there any cation mixing observed?
- What is the temperature experienced by the powders during the indirect flame pyrolysis?
- Any specific mitigation method, such as shorter time, etc., that may be employed to improve the direct flame pyrolysis method?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project has two collaborative team members, EaglePicher Technologies (EPT) and Storagenergy Technologies (ST), who are perfect for this project goals. ST will be the main scale-up partner for the materials, while EPT will be fabricating and testing the prototype cells in 250 Wh/kg battery cells using the material produced via this method.

Reviewer 2:

Partners and collaboration team seemed appropriate to the reviewer for the work presented.

Reviewer 3:

The project is collaborating with EaglePicher to fabricate 250 Wh/kg battery cells with this material. The project team should also benchmark it versus a commercially obtained material.

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 state project ended.

Reviewer 1:

The reviewer commented that any novel synthesis method that disrupts the current method of battery manufacturing will be adopted if the material being scaled up to make larger format cells is critical. The future work that has been proposed encompasses the aforementioned items, which is an obvious must.

Reviewer 2:

The reviewer asked why there is a pilot-scale production line being planned when the advantages of this technique and performance have not been validated.

Reviewer 3:

The reviewer reiterated earlier comments and stated that longer term it would be productive to ensure that a path toward greater than 250 Wh/kg energy density cells at a lab scale is possible prior to designing and fabricating parts for a pilot production line. The reviewer recognized that there may be timeline challenges that required doing both tasks in parallel, but from the presentation, it is not clear how the pilot production line is designed relative to the lab scale line and whether or not challenges observed at the lab scale will carry over to pilot scale and require substantia, non-optimal, and/or costly equipment redesign. This was not clear, based on the content presented, and it is an integral, concluding task for the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that DOE's mission of low-cost, high-capacity NMC is well addressed in this project, and the cost analysis has been already done, which has shown that this method is economical over the traditional methods used.

Reviewer 2:

The reviewer responded affirmatively and said the project identifies technologies that could lead to an economic or performance improvement in the scalable manufacture of battery electrode materials.

Reviewer 3:

If successful, the project is relevant to DOE's longer-term goals. Based on the data presented, the reviewer had some concerns about the feasibility of process scaleup, especially for NCM chemistries.

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, resources have been well spent over the project time, and funding should be sufficient to meet the milestones.

Reviewer 2:

It was not clear to the reviewer what the split is between EaglePicher and the PI. Also, plans to scale up should be evaluated in more detail relative to accumulated data to see if now is the time to pursue it.

Reviewer 3:

The reviewer assumed this project is near completion, but the funds provided for the results generated and milestones completed to date seem a bit high relative to other projects.

Presentation Number: bat293
Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries
Principal Investigator: Yan Wang (Worcester Polytechnic Institute)

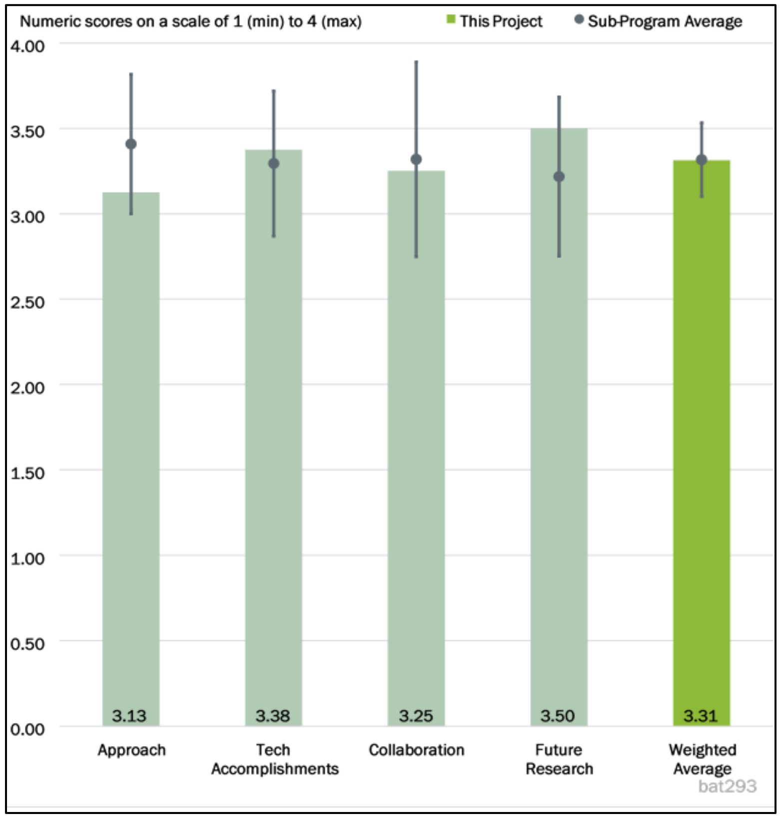


Figure 2-11 - Presentation Number: bat293 Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries Principal Investigator: Yan Wang (Worcester Polytechnic Institute)

Presenter

Yan Wang, Worcester Polytechnic Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project addressed the challenges including cost and materials supply with recycled LIB materials. The testing of cells with recycled materials is essential to demonstrate the capability of the recycling process developed previously and to ensure the recycled materials can be used in LIB production.

Reviewer 2:

The reviewer found no detail on the recycling process described the report, which prevents an evaluation on the approach and design of the project.

Reviewer 3:

The approach appears to be to recycle spent NMC electrodes by using them or their raw materials to fabricate new electrodes, although the exact technology and procedure were not entirely clear to the reviewer. Large-scale cells (10 Ah) have been fabricated and compared to controls, and a model was developed for scale-up of the technology. However, as mentioned previously, it is not entirely clear what that technology entails.

Reviewer 4:

This reviewer indicated that convincing proof-of-concept is demonstrated, with recycled cathode material demonstrated at large enough quantities for relevant cell testing (greater than 10 Ah). However, the mechanism by which the rapid capacity fade of the recycled NMC622 occurs (compared with virgin 622 material) is not clear from this poster. To allow for commercial adoption of the recycled 622, the cycle life must be improved. The reviewer explained that changes to the particle composition or morphology may be necessary, and failure analysis will help to identify the right path toward achieving high cycle life. Perhaps collaboration with a cathode manufacturer could be beneficial to this effort.

While cell-to-cell consistency is demonstrated here, the ability to produce consistent 622 material across different production batches (i.e., with different feedstock inputs) should be demonstrated and is a key technical barrier to "closed-loop" cathode production.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The cost model for the scale-up plant seems to be well developed, and the comparison to control cells is reasonable. The reviewer noted that the project ended in February; so, less work has been done compared to projects that have run throughout the entire fiscal year.

Reviewer 2:

According to the reviewer, the preliminary testing of the cells made with recycled materials is promising though more efforts may be needed to improve recovered NMC materials.

Reviewer 3:

The reviewer commented that the measurable objectives are not explicitly stated. There is no way to verify the operation cost of the recycling process because the details are not presented.

Reviewer 4:

The stated that the cost model indicates process feasibility with a realistic $/kg value given and suggested that it would be helpful to show the cost model's sensitivity to different feedstock inputs. As the amount of Ni greater than 50% cathode in the incoming cells increases, will the cost improvement versus virgin cathode widen?

While the cost model gives a feasible output for the Worcester Polytechnic Institute (WPI) process, the values given for the competing pyrometallurgical process seem quite high. This reviewer indicated that more explanation is needed to make a convincing argument here.

The reviewer further noted that one key point mentioned in the Project Objectives section is the ability to process spent batteries with non-standard chemistries, such as lithium titanate (LTO) and/or Si. No mention is made of the impurity content of the recycled NMC622, or how successful the process is at dealing with these non-standard cells. Cathode impurity specifications required for EV cells could also be a useful input from a cathode manufacturer or Tier 1 cell supplier.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the collaborations among team members are excellent.

Reviewer 2:

The reviewer noted that A123 is the main partner and has provided guidance. ANL's EverBatt model has also been used.

Reviewer 3:

There appears to be very close coordination between WPI and Battery Resourcers (BR), with good alignment on cost modeling. It was unclear to the reviewer to what extent A123 and auto original equipment manufacturer (OEM) partners are collaborating or offering feedback. One potential for input could be around the key performance indicators (KPIs) for cathode material and whether the performance demonstrated provides a realistic alternative to cathode cost-down efforts.

Reviewer 4:

A123 tests the cathode that the team recycled. The reviewer said that the team would be stronger if the team collaborates with industry to demonstrate a scaled-up recycling capability.

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 state project ended.

Reviewer 1:

The reviewer found that the future work planned for Phase III is reasonable and is well illustrated. Since cathode materials move to high- Ni materials, such as NMC811 or even higher content nickel, it will be interesting to see if the recycling process is applicable to those materials. In addition, the testing on cells made with reactivated materials may validate if they are compatible with pristine materials in vehicle operation range.

Reviewer 2:

This project was Phase II of the program, and Phase III has been awarded. The plans for Phase III seemed entirely reasonable to the reviewer and are focused on reducing costs of the recycling process.

Reviewer 3:

The reviewer said that the project ended in February 2021.

Reviewer 4:

The reviewer commented that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively and called the project highly relevant. Using recycled batteries as input into the cathode manufacturing value chain can lower the costs of batteries (and therefore EVs) as well as reducing the overall carbon dioxide (CO_2) footprint of battery and EV production. It can also help alleviate concerns around domestic supply of critical metals (Ni and Co).

Reviewer 2:

According to the reviewer, the research in recycling LIBs directly supports DOE goals for reducing battery cost and ensuring supplies of critical battery materials.

Reviewer 3:

The reviewer indicated that the development of battery recycling will be essential as more EVs come into the market. This project actively targets material recycling.

Reviewer 4:

The reviewer said that this project supports the overall DOE objectives by enabling cathode recycling.

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

Reviewer 1:

The reviewer called the resources sufficient. Given the competencies of BR in producing cathode material, the required amount should be feasible assuming that the feedstock of spent batteries is available.

Reviewer 2:

Resources are sufficient for the goals of the project, according to the reviewer.

Reviewer 3:

The reviewer found that the funding level is appropriate for the project.

Reviewer 4:

The reviewer stated that the team has sufficient resources.

Presentation Number: bat315
Presentation Title: Process R&D for Droplet-Produced Powdered Materials
Principal Investigator: Joe Libera (Argonne National Laboratory)

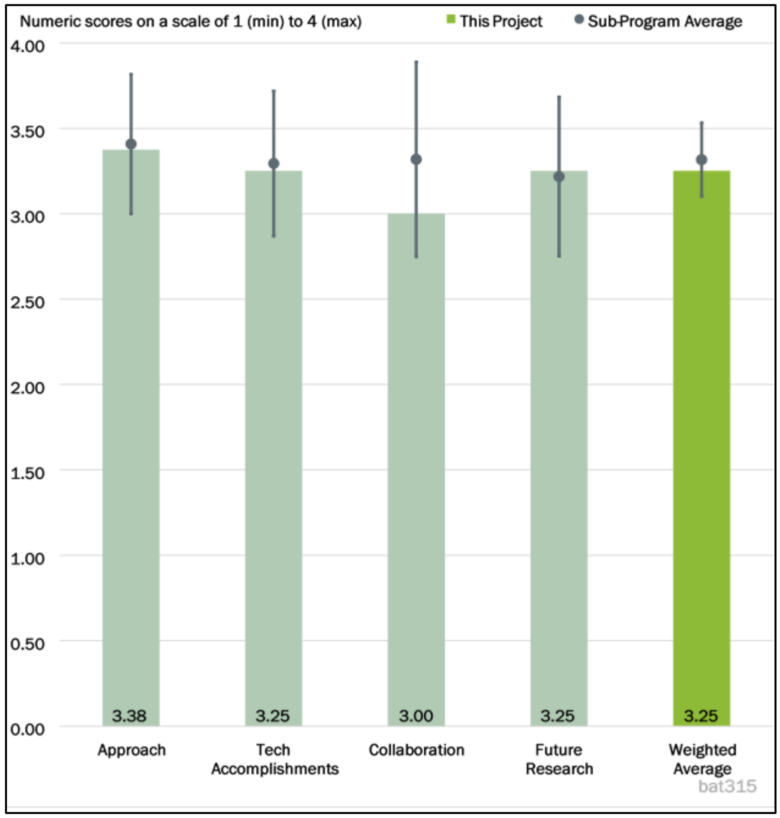


Figure 2-12 - Presentation Number: bat315 Presentation Title: Process R&D for Droplet-Produced Powdered Materials Principal Investigator: Joe Libera (Argonne National Laboratory)

Presenter

Joe Libera, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project aims to develop and optimize aerosol techniques, including flame spray pyrolysis (FSP), for producing LLZO-based SSE for lithium rechargeable batteries. FSP and aerosol techniques in general are an industry-proven production method and holds the promise for high-volume, low-cost manufacturing of SSEs. The team leverages the in-operando characterization techniques available at ANL’s FSP Facility to obtain useful insights and understanding of the manufacturing processes. Several techniques have been successfully added to the aerosol synthesis portfolio. They are used to synthesize several different SSE compositions, which support the research of various groups. Their study also reveals added benefits of the aerosol synthesis, such as the possibility of enabling one-step synthesis of layered cathode material without the calcination step and the co-sintering of LLZO green powder and cathode particles that leads to conformal coating of SSE on cathode surface. These findings are interesting and could further facilitate the manufacturing of solid-state batteries.

Reviewer 2:

The reviewer asserted that the approach to the project is strong and fills a need in the solid-state battery community to find alternate and scalable methods for material synthesis.

Reviewer 3:

Flame pyrolysis techniques have been in existence for decades by various companies, some in batteries, most not; the reviewer opined that the technology really deserves a deeper look as it offers a pathway to lower cost battery electrode materials. Even more importantly, it offers more intimate control of particle design and the promise of continuous-flow variable processes with very low cost. However, the reviewer suggested that the PI should do an economic analysis versus state of the art to truly establish that this route does have a cost advantage over state-of-the-art techniques.

Reviewer 4:

The reviewer indicated that Innovative material synthesis is one of the major areas mainly due to the economic incentives in the production of battery materials to drive the cost down at cell or pack level. Finding cheaper ways to synthesize battery materials is one of the predominant ways to achieve this goal.

Cost reduction has always been the basic need for battery material manufacturing, which the methods proposed. However, the presentation does not give a convincing argument for the need of the pyrolysis methods for battery material manufacture. Also, the overview slide is not showing the percentage complete as of now. The reviewer asked what the current status of the project is in terms of milestone accomplishments.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The PI really seems to have a handle on the practical issues and is focused on transitioning the shortcomings of flame pyrolysis to achieve high-quality materials for batteries. The PI is addressing positive electrode materials and also lithium lanthanum zirconium oxide (LLZO). The PI is aware of the goal to densify particles and particle-size distribution is an issue. The reviewer liked the in-situ Raman addition to the process to gain a more intimate understanding of the calcination processes.

Reviewer 2:

The reviewer found the results interesting and, outside of material production, the approach of investigating co-sintering of the cathode and LLZO is an interesting pathway with the potential for larger impacts on solid-state batteries if successful. While there maybe differing opinions on what are the most promising solid-state chemistries to pursue, it is not clear if anything beyond the family of LLZO materials will be considered in the future or if other materials like sulfides are not compatible with this process.

Reviewer 3:

The reviewer mentioned a number of technical accomplishments achieved during the project period, including:

- Synthesis of aluminum (Al)-doped LLZO to support the evaluation of solid-state batteries by collaborators.
- Synthesis of LLZO to support the comparative study of polymer composite SSE by collaborators.
- Development and demonstration of the Slurry FSP and Slurry Spray Pyrolysis instruments.
- Direct formation of the layered NMC811 structure during FSP through the control of flame temperature, which could potentially eliminate the calcination step and simplify the cathode synthesis. Nevertheless, the yield of the layered phase is still quite low (8%), and additional process optimization is needed to improve the conversion rate.
- The team demonstrates that sintering LLZO green powder together with cathode particles could generate a conformal coating of cubic LLZO on an NMC cathode surface. This benefits from the small particle

size of the green powder and could potentially improve the charge transport kinetics. An impurity phase was discovered in the product, the abundance and distribution of which need to be further studied. In particular, the interface structure between the LLZO coating and NMC should be carefully characterized. It is important to confirm that the co-sintering process does not lead to the formation of detrimental interphase at the interface.

Reviewer 4:

The project started in 2016, and the progress shown is not sufficient enough to arrive at any conclusive remarks about the techniques proposed as the next-generation manufacturing method. With the data presented, it is hard to gauge the novelty of the method for the synthesis of cathode materials and/or solid electrolytes and expect a mass industrial adoption. The reviewer wanted to know if the team has filed for any patents in this area.

An LLZO commercialization milestone had been set for September 2020; however, this is listed in the Future Work. The reviewer asked what the exact reason is for the delay and whether it is because of an inadequacy in the facility or any fundamental constraints in scaling up this method.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

While the aerosol synthesis is mainly carried out at ANL, the ANL team collaborates closely with a number of institutions (Cabot, Northwestern, ORNL, Lawrence Berkeley National Laboratory [LBNL], and Purdue). SSEs synthesized at ANL are supplied to collaborators for different research projects. The collaboration is productive and meaningful.

Reviewer 2:

The reviewer noted that the PI has a select, but broad segment collaboration (a relevant industry like Cabot to academic users such as Purdue).

Reviewer 3:

The project has a good set of collaborations but given the large emphasis on solid-state in the battery community, the reviewer thought that this project would benefit from additional collaborations with both industry and academia to help further validate the utility of the materials synthesized. Especially for LLZO, involving another university or company would be helpful for additional comparative studies and validation of the material consistency and performance. The reviewer also encouraged the project team to publish or present on their work more to further disseminate their results and capabilities, which may help attract more potential collaborators.

Reviewer 4:

The project does seem to have a strong team including industry leader, Cabot Corporation. However, the results presented are not showcasing the collaborative efforts. The reviewer wanted to know if there are any scale-up efforts attempted with Cabot on any of the materials that are being synthesized at lab scale, whether the material produced for a large-scale processing will be shared with LBNL and ORNL for testing, and if there were any updates on the collaboration between ANL and the LBNL-ORNL 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Synthesis of 1 kg/day of LLZO is very critical to validate the feasibility and scalability of this process. This has been mentioned as future work, and the reviewer expressed interest in seeing the scalability and economics of this method of material manufacturing.

Improvement in various aspects of material synthesis with an intent of cost reduction is very critical at this point of mass electrification, and this project aims to achieve that in the next year, which the reviewer said is important. Low-temperature (T) garnet is another interesting aspect the project aims to study in the next year, according to the reviewer.

Reviewer 2:

The reviewer really resonated with the planned future research in Slide 13 and where the flame pyrolysis techniques could bring a novel approach and disruptive change in how controlled solid-state composites are fabricated. The single-crystal goal is also interesting.

Reviewer 3:

The proposed future research appeared reasonable to the reviewer, who suggested that the team complement their efforts in process optimization with defect (e.g., cation mixing and interphase formation) characterization to mitigate unwanted side reactions and defect generation. Also, the reviewer did not see electrochemical measurement data of the synthesized LLZO in the current report and inquired if someone on the team is working on this.

Reviewer 4:

Future work plans seem reasonable and logical based on the results presented. However, the reviewer encouraged the team to better define the challenges and incremental milestones needed to scale up the synthesis process to more than 1 kg/day+. From the presentation given, it was not clear what the barriers are in scaling from 1 kg/day to 10 kg/day, etc., or if the challenges are the same no matter the amount of material scaled up for synthesis. Given the broader project goals, this is an item that needs more effort and clarity in order to have a larger impact going forward. The reviewer would like to have seen more analysis work on the cost and energy required to truly scale up this approach to larger quantities. On Slide 5, Fiscal Year (FY) 2019 has an ongoing task of "Commercialize c-LLZO production"; it was not clear to the reviewer if the aforementioned questions are being addressed intrinsically here.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer really liked this project, the progress obtained, and the goals moving forward. The process is somewhat novel, but more importantly the novelty in the changes to the process to address its shortcomings could result in a disruptive change to the way materials are fabricated. Again, spray pyrolysis has been around for a very long time, but this PI has a handle on the morphological changes that need to be made and the potential advantages for single-crystal development and especially composite fabrication.

Reviewer 2:

Overall, the reviewer found the project and results presented to be of high value and of general interest to the battery community. This project is a key component of enabling better scaleup and wider research investigation of new battery materials, especially LLZO.

Reviewer 3:

The reviewer commented that this project supports the overall DOE objectives by developing high-volume, low-cost SSE synthesis techniques and supplying SSEs to the DOE battery research community.

Reviewer 4:

The reviewer asserted that any effort to reduce cost in any battery component will lead to the low-cost goal of DOE at battery cell or pack level of approximately $75/kWh. This project aims to get the cost reduced by introducing an innovative method of material manufacturing. Once the process has been proven scalable and economical, the reviewer remarked that combining it with improved electrochemical performance will enable this technology to be compelling enough for mass adoption.

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 nearly impossible to make a robust comment without the LOE and/or loaded burn rate for the national laboratory. However, the reviewer believed that this project is one of the most efficient ever seen. Although it has been going on for 5 years, the reviewer believed that this is the type of project that deserves a continued moderate level of funding for long periods until it is time to build the next step in scaled equipment once viability is proven. It is a nice project.

Reviewer 2:

Resources seemed appropriate for now to the reviewer. It is unclear if more resources or equipment modifications will be needed in the future for larger synthesis scale-up.

Reviewer 3:

The team has a perfect mix of an industry leader, national lab, and university with appropriate expertise to carry out the proposed work, according to the reviewer.

Reviewer 4:

The reviewer indicated that allocated resources are appropriate for the scope of the project.

Presentation Number: bat355
Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications
Principal Investigator: Madhuri Thakur (Farasis Energy)

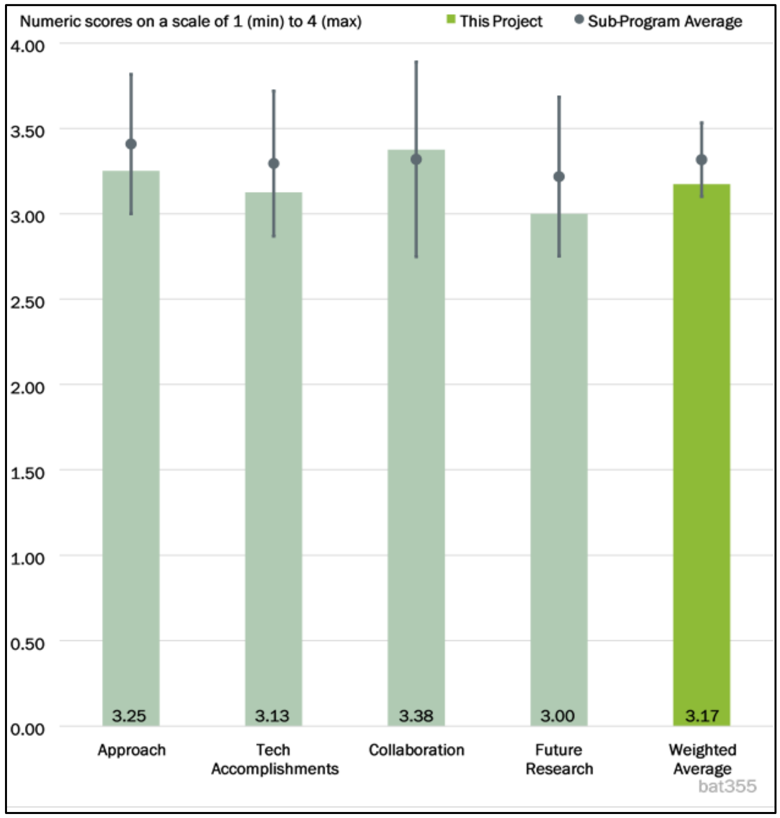


Figure 2-13 - Presentation Number: bat355 Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications Principal Investigator: Madhuri Thakur (Farasis Energy)

Presenter

Madhuri Thakur, Farasis Energy

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the approach is to optimize all materials in a Si-C composite/Ni-rich NMC cell to provide the best combination of performance and cost. This empirical approach resulted in some very nice cycling and performance metrics. Gen2 cells have approximately 330 Wh/kg energy density and were optimized beyond Gen1 cells.

Reviewer 2:

It seemed to the reviewer that major technical barriers, including binder, electrolyte life, etc., were considered in this project.

Reviewer 3:

The overall target of the project is very clear, and the team is focused on delivering. The approach seems to work although the poster presentation does not clearly specify the evaluation criteria for each component and material. The reviewer highly appreciated the independent analysis of the cells by the national laboratories, which seems to be working well.

Reviewer 4:

As two reviewer comments from last year pointed out, the project looks like a trial and error of the combination of existing technologies, which lacks a rational design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the initial performance targets have been reduced over the course of the project.

Reviewer 2:

The reviewer indicated that the team clearly showed the progress in the work. Points to consider to further develop the technology would be calendar-life aging at higher temperatures, swelling behavior of the cell, gas formation, and safety level compared to standard product.

Reviewer 3:

It appeared to the reviewer that all targets for the project were achieved. Although the cost ($0.10/Wh was the target) was not reported, the PI stated that the USABC cost goal was achieved.

Reviewer 4:

The developed cells seemed to the reviewer to meet the goals promised. The volt$_{min}$ (V_{min}) for baseline cells (3.0 V) and final cells (2.75 V) is different in the comparison table. It was unclear to the reviewer if the baseline cells have higher specific energy if its V_{min} changes to 2.75 V.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there is an outstanding number of contributors, and the workload and contributions seem to be balanced well.

Reviewer 2:

Many materials and characterization collaborators contributed to this project (ANL, LBNL, Daikin, 3M, Solvay, Celgard, Shin-Etsu, etc.). The reviewer stated that these are impressive collaborators.

Reviewer 3:

The reviewer opined that the collaborations among team members are excellent.

Reviewer 4:

The partners are more like suppliers. The reviewer said that true collaboration is lacking.

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 state project ended.

Reviewer 1:

The reviewer stated that the project has ended.

Reviewer 2:

The reviewer commented that the project has ended.

Reviewer 3:

The reviewer pointed out that the project ended in September 2020.

Reviewer 4:

No future work was provided. It was unclear to the reviewer how the technology can be transitioned for application.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer observed that the goals of this project—develop EV cell technology capable of providing 280 Wh/kg after 1,000 cycles at a cost target of $0.10/Wh—are in direct support of DOE objectives.

Reviewer 2:

According to the reviewer, optimization of lifetime, cost, and energy density are all relevant to DOE objectives and targets of this project.

Reviewer 3:

The reviewer indicated that this project supports the overall DOE objectives by increasing the energy density of LIBs.

Reviewer 4:

The reviewer said that the project fully supported the 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 found that the resources for this project are appropriate.

Reviewer 2:

The reviewer indicated that the resources were sufficient and well spent.

Reviewer 3:

The reviewer stated that resources for this project are sufficient.

Reviewer 4:

The reviewer asserted that some aspects of the project would have benefited from working with a university.

Presentation Number: bat356
Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials
Principal Investigator: Madhuri Thakur (Farasis Energy)

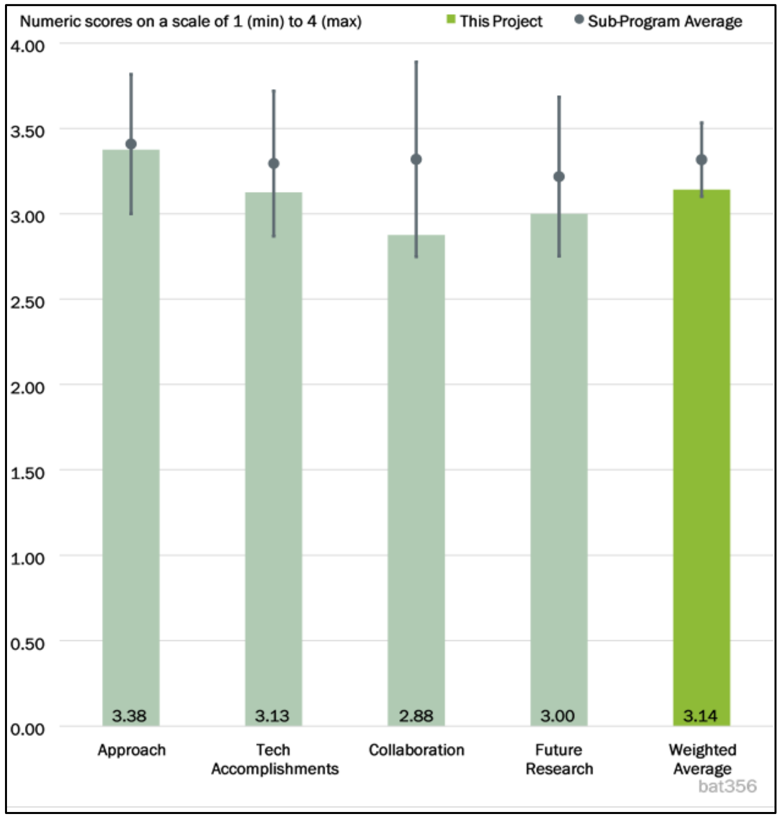


Figure 2-14 - Presentation Number: bat356 Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials Principal Investigator: Madhuri Thakur (Farasis Energy)

Presenter

Madhuri Thakur, Farasis Energy

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach relies on the direct recycling of used battery cell components. The extraction of active materials follows a loop that the reviewer found interesting: electrode shredding, sieving, density separation, and material regeneration. Recycled materials are then used in electrode formulations that contain both recycled and fresh materials. Cost modeling is also performed to evaluate savings using this technology. The project is well designed and feasible.

Reviewer 2:

The effort of this project support DOE’s goals by develop recycling technology for LIBs that will enable direct reuse of high-value active materials. The technical challenges of direct recycling process are addressed, according to the reviewer.

Reviewer 3:

The reviewer said that the tasks are well designed to meet the objectives.

Reviewer 4:

The ability to use mixed feedstock (i.e., different chemistry inputs) will be essential in the long-term as end-of-life (EOL) vehicle packs begin to represent a significant volume. The reviewer suggested that more work should be done to demonstrate the viability of this approach when multiple cell chemistries are used as inputs. The long-term impact of the impurities introduced by the direct recycling process (F) needs to be tracked.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The cells containing recycled materials had very similar performance metrics to cells containing only "pristine" materials, which the reviewer noted certainly serves as proof that the developed methods work. The cost analysis clearly shows an economic benefit to using recycled materials.

Reviewer 2:

The reviewer stated that the modified process for recovery scale-up for whole-cell feedstock has been developed. The cells built with the small quantity of recycled materials are almost comparable to those made with pristine materials though more future efforts may be needed to understand and optimize recycled materials. With further study on the process optimization and an increase in the purity of recycled materials, the developed technology may play an important role in LIB recycling. The cost analysis was not detailed, but it might have been provided in the final report.

Reviewer 3:

The performance targets are already met. However, the scalability of the approach remained questionable to the reviewer, especially the use of large amounts of non-water solvent.

Reviewer 4:

The data presented indicated to the reviewer that using recycled cathode material in the material supply chain is feasible. Data should also be gathered on long-term cycling and calendar life to examine the impact of the impurities identified from the recycling process on degradation behavior. More information on how the used cathode is "rejuvenated" would be helpful to understanding if this process can be generalized to larger scale LIB recycling.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration across the team members appeared excellent to the reviewer.

Reviewer 2:

The reviewer said that the PI works with a national laboratory to do characterizations.

Reviewer 3:

It was unclear to the reviewer if the national laboratories have provided technical input to the project beyond testing services. The main focus of the project seems to be on manufacturing scrap, internal to Farasis.

Reviewer 4:

LBNL is listed as a collaborator, but it was not entirely clear to the reviewer how its capabilities were utilized in 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that the project has ended.

Reviewer 2:
The reviewer noted that the project has ended.

Reviewer 3:
The reviewer said that the project ended in June 2021.

Reviewer 4:
According to the reviewer, no future work is described as this was the last year for this project; technical barriers and challenges for further word, however, were illustrated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer affirmed that the ability to use recycled batteries back in the cathode supply stream would be very beneficial to the DOE targets. Cost and sustainability could be improved. Even if the proposed technology is only applicable to manufacturing scrap, it could lower production cost, which would help lower the cost of EV adoption.

Reviewer 2:
The reviewer commented that optimized recycling processes decrease the lifetime cost of energy storage technology and maintain availability of critical materials. This study of implementing recycled active materials informs future battery designs to improve recycling process efficiency.

Reviewer 3:
The reviewer noted that this project supports the overall DOE objectives by increasing the energy density of LIBs.

Reviewer 4:
The reviewer asserted that this project targets battery material recycling, which will be essential for large-scale, sustainable deployment of EVs.

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

Reviewer 1:
Given that the main focus is on manufacturing scrap (not gathering EOL batteries), the reviewer remarked that a cell maker is uniquely positioned to develop and implement such a recycling approach.

Reviewer 2:
Resources are reasonable for the project, according to the reviewer.

Reviewer 3:
The reviewer indicated that some aspects of the project would have benefited from working with a university.

Reviewer 4:
The funding level and time appeared to the reviewer to be insufficient to support the research on direct recycling technique to a level that demonstrates the full capability of the technique.

Presentation Number: bat377
Presentation Title: ReCell–Overview and Update
Principal Investigator: Jeffrey Spangenberger (Argonne National Laboratory)

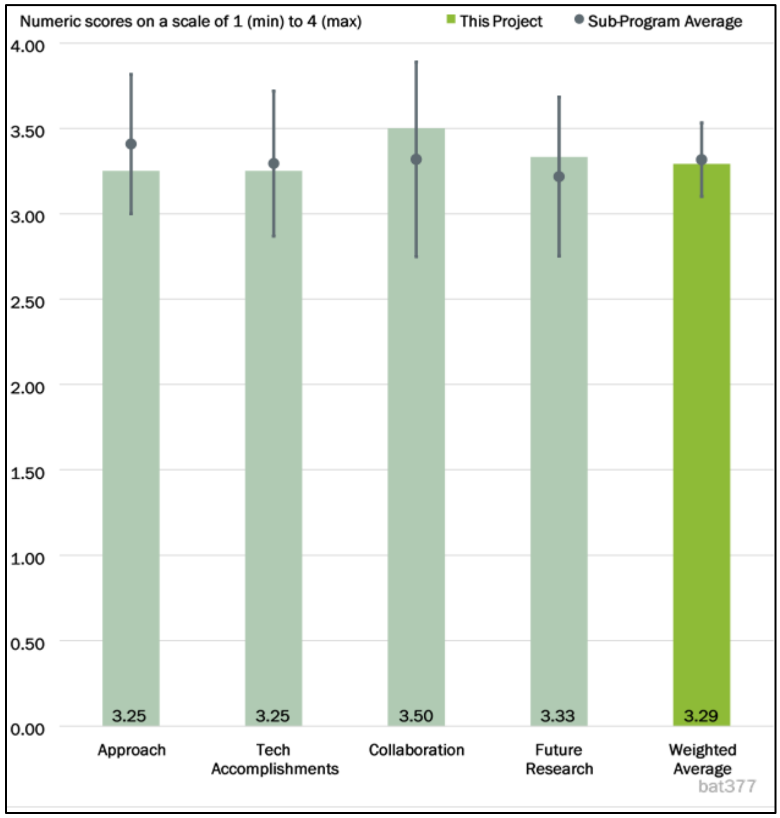


Figure 2-15 - Presentation Number: bat377 Presentation Title: ReCell–Overview and Update Principal Investigator: Jeffrey Spangenberger (Argonne National Laboratory)

Presenter

Jeffrey Spangenberger, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this is a sharply focused and well-organized project to address the recycling of LIB materials. The team has been working on various process options to minimize risk with simultaneous assessment of the results and options.

Reviewer 2:

According to the reviewer, this project is an aggressive attempt to recycling by using direct recycling of cathode materials without the breakdown to individual metal ions. This has the potential to substantially reduce recycling costs, if successful. The project is well designed and feasible.

Reviewer 3:

The reviewer found that the continuous review of new ideas and stopping of efforts that do not show promise is a sound approach. Direct recycling is a hard problem that will take many iterations.

Reviewer 4:

The reviewer said that the project is well designed and feasible for the intended tasks, but the significant focus maintained on methods specific to direct recycling continues to detract from an optimal approach.

Reviewer 5:

This project seemed to the reviewer to have focused in on direct recycling of materials. This is a noble pursuit, but fraught with many challenges. The project team is aware of these challenges but does not explicitly call out if the team sees a feasible path forward. The role of industry to sort out these questions is not to be minimized, but the community would benefit from a clear statement (including the signatures of the industry partners) of whether or not any paths have been crossed out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the presenter demonstrated exciting electrochemical cycling of directly recycled NMC622 materials, which showed promising cycling performance after 400 cycles compared to pristine (“virgin”) cathode materials. Although the performance is not as good as the original material, it demonstrates good first steps toward further development. The presenter did not cover how increasing impurities that may cause deleterious performance will be removed in future work.

Reviewer 2:

The reviewer observed that the project has been able to accomplish a number of significant results, such as studies toward direct recycling avenues, identification of the unit operations for preprocessing, separations and relithiations, appropriate solvent selection, recovery of copper (Cu) and Al, modeling studies, all with an overall eye toward sustainability. A good deal of IP has been generated as well.

While the above are clearly very encouraging given the early nature of these investigations, the reviewer reported that the recycling results shown from thermally and solvent-recovered cathodes performed significantly worse than the baseline. Hopefully, future work improves this aspect of the work significantly for these materials to be attractive commercially.

Reviewer 3:

The reviewer said that there has been demonstration of feasibility, but progress shows direct recycling is still far away even under the best of circumstances with relatively forgiving cathode materials (NCM622).

Reviewer 4:

The reviewer found that good progress has been made to identify options for recovering and reusing NCM111 and NCM622. However, battery testing of recycled NCM’s still lags behind virgin NCM cathodes. This is a key step to demonstrate viability of the approach.

Reviewer 5:

The project has demonstrated useful progress in several key areas, but in general the outcome and progress for the direct recycling activity portions seemed to the reviewer for the most part to be expected and underwhelming.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination across the project seemed to the reviewer to be very effective, and outreach to industry and related organizations seems excellent as well.

Reviewer 2:

The reviewer observed that the ReCell project has several ongoing collaborations with institutions at various levels, including universities and industry partners. The presenter mentioned actively trying to tour recycling centers to engage with industry players.

Reviewer 3:

The reviewer praised the team for having outstanding members, and it is great to see that ReCell is also working with the Battery Prize winners who might have a lot of out-of-the-box ideas, approaches, and solutions for recycling. It would have been nice to present a slide that identifies the activities of each of the individual team members and awardees.

Reviewer 4:

The reviewer stated that the interaction between the organizations is evident from the slides. However, deeper and more meaningful industry interaction would be appreciated, particularly with respect to the down-selecting of pathways as mentioned previously.

Reviewer 5:

The reviewer said that the team has a diverse background and 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The presenter highlighted that the future work would focus on demonstrating a recycled battery in real applications and improving its performance. The reviewer found this to be a critical step toward understanding the feasibility of using this approach and looked forward to seeing the results.

Reviewer 2:

According to the reviewer, the proposed future research captures all the key aspects of recycling. However, as it is obvious, if the materials are not at par with their commercial counterparts both from performance and cost points of view, then there will be no motivation for the cell manufacturers to use them. This task should be of the utmost significance.

Reviewer 3:

The proposed future work is sound, but the reviewer would like to have seen more focus on closing the performance gap between recycled and virgin NCM cathodes.

Reviewer 4:

The proposed future work seemed appropriate to the reviewer based on the work done to date, but the barriers to realization of some of the proposed technologies do not seem to have been fully considered. Alternate development pathways or possibilities for alternate implementations seems to be usefully open.

Reviewer 5:

The reviewer would really like to have seen very close connections to industry here.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

It was at last very heartening to the reviewer to see that recycling has now garnered significant attention from technical, environmental, political, and commercial considerations. In fact, this level of attention and commitment should have been given maybe 5 years ago when EVs were just slowly entering the market. We are now late in handling all these EVs that are coming to their EOL soon, and there is still no robust technology in place to tackle this issue. The reviewer appreciated the renewed efforts by the DOE in this area.

Reviewer 2:

The reviewer remarked that recycling is a critical step to create a circular economy for EVs. Without this, EVs will never be a mass market solution.

Reviewer 3:

The reviewer stated that recycling battery materials, especially cathode metals, can provide a critical pathway toward achieving overall DOE objectives of reducing battery costs for electric vehicles.

Reviewer 4:

According to the reviewer, battery recycling is a key step in a sustainable battery supply chain.

Reviewer 5:

The reviewer asserted that battery recycling is, and will continue to be, of key and ever-growing importance in supporting 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:

As the reviewer previously mentioned, the industry and the country are both way behind in the recycling technology. Vigorous activities need to be initiated to catch up to develop robust, commercially, and environmentally attractive recycling technologies.

Reviewer 2:

Resources devoted to the project seemed sufficient to the reviewer and relatively appropriate within the overall DOE portfolio in the related time period.

Reviewer 3:

Resources appeared to be sufficient to the reviewer.

Reviewer 4:

Resources seemed sufficient to the reviewer.

Reviewer 5:

Sufficient resources were observed by this reviewer.

Presentation Number: bat382
Presentation Title: ReCell–Modeling and Analysis for Recycling
Principal Investigator: Qaing Dai (Argonne National Laboratory)

Presenter

Qaing Dai, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 14% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

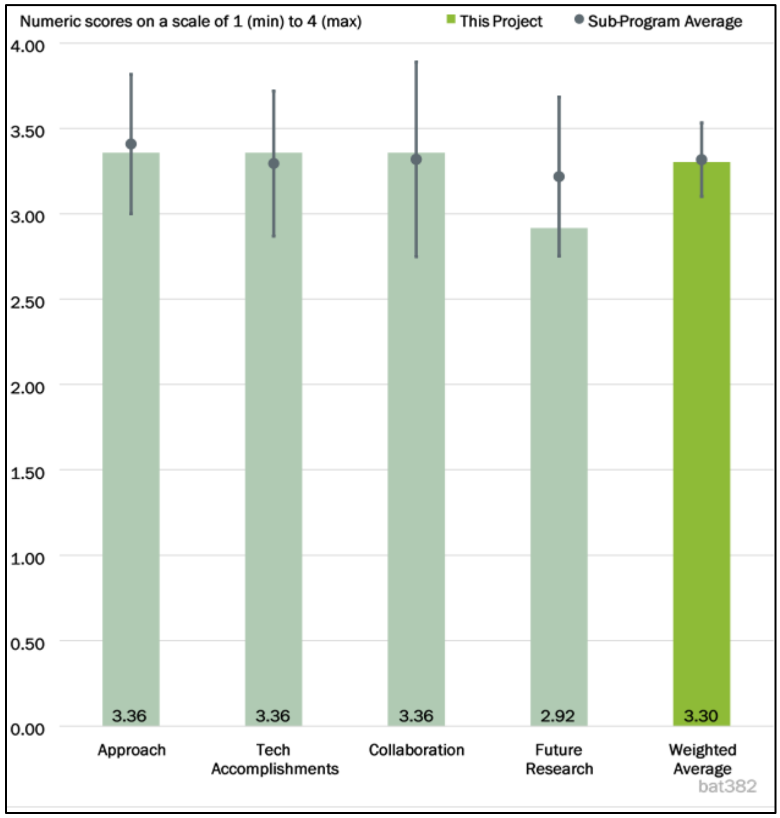


Figure 2-16 - Presentation Number: bat382 Presentation Title: ReCell–Modeling and Analysis for Recycling Principal Investigator: Qaing Dai (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer remarked that the approaches taken to decrease recycling cost and then use recycled material for LIB remanufacturing will lower the cost of these batteries, resulting in an increased adoption of green energy technologies. The Principal Investigator's (PI) approach offers a winning combination to the automotive and renewable energy industry.

Reviewer 2:

The reviewer stated that the project is focused on developing models to show the viability of recycling Li-ion cells and will be extremely useful for companies and government agencies planning on investing capital in battery recycling.

Reviewer 3:

The reviewer commented that it is very nice to get the quantitative data indicating the necessity of recycling LIBs. Through EverBatt and Lithium Ion Battery Resource Assessment (LIBRA) models, meaningful data were obtained and assessed for the sustainability of LIB recycling.

Reviewer 4:

The reviewer asserted that EverBatt and LIBRA are important tools in evaluating the market relevance of any new battery recycling technology. These recycling technologies are needed to be implemented immediately in industry, and these tools help in realigning the focus of the research toward things that are more practical and something that can be actually implemented.

Reviewer 5:

According to the reviewer, useful modeling and simulation tools LIBRA and EverBatt have been developed in this project by addressing the need to evaluate the macro-economic viability of the battery supply chain as well as cost and environmental impacts of recycling processes.

Reviewer 6:

The basic approach to recycling analysis of using macro-economic and life-cycle analysis (LCA) modeling appeared sound and well reasoned to this reviewer.

Reviewer 7:

The reviewer found little substance in the slide deck to allow a sufficient review of approach. From what is available, the project team is trying to create a model to predict cost projections for 2025 and beyond based on 2020 and before material usage. The cathode material recycling model weighs heavy on the burden of Co, but the true issue in 2025 and beyond will be the availability of high-quality Ni. As chemistries shift toward Ni-rich NMC, the cost of Ni and its availability will be what drives the industry toward recycling.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the two models are quite well developed to answer the important questions as to the viability and approaches needed to achieve LIB recycling.

Reviewer 2:

The reviewer stated that the modeling and simulation tools developed meet the planned goals and are in alignment with the schedule.

Reviewer 3:

The reviewer commented that Libra and Everbatt models are great accomplishments and could guide new businesses to enter battery recycling business with somewhat improved confidence.

Reviewer 4:

Technical accomplishments to date appeared to the reviewer to be on track and are very timely, considering the anticipated rapid increase in battery manufacturing that will be occurring over the next decade.

Reviewer 5:

The progress made meets all the project requirements set at the start of the project. The variables included are very useful and relevant to the objective. The reviewer asserted that there are still some corrections that would be needed, based on real data, but they can be made as a version update.

Reviewer 6:

The reviewer found good achievement by sharing the model results indicating the significant impact of LIB recycling on many different aspects in economy. It is very valuable information to get the cost and revenue breakdown associated with cell recycling. However, further assessment with the latest and near future materials would be more meaningful, and it would be very informative to get the source of the data for EverBatt model. For instance, manufacturing scrap rates would vary depending on key suppliers and informing data source will give more confidence to users.

Reviewer 7:

The project team has created a parametrized model that may be useful in predicting the true value of recycling of cell materials at various stages of life. Although the reviewer disagreed with the values being used, the tool being set up is novel and should allow for more robust inputs to guide it toward a more accurate solution in the future. It is unclear how this tool will be used going forward. This tool should be available to the greater battery industry to refine, improve, and utilize.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project team is working well to incorporate modeling with data available from team.

Reviewer 2:

According to the reviewer, there is good collaboration and coordination across the project team.

Reviewer 3:

This reviewer noted great collaboration among many DOE labs and some well-known universities in the United States.

Reviewer 4:

The team consisted of researchers from several closely collaborated organizations and is well organized. However, it was unclear to the reviewer how the EverBatt model leverages previous modeling efforts, such as BatPaC.

Reviewer 5:

The reviewer indicated that there are good collaborative efforts among universities, national laboratories, and companies by providing them with technical knowledge in great depth along with commercial and business inputs leading to delivery of viable models. The reviewer suggested that it would be better to include OEMs in different industries to get their approximate roadmaps in LIB usage to better project the size of the recycling industry.

Reviewer 6:

The reviewer recommended the involvement of major industry partners. Considering the high value of manufacturing scraps, the reviewer expected that direct participation or partnering with a major Tier 1 battery cell supplier would be necessary to fully capture how recycling of manufacturing scraps can be practically implemented.

Reviewer 7:

The reviewer could not really tell what the collaboration is or is not from the reviewer slides. There is a wide list of national laboratories and academic authors, but the contributions are 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that the project is ending in September 2021. But, as a final task, both teams will work with Battery Recycling Prize winners to inform their process development.

Reviewer 2:

The reviewer asserted that planned support to battery recycling prize winners is a great future plan. It will encourage new businesses and small businesses to work with ANL and other DOE labs.

Reviewer 3:

There are good plans for future work with the details on recent recycling processes. The reviewer stated that it would be good to see more environmental impacts of processes in the near future.

Reviewer 4:

The model will be applied appropriately. A little more detail would improve understanding of future plans, according to the reviewer.

Reviewer 5:

The reviewer commented that the future work described was not detailed though the proposed work seems reasonable.

Reviewer 6:

While both models appear to be useful additions, the reviewer found that very few specifics were provided regarding how future work would be conducted and how the models would be specifically used.

Reviewer 7:

The reviewer stated that it sounds like the model will be applied to "Battery Recycling Prize" winners but was unsure what this contest is or the significance it may have on utilizing this research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, having a better understanding of battery supply-chain issues will be critical to increasing electrification of the light-duty and heavy-duty vehicle fleets in the United States. Both the LIBRA and EverBatt models and their incorporation of recycling analyses will assist with evaluation of battery supply chains within the United States and the role of recycling in continuing to both reduce the future cost of automotive battery packs and to improve a secure supply of critical battery raw materials.

Reviewer 2:

Reducing the need for foreign goods and raw materials is a core DOE objective. Recycling is key to that future. The reviewer asserted that recycling only occurs if financing occurs, and financing occurs only if a value can be seen. This model can help to draw conclusions on the value of investing in battery recycling.

Reviewer 3:

From the reviewer's perspective, it is very important to make an assessment of technology in relation to cost and industry relevance. DOEs objective of developing recycling technologies relevant to industry is highly dependent on making it cost effective, and this research project fits into that task.

Reviewer 4:

The reviewer remarked that battery cost is the main driver for the success of vehicle electrification. These project results greatly impact the DOE VTO objectives.

Reviewer 5:

The reviewer commented that the project supports the goals for battery cost reduction and environmental protection, and helps the future supply of battery critical materials.

Reviewer 6:

The reviewer found this work to be very important and showed the viability of recycling of LIB materials.

Reviewer 7:

The reviewer commented that lowering the price of LIB to $60/kWhr by 2030 is a great aspect of this project. Hope it materializes because if this happens, it will change the paradigm of eMobility.

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 the team is well resourced and gets help from DOE labs and universities.

Reviewer 2:

The reviewer stated that the project is appropriately resourced.

Reviewer 3:

The resources were sufficient to meet the project objectives, according to the reviewer.

Reviewer 4:

The resources appeared to be sufficient to the reviewer for the proposed efforts.

Reviewer 5:

The reviewer commented that no information was provided to indicate insufficient funding levels.

Reviewer 6:

The reviewer remarked that there were sufficient resources to deliver the initial results. As mentioned previously, the reviewer recommended that there be more involvement from industry (i.e., automotive, electronics, and utility) to develop more viable modeling tools.

Reviewer 7:

Approximately $15 million to produce this seemed excessive to the reviewer. The reviewer slide deck did not convey the detail of work done so the reviewer could only judge on what has been provided. Given that this model is only version 1.0, it will need critical alpha and beta testing phases to become a valuable tool. Some alpha testing should occur with the future work, but it is unclear how much the software will be improved from that feedback.

Presentation Number: bat386
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

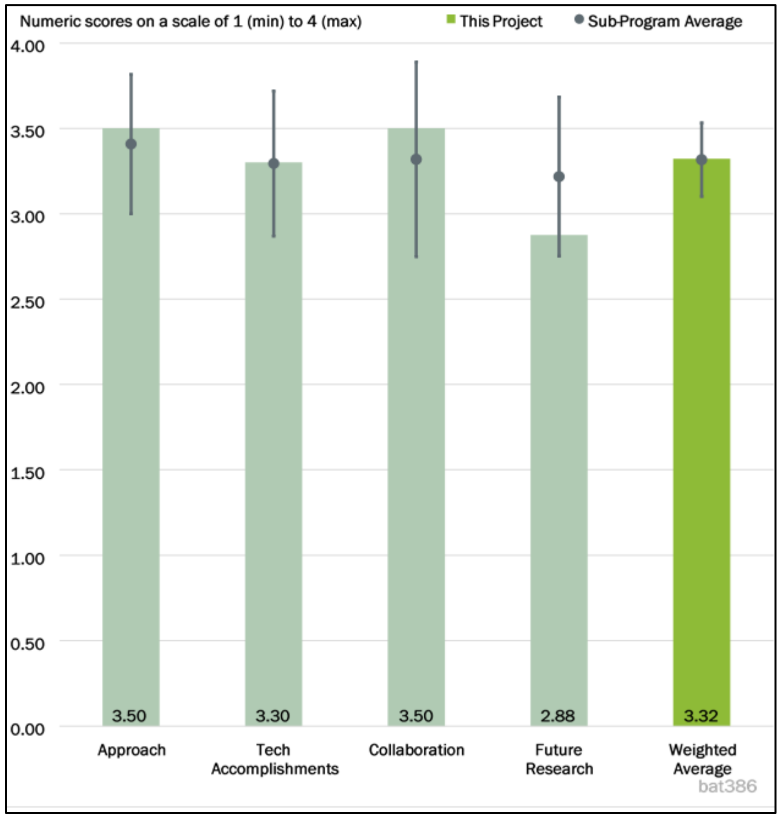


Figure 2-17 - Presentation Number: bat386 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Overview and Progress Update Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter

Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that the project approach is well suited to national laboratories: understand the fundamentals of what is limiting fast charge and use and communicate that understanding so that the problem can be solved. In addition, the fast-charge problem is not due to one failure mechanism. This project does a good job at looking holistically at the cell to understand all areas for improvement.

Reviewer 2:

This reviewer indicated that basic material research to realize battery chemistry suitable for fast charging is an excellent approach. The Spider chart on Slide 3 serves the project PI and team very well to push the envelope of new battery technologies.

Reviewer 3:

According to the reviewer, this project showcases how to leverage the toolbox at the national laboratories. This project really focuses in on identifying the root cause of lithium plating. Although the conclusions are not relatively novel, the tools put in place are novel and the ability to quickly identify core failure will call for rapid development in this area. The challenge to the team is how to leverage this information into lower cost tools to further accelerate product development.

Reviewer 4:

The reviewer indicated that the project aims to approach the identified major issues of cell degradation limiting fast-charging capability of LIBs. Therefore, different approaches toward problem solution were chosen and processed by experts from the named partners. An additional barrier of low energy density and high costs for fast-charge cells was also identified and addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the PI provided a high-level description of the work done as well as the future work. The partner teams have proposed several different fronts for future work, which align well with the fact that multiple PIs are involved in the project.

Reviewer 2:

The reviewer remarked that the project shows key improvements in electrolyte, design, and diagnostic tools. Although these are not meeting the larger performance goals, this project puts the larger research industry on a pathway toward success.

Reviewer 3:

The AMR presentation and data indicated on Slide 10 demonstrate that great progress has been made since last year.

Reviewer 4:

The reviewer thought that the team has done a great job looking at failure mechanisms and developing techniques to detect failures like lithium plating. But, applying that knowledge to commercially relevant loadings needs to be pushed. Also, the reviewer thought that all this work was done using a graphite anode. Many EV cells contain some amount of Si; this should be included in the studies. The reviewer did not see that the goals and milestones of the project were communicated clearly at the beginning of the presentation, so it was hard to judge progress against those.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer thanked the PI for putting up a clear slide showing the distribution of the project. It was clear to the reviewer that the PI and team leveraged expertise from across the team, which has led to a successful project. This project should serve as an example of excellent cross-lab collaboration.

Reviewer 2:

The reviewer asserted that the PI showed clearly that the different researchers within this project are doing excellent work in team’s fields of expertise as well as interconnecting well considering the topics that require collaboration of different teams.

Reviewer 3:

The U.S. national laboratories have done a good job coordinating on deep dive projects, such as voltage fade, Si anode, and now fast charge. The reviewer said that this is great teamwork.

Reviewer 4:

This reviewer noted great collaborative work between Venkat Srinivasan and Sam Gillard and reported that all contributors are indicated on Slide 7. This is a great ecosystem DOE has created to solve difficult science and engineering problems.

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 state project ended.

Reviewer 1:

The reviewer stated that getting 6C chemistry will serve the automotive industry well.

Reviewer 2:

The proposed future plans are well focused on the identified problems. However, the question remaining from the reviewer is how these approaches can be adapted from laboratory work to real-life, industrial application, as the capability of fast charging is supposed to be a game-changer for broad customer acceptance (or better, the end of range anxiety).

Reviewer 3:

Spending a lot of effort getting good cycle life on 3 Ah/cm^2 cells might not be the right direction. The reviewer encouraged the team to start working on more commercially relevant loadings with EV energy-density targets. Industry does not care about the lower loadings.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that widespread EV adoption can only happen with consumer acceptance. The development of fast charge minimizes range anxiety and opens the market to a large number of consumers who do not have a place at home to charge their vehicles.

Reviewer 2:

The reviewer stated that fast charge is a key step toward passenger EVs, and this project positions researchers to develop toward the fast-charge goals.

Reviewer 3:

Extremely relevant work for the U.S. automotive industry was noted by this reviewer.

Reviewer 4:

The reviewer called the project highly relevant to DOE's objectives and, if fully successful, would enable different approaches and routes to fast-charging cell design to avoid the side effects of enhanced cell degradation.

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

Reviewer 1:

The value of the output is in line with the reported spending, according to the reviewer. The team had clear access to high-power unique tools within the national laboratory portfolio.

Reviewer 2:

This reviewer observed a well-resourced team led by a very knowledgeable PI, Venkat, in collaboration with Sam.

Reviewer 3:

The reviewer stated that the resources appear to be adequate for completing the tasks within the mentioned time frame.

Reviewer 4:

The reviewer commented that the work across the national laboratories ensures adequate resources, skill sets, and technologies to make progress on this important work.

Presentation Number: bat402
Presentation Title: Improving Battery Performance through Structure-Morphology Optimization
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter

Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

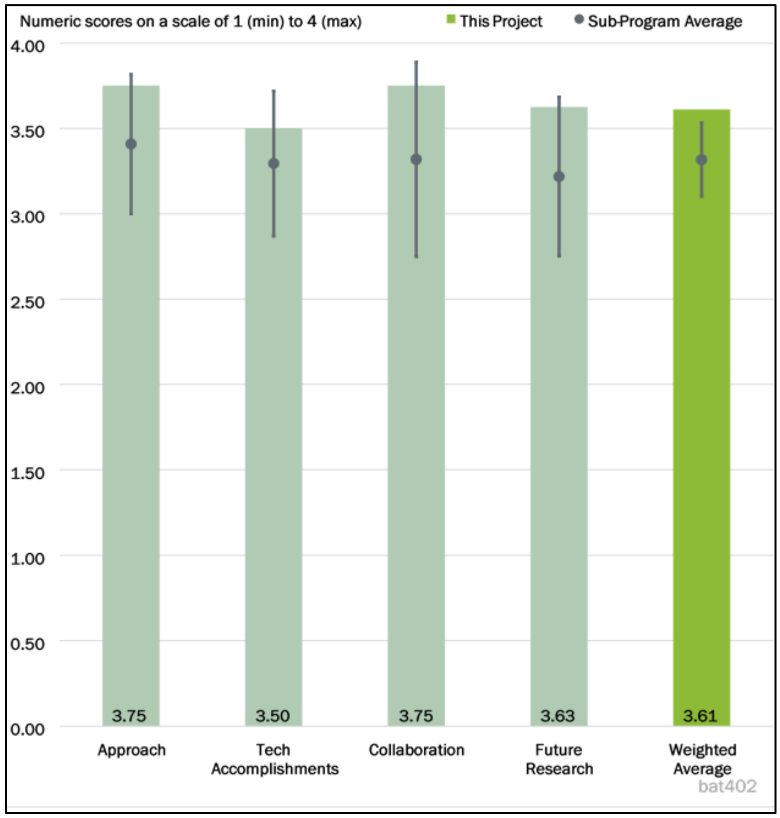


Figure 2-18 - Presentation Number: bat402 Presentation Title: Improving Battery Performance through Structure-Morphology Optimization Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called this an outstanding project that approaches synthetic challenges by a combination of experimentation and phase field models. Particle complexity, a parameter that is difficult to quantify, is evaluated rigorously by a judicious choice of experimental approaches. In addition, effects such as densification of ceramic electrolytes are studied and modeled with high fidelity.

Reviewer 2:

The approaches of calculations and simulations are applied to various systems to predict the process of co-precipitation, calcination, and densification. The approaches are important, according to the reviewer, as they can guide the experiment to be more effective.

Reviewer 3:

The reviewer commented that the approach taken by the team is highly novel and can have great impacts on the field.

Reviewer 4:

The approach is very clear and concise. One barrier was that there was limited control of the structure and morphology during NMC cathode synthesis. It is still very much unclear what promotes particular morphologies during synthesis. The reviewer wanted to know if there is a method to elucidate reasoning for certain morphological control. Transition metal selection has a certain influence on morphology, but the reviewer asked about what drives the primary particle morphology in the transition metal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is an ambitious project, and the PIs have made significant progress. The reviewer praised the quality of the publications as outstanding.

Reviewer 2:

The reviewer stated that the team has made major progress toward understanding the formation process of different battery materials. The in-situ synthesis work is interesting and novel.

Reviewer 3:

The synthesis condition or parameters in each work were studied in detail, such as temperature, time, pressure, ionic concentration, etc. The promotion of layered structure by the pre-conversion of $Ni_{0.8}Mn_{0.1}Co_{0.1}(OH)_2$ to cubic $Ni_{0.8}Mn_{0.1}Co_{0.1}O$ is especially promising, which is helpful for obtaining high-Ni materials with high quality. The only concern from the reviewer is what the advantage of the carbonate precursor is compared with the hydroxide one.

Reviewer 4:

There have been great efforts made toward tackling the barriers. The calculations and simulations show how primary particle morphology could be deciphered. It would be nice to couple theoretical modeling to experimental data to correlate morphology to performance indicators, like capacity fading and Coulombic efficiency. The pre-converted cathode material work was very impressive, but the reviewer was unsure if this reaches the target of decreasing overall cathode synthesis cost since the calcination process is longer with this added process. With the LLZO work, practical temperature and pressure systems need to be analyzed. Very nice baseline work is underway for LLZO densification.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The work is highly collaborative, involving X-ray diffraction, microscopy, thermodynamic modeling, and phase-field modeling. The coordination of different aspects of the work is outstanding, according to the reviewer.

Reviewer 2:

The reviewer stated that there are very good collaborative efforts between the scientists working on the project. In this work it is important to ensure that theoretical and experimental work are complimentary. Neither stand alone well without scientific doubt.

Reviewer 3:

The reviewer noted that the team is highly collaborative across multiple research groups funded by VTO.

Reviewer 4:

There is strong collaboration, but the reviewer was wondering about the contribution of each collaborator.

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 state project ended.

Reviewer 1:

The problems identified—the reason for the formation of disk-like particles observed by Battery Materials Research (BMR) PI Wang, the surface reorganization of LLZO, and the possibility of enabling lower energy processes by starting with low-melting precursors—are important and significant, according to the reviewer.

Reviewer 2:

The reviewer said that the future work plan about further improvement of synthesis is clear and complies with the milestones.

Reviewer 3:

The team has clearly identified major research challenges and a plan to resolve them. If the team plans to use the imaging method to study the lithiation progress, the reviewer suggested that the mobile nature of melt Li precursors should be considered.

Reviewer 4:

The reviewer recommended that a part of the future work should also include the ab initio molecular dynamics (AIMD) simulation for nickel oxide (NiO) and LiOH when there is no O adsorbed at the surface (inert surface, nitrogen). This was discussed with the presenters during the live presentation. This would further convince the reviewer that lithiation of the intermediate cubic phase is promoted by surface oxygen. All other future work suggested is on a par with the milestones mentioned.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that the PI has done well to identify the important barriers that must be resolved to improve the performance of rechargeable LIBs.

Reviewer 2:

The reviewer found the project to be very relevant and critical to DOE in terms of building up U.S. manufacturing capability in advanced battery materials.

Reviewer 3:

The work supports the overall DOE objectives. The reviewer said that the work advances energy research and promotes scientific and technological innovation.

Reviewer 4:

The project is related to the synthesis of NMC cathode materials and SSEs, which supports the overall DOE objectives well, according 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 stated that the PI has used the resources well to achieve the set milestones in a timely fashion.

Reviewer 2:

The reviewer identified no weaknesses.

Reviewer 3:

The resources seemed reasonable to the reviewer for the projects, and the goals are relevant toward reaching the overall milestones.

Reviewer 4:

The resources are sufficient for the project to achieve the milestones, according to the reviewer.

Presentation Number: bat441
Presentation Title: High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LMNO)/Lithium-Titanate (LTO) Batteries
Principal Investigator: Jennifer Hoffman (Gotion)

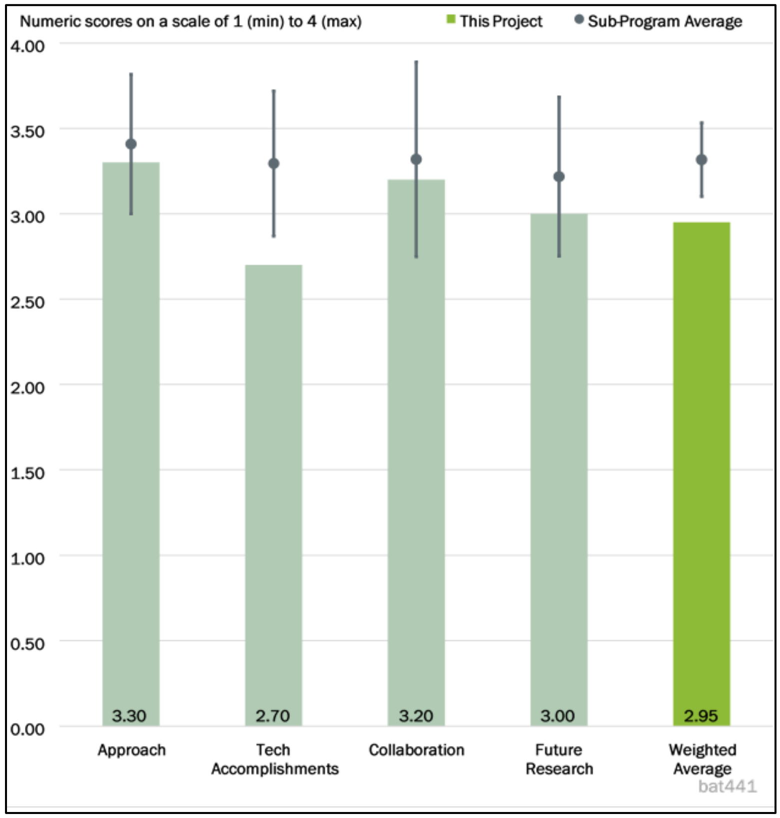


Figure 2-19 - Presentation Number: bat441 Presentation Title: High-Performance Electrolyte for Lithium-Nickel-Manganese Oxide (LMNO)/Lithium-Titanate (LTO) Batteries Principal Investigator: Jennifer Hoffman (Gotion)

Presenter

Jennifer Hoffman, Gotion

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the efforts of developing electrolytes and additives in support of fast charging for cells with LTO and lithium nickel manganese oxide (LNMO) are aligned with the DOE goals and address the same major barriers for battery fast charging.

Reviewer 2:

The reviewer said that the technical barriers are properly addressed.

Reviewer 3:

The tasks are well designed to meet the objectives. The reviewer proposed that a more rational strategy can be used, instead of trial and error.

Reviewer 4:

Given the circumstances last year, this reviewer described the project renovation and newly refocused project development plan as good. The focus on carbonaceous anodes will help to increase the project output, although it would be nice to also see a very safe and stable LTO- high voltage (HV) LMNO cell being developed. Multi-layer pouch cell testing is a very viable way to investigate and continue the progress. Extended lifecycle testing and a direct current internal resistance (DCIR) investigation would be also beneficial.

Reviewer 5:

The approach is to synthesize and develop new electrolyte additives that improve the cycling stability of LNMO/titanate and LNMO/C cells. Multi-layer pouch cells (MLPCs) are to be evaluated, and electrolyte properties (e.g., vapor pressure, transport properties, purity, and electrochemical stability) are to be measured. The approach seemed reasonable to the reviewer, although it was not clear what materials design strategy is being used (it appears entirely empirical).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It appeared to the reviewer that the project has been dramatically impacted by COVID-19, and this reviewer is certainly empathetic of this situation. So far, a few promising additives have been synthesized and evaluated, and their presence improves the performance over a baseline electrolyte in both LNMO/LTO and LMNO/C cells. A patent application and a couple manuscripts have been submitted. A USABC gap chart shows that the additives perform better in LNMO/LTO cells than LNMO/C cells. It will be interesting to see how further development can improve LNMO/C performance.

Reviewer 2:

Again, given the circumstances, the team made progress. The development of the new additives to enable HV-LMNO is ongoing and on a good path. The reviewer noted that it would be interesting to see if the progress of the improved formation protocol will also benefit the carbonaceous anodes part of the project.

Reviewer 3:

The reviewer stated that some performance targets have been met. However, the cycle life is still far from the target.

Reviewer 4:

According to the reviewer, some interesting progress, such as additive development, has been achieved. However, numerous challenges still exist to be overcome to meet the goals of this project. The technical challenges of LNMO in terms of cycle life and high-temperature performance may be potential challenges to the success of this project.

Reviewer 5:

It was difficult for the reviewer to see what was really achieved. The MLPC cycle life does not look good, and no noticeable improvement was presented. The project team claimed to have developed a procedure that formed more stable SEI, but no physical proof of stable SEI was not presented. No meaningful data are included for the Technical Achievements and Progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found the collaborations among partners to be excellent.

Reviewer 2:

The University of Rhode Island (URI) is listed as a collaborator to synthesize and analyze electrolyte additives. According to the reviewer, URI’s involvement appears to be essential, particularly for the synthesis work.

Reviewer 3:

The reviewer remarked that URI synthesizes the electrolyte additive.

Reviewer 4:

For electrolyte characterization, the collaboration partner was well chosen, but the collaboration partner's contribution was not clear to the reviewer.

Reviewer 5:

The reviewer suggested that the team could benefit from some support from analytical groups deciphering some of the mechanisms behind the team's progress and maybe pointing the project into the right direction.

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 state project ended.

Reviewer 1:

Future work appeared to the reviewer to be reasonable, with directions focused on continuing additive synthesis and evaluation, particularly in HV-LNMO/carbon containing cells.

Reviewer 2:

The technical barriers for future are properly identified. However, the reviewer noted that options to address the challenges were not detailed.

Reviewer 3:

The reviewer suggested focusing only on electrolyte development. It is a right decision to focus on graphite anode instead of LTO anode for the test platform.

Reviewer 4:

There was a good plan on future research, but the reviewer said that more versatile testing would be helpful, such as resting at high temperature.

Reviewer 5:

Focusing on carbonaceous anodes will clearly speed up things with the deep knowledge already present in this field. It would be interesting to see an estimation of the costs of such a system including the novel electrolyte additives. The reviewer asked for the project team to please provide some information regarding toxicity and potential environmental concerns of the new additives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the objectives of this projects are targeted to reduce battery cost and increase battery life and energy density.

Reviewer 2:

The reviewer affirmed that development of HV electrolytes could enable higher energy density cathode materials, such as LNMO.

Reviewer 3:

The reviewer said that this project supports the overall DOE objectives by extending the cycle life of LIBs.

Reviewer 4:

The reviewer asserted that the project fully supports the DOE objectives

Reviewer 5:

Neither LNMO nor LTO can bring about a high energy density Li-ion cell. It was difficult for the reviewer to see what the focus of this project is among higher energy, fast charge, long cycle life, and low cost. Low cost is only meaningful when other cell performances are not compromised.

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

Reviewer 1:

The resources for this project seemed appropriate to the reviewer.

Reviewer 2:

The reviewer indicated that resources seemed to be sufficient.

Reviewer 3:

Resources appeared sufficient to the reviewer for this project.

Reviewer 4:

It seemed to the reviewer that the resources are more than enough to achieve the goal.

Reviewer 5:

The electrode optimization part of the project would have benefited from working with a second university partner.

Presentation Number: bat442
Presentation Title: Behind-the-Meter-Storage (BTMS)–Overview and Update
Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

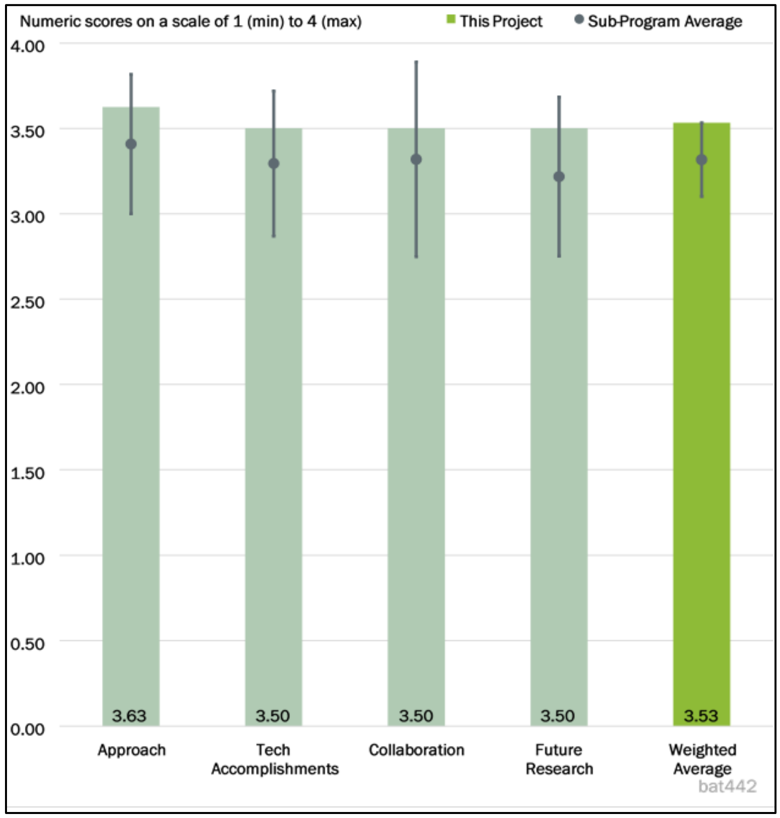


Figure 2-20 - Presentation Number: bat442 Presentation Title: Behind-the-Meter-Storage (BTMS)–Overview and Update Principal Investigator: Anthony Burrell (National Renewable Energy Laboratory)

Presenter

Anthony Burrell, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

As the PI stated, this is a large and complex issue. According to the reviewer, the problem statement was well thought out, and the various factors that would determine success are well stated. This is ultimately a complex technical and financial analysis project, but all bases seem to be covered adequately.

Reviewer 2:

The reviewer said that the project has articulated well the problem of peak power demand and its impact on grid power. The need for fast charging is clearly identified. The project is identifying energy storage options specifically tailored for use at the gas station. The approach to use known anode materials like LTO for fast charging is credible and appropriate. Demonstration of fast charging capability is based on predictive modeling with accelerated life. The project is also adequately addressing the safety aspects of the LTO-based batteries.

Reviewer 3:

The reviewer indicated that the project is well designed. Inclusion of LTO systems and work are significant and non-trivial but was/is an excellent inclusion as the most relevant baseline/ideal. Enhanced explanation and background regarding the basis for this inclusion may help others understand its value.

Reviewer 4:

In Slide 2, the technical barriers for a fast-charging energy storage system were shown to be cost, performance and safety. However, the reviewer remarked that there is no preliminary cost estimate for such behind-the-meter storage (BTMS) or nor were the approaches to lowering the BTMS addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

A surprising amount of data has been collected on the potential technologies under consideration to address the topic. As stated, there are more protocols to test for, but the reviewer was impressed with the amount of work so far.

Reviewer 2:

The reviewer noted that the project has demonstrated the preliminary feasibility of LTO-based batteries as a viable fast charging option. The initial experiments on optimization of LTO-based batteries appear promising. While the safety aspects have not been demonstrated, the project has outlined an excellent path forward to achieve safety. The modeling capabilities need to be explored extensively to address the safety of the batteries. The project is beginning to address the power electronics aspects of battery management system.

Reviewer 3:

The team has shown that LTO-based cells, specifically LTO-lithium manganese oxide (LMO), can meet the BTMS lifetime and cycle targets. The reviewer reported good progress on the performance of the LTO-based cells, but stated that cost and safety of BTMS have not been addressed.

Reviewer 4:

The reviewer found excellent technical accomplishments and progress to date. The contribution to knowledge in terms of economic implications may be an area that stands out a little for more enhancement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is a large team effort. The reviewer had not yet gone through every other presentation associated with the project, but the emphasis on coordination in the overview presentation suggests that the coordination efforts are significant.

Reviewer 2:

Considering that the project is between VTO and three other DOE organizations, the reviewer assumed that collaboration and coordination across the project team is excellent. However, details illustrating the nature of collaboration or responsibility among national laboratory partners are not obvious from the review presentation, although this is also assumed to be excellent based on project activities and prior knowledge of specific national laboratories.

Reviewer 3:

The partners in the project (SNL, ANL, INL, PNNL) have outstanding battery technology development capabilities, and the reviewer asserted that their contributions have been partially responsible for the success of the project.

Reviewer 4:

The collaboration and coordination across the team were not clearly described even though data from project identification (ID) numbers BAT473, BAT492, and BAT472 were presented. The reviewer could not correlate the coordination between teams from their project IDs.

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 state project ended.

Reviewer 1:

Proposed future work appeared to be excellent to the reviewer. The intent to assess the impact of cell configuration (prismatic, pouch, and cylindrical) seems especially useful.

Reviewer 2:

The work plans seemed to the reviewer to be completely reasonable for the project.

Reviewer 3:

The reviewer found that the proposed future work is well thought out and appropriate. An integrated modeling approach that addresses safety, lifetime, and cell and pack design will help guide the project. Also, computational modeling tools can help guide the combination of no-Co chemistries and new electrolytes. Failure modes for various alternate chemistries need to be understood to address the safety aspects of the project.

Reviewer 4:

This reviewer commented that the plan for quarter (Q) 3 is to use the NREL EnStore model for evaluating the economic feasibility of BTMS using testing data from team members. However, the critical-material-free pouch cells (2 Ah) LTO/LMO will be prepared and tested using BTMS only in Q4. The reviewer suggested that NREL may be able to look into LTO/LMO cell data developed by Enersys and funded by DOE.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The development of a charging infrastructure is critical to the expanded deployment of EVs. The issue of addressing charge time at the charge station is much more complex than might be imagined, and this is a far-ranging analysis and project for methods to deal with this issue. The reviewer said that it is of course a given that the charge station dynamics must match the capabilities of the target EVs and so this is another area of coordination that will have to be considered along the way.

Reviewer 2:

According to the reviewer, fast charging is the key technology that will enable the building of charging infrastructure that will provide a “gas-like” station for charging an EV in less than 15 minutes.

Reviewer 3:

The reviewer stated that the project supports DOE’s goal of low-cost, long-life stationary storage systems and fast charging capability.

Reviewer 4:

Although not directly relevant to EV performance objectives, the reviewer indicated that practicality and optimization of BTMS energy storage can impact viability and cost of more widespread EV adoption.

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 FY 2021 funding of $2.4 million is adequate for the BTMS proof-of-concept demonstration.

Reviewer 2:

Resources are sufficient for the moment. As the project moves to execution, the reviewer warned that a re-evaluation of resources will need to occur.

Reviewer 3:

The reviewer noted that resources devoted to the project seem to potentially be insufficient for the relevant project time period and intended future work.

Reviewer 4:

There is significant experimental effort (e.g., assessment of no-Co chemistries and development of new electrolytes) and design activities in the proposed future work. The reviewer was not sure if all the proposed work can be completed within the remaining budget. The reviewer was not privy to the detailed budget breakdown and could not provide more comments here.

Presentation Number: bat456
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Anode Structures that Enhance Fast Charge
Principal Investigator: Andrew Jansen (Argonne National Laboratory)

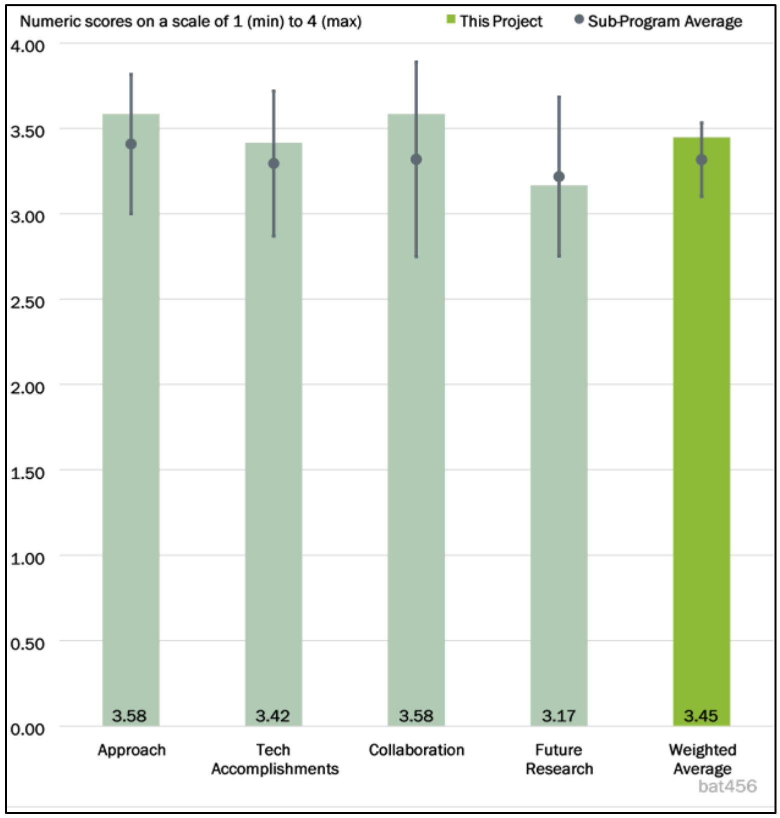


Figure 2-21 - Presentation Number: bat456 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Anode Structures that Enhance Fast Charge Principal Investigator: Andrew Jansen (Argonne National Laboratory)

Presenter

Andrew Jansen, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that this project is responsible for developing and fabricating physical electrodes and cells for examination within the larger extreme fast-charging (XFC) program. This project (the Electrode and Electrolyte Thrust) provides materials and cells to other portions of the XFC program for testing and characterization and then creates iterative designs to minimize the possibility of Li plating under fast-charge conditions.

Reviewer 2:

The reviewer commented that the project is a highly focused and well-planned approach to improve upon the issues stemming from fast charging, such as anode compositions, structures, electrolyte compositions, formation process, among others, and combines both experimental studies and modeling work. Interestingly, the reviewer noticed that the PI mentions thick anodes and lower temperature as factors for Li plating but does not mention state of charge [SOC] or voltage.

Reviewer 3:

The reviewer remarked that fast charging is a hard problem and requires a broad approach that will address electrode and electrolyte design.

Reviewer 4:

The reviewer asserted that the project clearly addresses the barriers of an electrode design for a fast-charge application. The proposed and developed methods are sound and well designed. One area for improvement would be to focus more on the volumetric energy density effect of the approaches on the anode level and to provide an indication how this would affect the overall cell parameters, i.e., volumetric and gravimetric energy density on the cell level.

Reviewer 5:

This is excellent research effort combining modeling, electrode fabrication, and testing using modeling outputs. It was not clear to the reviewer how the cost of the fast-charging cells was calculated (Slide 19). The reviewer asked whether the cost was just based on the energy output, what the cost was of manufacturing these special electrode architectures, and if the cost of using special solvents and additives had been considered.

The negative-positive (N/P) ratio is about 1.14 (Slide 18), which might be slightly on the higher end of what industry uses and this might help mitigate Li plating due to extra anode capacity. For the future work, the reviewer questioned whether the team had considered balancing N/P ratio such that there is no extra anode capacity and taking irreversible capacity out of the equation through prelithiation. The reviewer asked if doing this might allow for a better benchmarking of the anode materials and architectures.

Reviewer 6:

The approach used combined modeling and experimental methods, which the reviewer applauded. As volumetric energy density is still a key metric for automotive use, it would have perhaps been better to examine an approach that maintains (or improves) energy density while simultaneously achieving fast-charging goals. The use of electrolyte channels within the electrodes themselves is most likely a nonstarter on account of the volumetric energy density requirements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the team has achieved successive pouch cell builds using iterative materials and designs to create improved cells for XFC applications. Over the subsequent builds, the binder and carbon additive content have been reduced to increase energy density and charge rate. The team has so far produced a "Hero" cell as an intermediate milestone cell on the way to final cell deliverables scheduled for the end of FY 2021. Additionally, the team appeared to complete the milestones on time thus far.

Reviewer 2:

The reviewer said that progress was shown both in designing the electrode and optimizing electrolyte. The underlying mechanism of performance improvement was also detailed, which enables a foundation for future work.

Reviewer 3:

There has been excellent progress to date and definitely a lot of interesting experiments under a variety of conditions. It would be really important to the reviewer for the team to do some repeatability and reproducibility studies for the "Hero" and next generation cell builds.

Reviewer 4:

The project appeared to the reviewer to be well structured and managed. Progress is quantified with standard measurements. It would have been good to see how other typical aging characteristics (calendar life) are affected by any changes in the electrolyte or by using smaller particle sizes.

Reviewer 5:

The reviewer found that considerable excellent results have been obtained thus far both experimentally and via modeling. There is nice agreement between modeling and experimental data for loading studies, and demonstration via modeling that graded anode shows improved Li plating characteristics., The beneficial effect of pore architecture and transport and electrolyte studies all add to a very robust database of excellent results that will aid in improved understanding and mitigation of Li plating issue. The B26 electrolyte does indicate good improvement also.

While conceptually it may be elegant, the reviewer was not sure freeze tape casting is a commercially attractive process. Also, while the structures of the proprietary electrolytes are not given, the reviewer saw one with a nitrile functional group. Nitriles are usually not stable as cathodes. Also, the reviewer wanted to know how the PI ensured that the electrodes were fully wetted and that no gas-bubbles were trapped.

Reviewer 6:

The progress is good; however, further investigation into the combination of the formation process and the electrode design toward the fast-charge capability of the electrode would be appreciated. It also seemed to the reviewer that the fluoroethylene carbonate (FEC) component of the electrolyte could be consumed irreversibly over time, it would be great if the team could investigate the FEC content after more than 1,000 cycles.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

It was a pleasure for the reviewer to observe how the team members actively participated and answered questions in the chat room and referenced each other's work; clearly, there is full transparency, engagement, and good communication among team members.

Reviewer 2:

The role of the individual organizations was detailed nicely, and it was very apparent to the reviewer that the project benefitted immensely from the complementary strengths of the individual organizations.

Reviewer 3:

The reviewer found the project team and collaboration to be excellent.

Reviewer 4:

This reviewer reported that collaboration extends across multiple institutions.

Reviewer 5:

The XFC program is a collaboration between six national laboratories and multiple universities. This thrust (the electrode and electrolyte) provides materials and cells to other collaborations within the team, including providing cells to INL for testing as well as Stanford Linear Accelerator Center (SLAC) for understanding of lithium plating. Although the existing collaborations are strong, the reviewer suggested getting additional collaboration and input from industrial partners to ensure approach, cell design, and details are using best practices that have been determined commercially.

Reviewer 6:

The reviewer suggested that a collaboration with a team that could investigate the evolving temperature rise within the cell during the fastcharge would be helpful to gain further insights.

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 state project ended.

Reviewer 1:

The presenter proposes to continue to develop new anode electrode technologies including bi-layer anode cell design in order to improve fast-charge performance. The team also plans to investigate higher loading cells, including 4 mAh/cm^2 loading electrodes. The reviewer agreed that higher loading cell investigation will be critical to translating this development to the industrial level for EV applications. Additionally, the presenter mentioned a focus on investigating formation conditions and advanced electrolyte investigations into the impact for XFC performance. The reviewer agreed that these are important variables for future research and looks forward to the results.

Reviewer 2:

According to the reviewer, proposed future work is a logical extension of prior work.

Reviewer 3:

The reviewer appreciated the focus on graded electrodes, formation conditions (especially at higher temperatures), and stable electrolytes. Some of the work, while novel (pore formers and increased salt content) might not be practically attractive from manufacturing or cost points of view. The reviewer suggested that the team keeps this aspect in mind while pursuing these activities.

Reviewer 4:

The reviewer indicated that future research is well thought out. It would be great to see a design-of-experiment approach after the “Hero” materials and conditions are defined.

Reviewer 5:

Again, there is a need for both improved volumetric energy density and decreased cost while simultaneously achieving fast-charging times. The reviewer commented that future work would be better focused on Si in the anode, allowing higher temperature operation and/or magnetic ordering of graphite.

Reviewer 6:

It would be great if the team could focus more on cell level parameters, the heat evolution in the electrode during the fast-charge and investigate the practicability of their approaches for industrialization and mass production. Furthermore, the reviewer asked the team to please consider contamination due to the use of pore formers in the proposed research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this is an extremely relevant project since fast charging is of utmost concern to vehicle users.

Reviewer 2:

The reviewer commented that fast charging is believed to accelerate adoption of the e-mobility and potentially reduce the size of the batteries without contributing to range anxiety.

Reviewer 3:

The reviewer indicated that fast charge is one of key challenges to enable broader commercialization of LIB technology.

Reviewer 4:

The reviewer noted that this project does support the overall DOE objective of accelerating EV adoption and reducing cell costs by providing fast-charging capabilities.

Reviewer 5:

Fast charging is a key barrier to the widespread adoption of EVs, according to the reviewer.

Reviewer 6:

The reviewer found that 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:

According to the reviewer, this is a key issue with cells and batteries, and it would be nice to have a higher amount of resources allocated for this project.

Reviewer 2:

The reviewer remarked that resources are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 3:

Resources are sufficient for the scope of the project.

Reviewer 4:

The reviewer said there are sufficient resources.

Reviewer 5:

The reviewer noted that there is a great team working on this project.

Reviewer 6:

Sufficient resources were noted by this reviewer.

Presentation Number: bat457
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Methods for the Detection and Quantification of Lithium Plating
Principal Investigator: Johanna Nelson-Weker (SLAC)

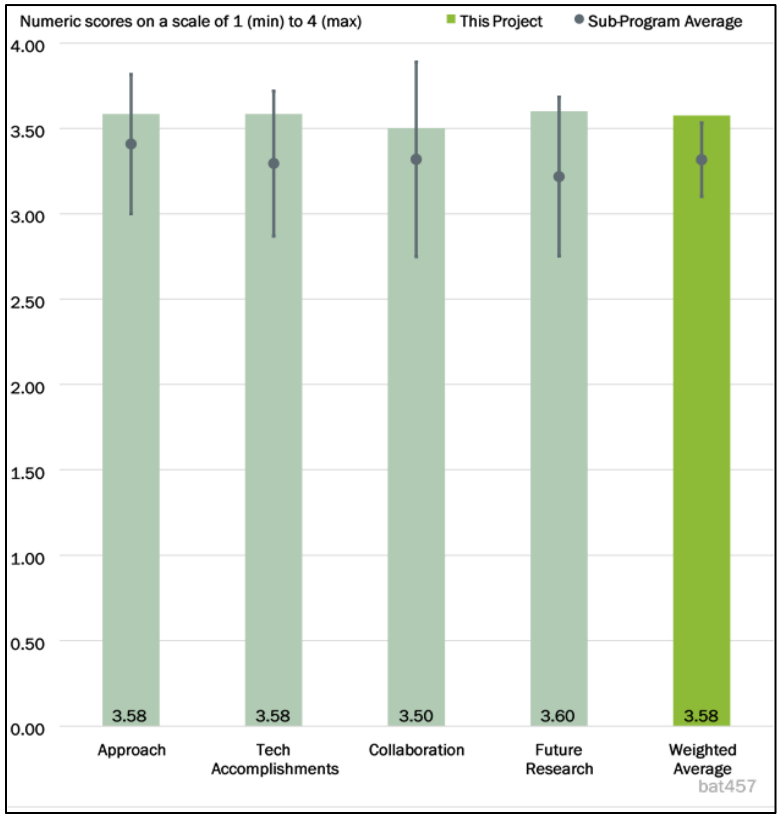


Figure 2-22 - Presentation Number: bat457 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Methods for the Detection and Quantification of Lithium Plating Principal Investigator: Johanna Nelson-Weker (SLAC)

Presenter

Johanna Nelson-Weker, SLAC

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the objectives of this project are extremely challenging, and the ability to think outside the box is critical to finding the right methodology. The milestones reflect well the questions that need to be asked and answered to progress toward finding a solution.

Reviewer 2:

The reviewer called the approach in general outstanding. The inclusion of and approach with a particular Coulombic efficiency (CE) study, thermal wave investigations, and comprehension of pressure effects appear to be very effective choices.

Reviewer 3:

According to the reviewer, this is a well-organized research project that tackles the very important issue of Li detection and its quantification utilizing a diverse array of techniques and modeling.

Reviewer 4:

The reviewer commented that the project examines a variety of different Li detection techniques to understand where the Li is trapped or lost during cycling, when Li plating occurs, and whether it creates irreversible damage contributing to cell failure. These examinations are toward the goal of achieving an XFC technology. It is part of a larger project to understand how to best develop XFC technology.

Reviewer 5:

The project is well designed and addresses the key questions of the challenge. The reviewer would highly appreciate benchmarking with existing technologies, especially considering the vast partner network and knowledge already established in the national laboratories.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that this is a critical area, and tangible practical progress is challenging. However, the tight focus in the project on key aspects and accomplishments to date are excellent.

Reviewer 2:

The technical plan is comprehensive, and the reviewer stated it is easy to follow what is being done and why. Regarding Slide 15, the reviewer asked that the PI elaborate on what N/P ratio is, explain why it had been selected to be much less than 1, and what the rationale for the experiment is.

Reviewer 3:

The reviewer remarked that very impressive progress has been achieved in identifying the onset and quantity of Li plating. This is a challenging task, but the use of electrochemical and mechanical diagnostic tools has given excellent insights into the usefulness of these techniques to reliably predict and quantify Li plating.

Given the fact that the industry needs inexpensive, robust, and fast methodologies to minimize and manage this issue, the reviewer stated that the data do not show that aside from CE-related studies the others will pass muster in this regard.

Reviewer 4:

The team has made significant progress in the detection and quantification of Li in different electrochemical setups. The methods are in part novel and innovative. The reviewer would have appreciated a review and comparison with existing methods on academic and commercial scale, e.g., a comparison with state-of-the-art digital pressure foils used commonly for pouch cell pressure testing, and a stronger emphasis on the difference between reversible and irreversible Li deposition and plating. One open question would be also the quantification and the modeling of a recovery effect. The reviewer asked if and how irreversibly plated and deposited Li can be recovered. Another point would be the influence of heterogeneity on the recovery effect; specifically, how structured electrodes, proposed in other projects, would influence the Li deposition.

Reviewer 5:

The presenter has examined multiple Li-detection techniques to build a picture on where the Li is trapped during cycling. Of note, the presenter described the use of mass spectrometry (MS) and titration to get quantitative values for the trapped Li inventory in an electrode structure and was able to deconvolute the location and cause of the Li inventory by the molecule created via MS. However, it is the reviewer's opinion that plated Li metal in the presence of graphite or partially lithiated graphite is not thermodynamic, and the resulting phases may vary as a function of time as the cell relaxes. Therefore, it is critical that variables such as time from charge cutoff to characterization be carefully controlled in order to increase the precision of results.

The presenter also showed XPS depth profiling results. The reviewer said it would have been good to understand the standard deviation of the individual components to understand whether the differences in calculated concentrations were statistically significant.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer praised the team for having members who can very effectively complement each other's strengths, and this project clearly benefitted from that, given the nature of all the experiments and simulation.

Reviewer 2:

According to the reviewer, the teams involved in XCEL demonstrated outstanding collaborative spirit and engagement that is reflected in the progress shown.

Reviewer 3:

The reviewer remarked that the team seems to be well connected in a strong partner network.

Reviewer 4:

The reviewer stated that collaboration appears to be very effective and activity area responsibilities are illustrated usefully.

Reviewer 5:

This presentation is part of a larger project that is a collaboration between six different national laboratories and multiple universities. The reviewer believed it may be helpful to have some industry collaborations as well to ensure that the cell design and chemistry considerations are utilizing best practices.

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 state project ended.

Reviewer 1:

The reviewer asserted that the proposed future work will focus on connecting Li- plating results with understanding more about their impact on electrochemical performance.

Reviewer 2:

The reviewer stated that the project will end in September 2021. The remaining tasks are well designed to fulfill the goal of the project.

Reviewer 3:

The reviewer called the understanding of the challenges excellent but cautioned that it is important to include statistical analyses.

Reviewer 4:

The proposed future work looked excellent to the reviewer. If there is any suggestion for improvement, perhaps slightly less focus on X-ray photoelectron spectroscopy (XPS) studies and more on other activities that may lead to most tangible results.

Reviewer 5:

The future research listed (e.g., how much Li plating is acceptable and how to estimate it) is keenly focused on understanding, quantifying, and predicting Li plating. However, the reviewer asserted that the laser-sharp focus should be on the development of very reliable (robust), fast, and low-cost methodologies that can be deployed in real applications preferably under dynamic conditions, too. Also, the work should also focus on tools that could be used both in metal can and pouch-type of cells. According to the reviewer, some techniques such as pressure may never be sensitive enough to be used as a diagnostic tool.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer observed that fast charge is and will continue to be a critical area for further work, development, and understanding in support of overall DOE objectives and will serve alongside energy density as a key interdependent metric in the more widespread adoption of EVs.

Reviewer 2:

The reviewer affirmed that this project is focused on decreasing battery charging time via development of XFC technology, which is a known objective of the DOE. Understanding current limitations to XFC technology is critical to overcoming challenges and enabling industrialization.

Reviewer 3:

The reviewer indicated that this is a highly relevant issue since Li plating affects both life and potentially safety of the batteries.

Reviewer 4:

XCEL is extremely relevant to the industry current and future technologies, according to the reviewer.

Reviewer 5:

Overall, the project supports the DOE objectives.

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

Reviewer 1:

Given the nature and urgency of this issue, the reviewer opined that the funding level should be increased.

Reviewer 2:

Resources devoted to the project seemed sufficient to the reviewer and relatively appropriate within the overall DOE portfolio in the related time period.

Reviewer 3:

According to the reviewer, resources are sufficient for the project.

Reviewer 4:

The reviewer indicated that the team seems to have sufficient resources for the work provided.

Reviewer 5:

The reviewer said the resources are just right.

Presentation Number: bat459
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Heat-Generation Concerns Associated with Extreme Fast Charging
Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

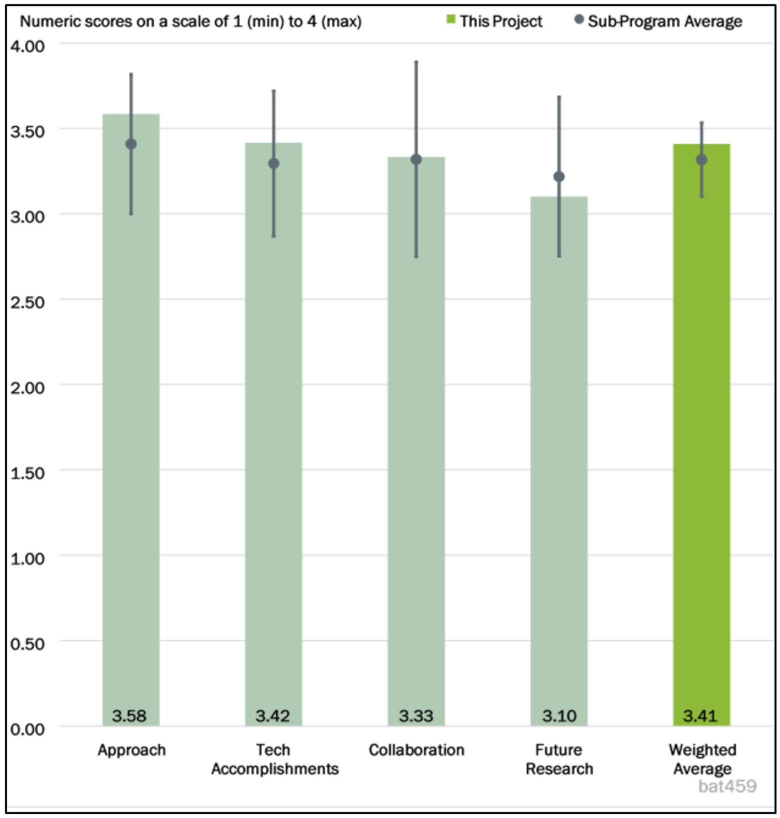


Figure 2-23 - Presentation Number: bat459 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Heat-Generation Concerns Associated with Extreme Fast Charging Principal Investigator: Matthew Keyser (National Renewable Energy Laboratory)

Presenter

Matthew Keyser, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the approach toward the issue is outstanding. Developing techniques that can detect temperature increase and correlate that with modeling makes it very relevant. The developed model can be used to run several conditions using multiple variables.

Reviewer 2:

The reviewer observed that this is an overlooked problem from a fundamental perspective and was very glad to see the national laboratories addressing it. The project objectives were clearly communicated, and the project seems on track. The combination of modeling and experiments is well coordinated.

Reviewer 3:

This reviewer remarked that considering what is going on inside the battery cell (by temperature measurement) in the battery model development will lead to insightful information about how the battery is functionating including ideas about capacity loss with battery use.

Reviewer 4:

Thermal modeling during fast charge is very common, however, the reviewer asserted that the novel part of this is the spatial resolution, which may provide insight into novel ways to combat thermal issues during fast charge. It is nice to see an approach that can operate on a practical cell size instead of being limited to small geometries.

Reviewer 5:

The reviewer pointed out that the project is strongly focused on the impact of heat generation within the battery cell during fast charging while considering lifetime, costs, performance, and safety. However, especially while measuring and understanding temperature inhomogeneity within the battery cells is solidly investigated using both empiric and three-dimensional (3-D) modeling simulations, a direct connection to cost targets was not clearly addressed. It would have been helpful to see the estimated cost reductions targeted or at least understand the requirements that need to be changed to reach costs targets. Also, it would have been helpful to understand the approach of how the resulting adaptive protocols can be incorporated into real-life EV applications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress on experimental methods and validated models has been good; milestones have been accomplished. The project is now moving on to making improvements in reducing heat generation and improving thermal transport. The reviewer stated that it was great to see the linking of understanding leading to ideas for improvement and asked if the model(s) can be generalized and made available to the public.

Reviewer 2:

The reviewer indicated that showing the effect of high temperature charging followed by lowering temperature before discharge begins is good data and can help industry design their product inducing charger. Can this feature be built-in with the application of LIB?

Reviewer 3:

The approach appeared strong to the reviewer, but without a robust set of technical results, it was difficult for the reviewer to evaluate. The data results, such as on Slide 8, are not novel, and it would beneficial if the project team could model ways to improve heterogeneity challenges instead of only showing a well-known baseline case.

Reviewer 4:

The project met all the objectives set when it started, but the reviewer said that there is still some more work needed to fit the model to real data.

Reviewer 5:

As indicated by the PI, the project is on track, having reached all previous milestones so far. While there are still a lot of remaining challenges and barriers (see Slide 20), the data collected and the progress so far are excellent. Still, the approach of how the adaptive protocols are planned to be applied to test packs, for example, has not been outlined clearly. Also, the amount of contribution of each individual measurement method toward the adaptive protocol as well as interdependencies and interconnections of the methods used were not very clear to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, there is outstanding collaboration and coordination across project teams.

Reviewer 2:

The collaboration between all contributing partners seemed to the reviewer to be in perfect alignment.

Reviewer 3:

The deep dive into fast charge appeared to the reviewer to be well coordinated, and varying approaches were designated to the labs with the best experience in the technology. This project, with more focus on modeling of larger cells, seems perfect for NREL.

Reviewer 4:

This reviewer reported that many DOE labs are working together with two leading universities in the United States.

Reviewer 5:

Although the cross-lab team is listed, the Results slides do not reflect inputs from anyone outside of NREL and LBNL. Future work may drive toward more collaboration, but it was not clear to the reviewer that all listed contributors had key contributions in this update.

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 state project ended.

Reviewer 1:

Making accurate temperature measurements as part of the proposed research was described as a good idea by this reviewer.

Reviewer 2:

The reviewer reported that the project is coming to an end in September 2021. However, the proposed future work warrants another project to continue this research because there is still a lot more work that is relevant to the industry.

Reviewer 3:

Proposed future work made a lot of sense to the reviewer, who was glad to see the work extended to the module, pack, and charging station. If the cell thermal issues can be fixed, then a problem should not just be moved to the next component.

Reviewer 4:

It seemed to the reviewer that the challenges and barriers of the project are well addressed. Nevertheless, the project plan still seems to have more open questions than questions answered. Also, a clear red line why specific measurement methods are chosen and a pathway and/or explanation how methods are complementing each other has not been clearly shown.

Reviewer 5:

The reviewer remarked that the method of trying to manage fast charge with thermal controls as a system is an approach industry will not want to adopt. System designs are all about efficiency in space, weight, and cost; if the coolant system must be orientated in a way to reduce volume usage or requires oversizing to manage fast-charge events, the costs are likely too great for industry to overcome. The project team should focus their attention on the final project of 3-D architectures as this is a solution that has more viability for highly efficient, commercial battery packs.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project is more relevant because the reviewer said that heat generated in direct-current fast charging (DCFC) is the most important roadblock that needs to be solved or improved to make EVs more comparable to internal combustion engine (ICE) vehicles.

Reviewer 2:

According to the reviewer, widespread adoption of EVs in the United States requires more consumer acceptance. Implementation of fast- charge technology reduces range anxiety and opens the market to many consumers who do not have a place to charge their vehicle at home.

Reviewer 3:

The reviewer stated that fast charge is a key barrier to passenger EVs. The project supports improving this metric to enable a larger market.

Reviewer 4:

The reviewer remarked that the project addresses challenges that are highly relevant in all fast-charging R&D topics.

Reviewer 5:

This reviewer commented that getting technology behind reliable and durable battery operation is going to be quite useful and relevant to 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 opined that the objectives can be met with the resources allocated to this project.

Reviewer 2:

The funds provided for the project seemed to the reviewer to be sufficiently used.

Reviewer 3:

The reviewer asserted that the national laboratories have the right resources, skills, and technologies to accomplish the goals of this project.

Reviewer 4:

This reviewer described the team led by Matt as very well resourced and supported by universities and various DOE labs.

Reviewer 5:

It was difficult for the reviewer to evaluate a $5.6 million spend in about 20 slides. Work appears to be heavy on modeling and lighter on lab work, which may indicate that the budget is slightly excessive, but the complete story may not be in these slides.

Presentation Number: bat461
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Quantifying Heterogeneities/Degradation During Fast Charge
Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

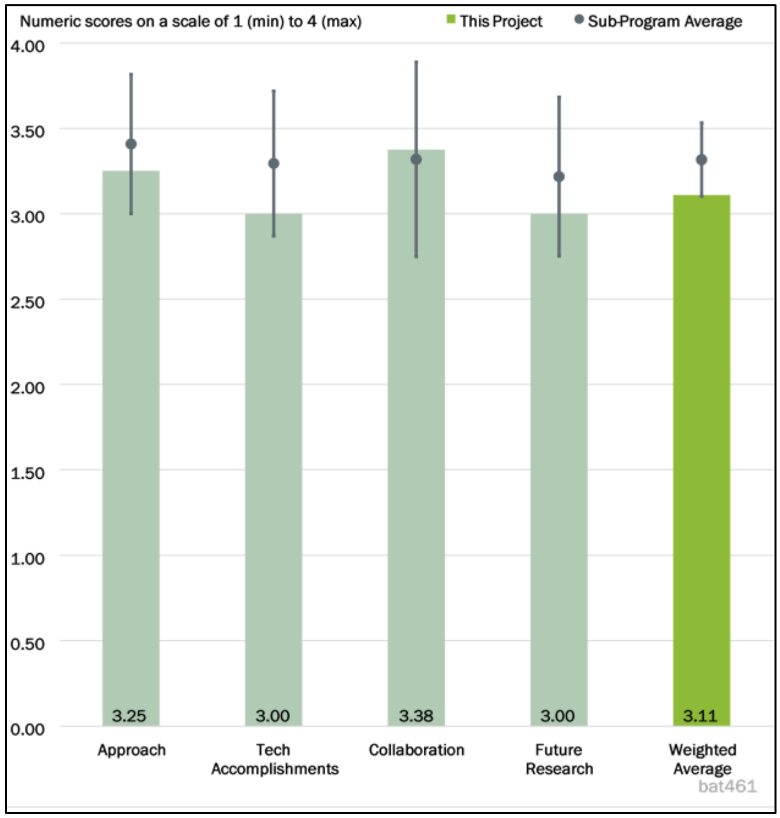


Figure 2-24 - Presentation Number: bat461 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Quantifying Heterogeneities/Degradation During Fast Charge Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

Presenter

Andrew Colclasure, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is very complementary to the other projects in this portfolio. The combination of experimental methods and models is a key strength of the work. The focus on practical issues such as wetting is important to the industry. The reviewer's only concern is that conclusions may be unique to the cell size, design, and methods studied in the project. The reviewer thought that the lithium nucleation and plating model is quite interesting and would like to see it extended and validated with different types of cells.

Reviewer 2:

The reviewer asserted that understanding heterogeneity in electrodes and how it affects Li plating is very important to DCFC. In that case, the research has employed several techniques to quantify these effects, but it is still only confirmed in ideal conditions. How this research affects cells in real-world conditions has to be a priority to make it more relevant.

Reviewer 3:

The project team has used significant funding and high-powered instrumentation to provide small- scale resolution of in operando and ex situ measurements of the lithium plating process. While the data are quite elaborate, the results do not appear to the reviewer to be novel compared to what has been known prior to this work. The work is not well controlled: some tests are at 4.4 V, others with just 4.1 V. Timing details are not discussed yet the presentation shows wetting timing is a critical area to understand. Some tests are done at 9C, some at 1C, and others at 6C. The approach needs to be more systematic, and care needs to be taken to ensure the data collected from one subsection can be used to better understand another. The PI highlights material selection, such as electrolyte and graphite, as being critical but gives little insight in this presentation into the specific details of their designs. NMC 532/graphite can have a wide range of particle shapes, sizes, load weights, electrolytes, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The results met the objectives set at the start of the project, but the reviewer stated that the impact of the results is not profound. There are some excellent accomplishments in getting more understanding of the phenomenon, but there is lot more work that needs to be done.

Reviewer 2:

Project milestones appeared to the reviewer to be on track. This project does have a number of different techniques and approaches, which can seem disconnected. For example, high-speed XRD depth profiling was done on highly oriented pyrolytic graphite (HOPG), and the reviewer asked if this were a relevant material. The next slide is on graphite nanoplatelets, which may be more relevant. The reviewer did think that the work is fine— just that the presentation needed a key take-away on each slide. It looks like tools are in place, but now need to be used in a consistent fashion to determine the causes of the heterogeneities. Regarding electrolyte wetting, the reviewer wanted to know if this is a big industry problem or if the project is solving a problem to which there is already an answer.

Reviewer 3:

This work has found a few interesting areas of how Li plating occurs in preferential ways. Most of the findings are confirmation of old approaches, such as the comparison of Dahn’s in-situ XRD to the PI’s methods. For the amount of funding in this project, the reviewer asserted that there should be more novel accomplishments and less confirmation of previous work. After more than 3 years into this project, the reviewer expected to see more novel findings by this time or robust methods that other researchers could apply to their systems.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that there is good collaboration and coordination across the project teams.

Reviewer 2:

According to the reviewer, there is good coordination and teamwork for the entire fast-charge effort.

Reviewer 3:

As the reviewer previously stated, the partners are not well coordinated, and there are differences in test parameters that do not allow collaborative data analysis. The discussion in Future Work on the “Hero” cell may be a good chance to align parameters. It was also very difficult for the reviewer to tell what work in the presentation is within this project and what is previous work. For example, Brigham Young University (BYU) is not listed on the front page but has an extensive data section slide and a logo in the conclusion.

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 state project ended.

Reviewer 1:

The reviewer reported that the program is ending in September 2021, but there is still a lot more to be done to answer the question of why there is Li plating in DCFC. This requires a follow-up project to answer these questions.

Reviewer 2:

The work on the Hero cell is a good project. The rest of the proposed work appears to confirm methods already done. Given the extensive publication list in the presentation list, the reviewer would have expected most methods to be confirmed at this time so it is not necessary to complete this work. It would be beneficial if the project team were to look at the requirements for some fast-charge projects and provide insight into key challenges to meet the fast-charge and life portions of those requirements.

Reviewer 3:

The reviewer wanted to know if the tools are adequate to answer the question on the underlying cause of heterogeneities. The reviewer was not sure from the presentation and asked if there were a Plan B. This is a very challenging problem, and the reviewer thought that more advanced characterization techniques will be needed to fully understand all the issues. The reviewer was not sure this can be completed by the end of the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that fast charge is a key area for DOE, and this project focuses on analysis of fast-charge failures.

Reviewer 2:

Understanding what causes Li plating and how that can be managed are very important to get DCFC more applicable, according to the reviewer.

Reviewer 3:

The reviewer asserted that widespread adoption of EVs requires consumer acceptance. Fast charge addresses two key concerns: range anxiety and the ability to charge EVs for those that cannot do it at home.

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 has sufficient resources to complete the project.

Reviewer 2:

The reviewer did not think there is enough time left in this project to fully understand the issues. This really is not the fault of the investigators as it is a big challenge.

Reviewer 3:

The reviewer stated that DOE's goal in funding battery projects should be on the impact they make toward domestic electrification and use of batteries. This work appears to be an opportunity for the project team to publish articles and does not clearly provide a benefit to the domestic market that is in line with the spending of this project. Although fundamental research is removed from the final good, it is still important that the work focuses on an end point and is not simply there to create publications.

Presentation Number: bat462
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Aging and the Role of Fast-Charge Protocol
Principal Investigator: Eric Dufek (Idaho National Laboratory)

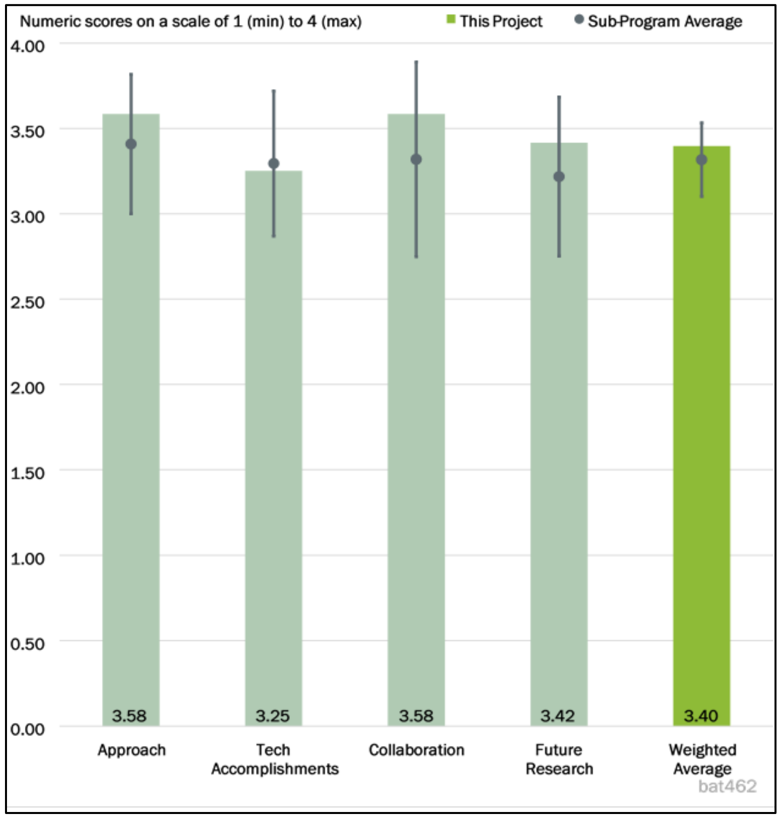


Figure 2-25 - Presentation Number: bat462 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Aging and the Role of Fast-Charge Protocol Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the teams within the XCEL project do great work defining workstreams, and each team complements the other without duplicating the efforts. The project uses the skills and knowledge of the team members to meet research objectives.

The teams might start considering validation work using larger cell format with industry partners.

There is excellent use of the decision-tree framework.

Reviewer 2:

The reviewer found the approach in general to be outstanding. The focus on thermal ramp and on ramp protocols is particularly effective.

Reviewer 3:

The reviewer asserted that development of new charging protocols and methods to analyze degradation mechanism under fast charge is very important for commercialization of LIBs.

Reviewer 4:

The reviewer noted that the approach taken combines experiment with modeling. The system-level accessible parameters (current profile and temperature) were examined for their influence on improving lifetime under fast-charging conditions.

Reviewer 5:

The approach appeared well thought out to the reviewer, who said that shows a clear relationship between charge protocols and Li plating. It would be great to incorporate this approach together with electrode-level improvements to the anode. The reviewer also remarked that it is necessary to track the cell temperature as well as Li plating. A fast-charge approach without consideration of temperature will not be practical for EV applications due to safety and long-term degradation concerns.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, this is a critical area and tangible practical progress is challenging. However, tight focus in the project on key aspects and accomplishments to date are excellent.

Reviewer 2:

The reviewer remarked that work done to date meets overall project objectives for the selected cell design. It is also important to demonstrate the applicability of the framework to advanced battery systems using increased Si content in the anode.

Reviewer 3:

The reviewer commented that the ability to influence Li plating on the anode by charge protocol development is clearly shown. Good results showing improved charge acceptance at high C-rates.

It is clear that temperature has a large impact on the system so the reviewer wanted to know how the cell temperature impacts degradation. In addition to anode mechanical issues shown in the presentation, this could cause degradation issues during long-term cycling.

In Slide 8, the reviewer asked that the lack of changes in the electrolyte be confirmed under lean-electrolyte conditions (as would be used in a commercial EV cell).

Reviewer 4:

While some aspects are excellent, it was still unclear to the reviewer what the actual practical impact is of the technical accomplishments of this project.

Reviewer 5:

The reviewer mentioned that a reference electrode cell in combination with a numerical model was used to identify a charging profile that improved lifetime. This is good, of course. A way to modify this over life or for different temperatures is also needed. The next logical step in this development was not carried out. Therefore, the results are mostly confined to this study and not transferable to the field at large.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is excellent collaboration and coordination, and the reviewer offered kudos to the project team. The reviewer was impressed watching the chat conversations, which demonstrated true engagement, support, and knowledge.

Reviewer 2:

The reviewer affirmed that collaborator impact and contributions are clear and well stated, and the reference to electrolyte from other projects indicates good collaboration.

Reviewer 3:

According to the reviewer, collaboration appears to be very effective and activity area responsibilities are illustrated usefully.

Reviewer 4:

The reviewer found the team to be very competent.

Reviewer 5:

The reviewer believed that the collaboration could have been better than it appears in the presentation. In the future, it would be good to show on each slide how the different institutions are contributing.

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 state project ended.

Reviewer 1:

Proposed future work looked excellent to the reviewer, and the intention to explore mid-range SOC in particular should be especially relevant to the real world.

Reviewer 2:

The reviewer said that the proposed future work plan is sound.

Reviewer 3:

The reviewer noted that the project definitely needs to be continued.

Reviewer 4:

As mentioned by the presenter, adaptive charge protocols are essential for EV-relevant fast-charge systems. In the reviewer's view, the ability to react to different degradation profiles and user profiles will be necessary as the system continues to be developed. To examine calendar life effects and long-term degradation, it could be helpful to test some "Hero" cells using a lower fast-charge duty cycle (i.e., fast-charge every other cycle of one-third of the cycles).

Reviewer 5:

The reviewer responded affirmatively and said that adaptive protocols are necessary. But, there is no mention on how and what approach could be used. The reviewer expected there to have already been action on this front.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that fast charge is and will continue to be a critical area for continued work, development, and understanding in support of overall DOE objectives and will serve alongside energy density as a key interdependent metric in the more widespread adoption of EVs.

Reviewer 2:

The reviewer opined that understanding aging under fast-charge conditions is very relevant to DOE objectives.

Reviewer 3:

According to the reviewer, fast-charging protocols are very important to overcome the charging challenge.

Reviewer 4:

The reviewer stated that Industry needs high-energy and high-power cells for multiple applications.

Reviewer 5:

The reviewer affirmed that fast charge is key for customer adoption of xEVs. Addressing Li plating will help mitigate key failure modes and safety issues of fast-charging 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 noted that resources are sufficient.

Reviewer 2:

Resources devoted to the project seemed sufficient to the reviewer and relatively appropriate within the overall DOE portfolio in the related time period.

Reviewer 3:

The reviewer recommended that the team work with an OEM partner.

Reviewer 4:

The reviewer would like to have seen more results from this part of the project, as mentioned earlier.

Reviewer 5:

The reviewer said that there seems to be the ability to fully characterize the system between all the partners.

Presentation Number: bat463
Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Effects of Extreme Fast Charging on Lithium-Ion Battery Cathode
Principal Investigator: Tanvir Tanim (Idaho National Laboratory)

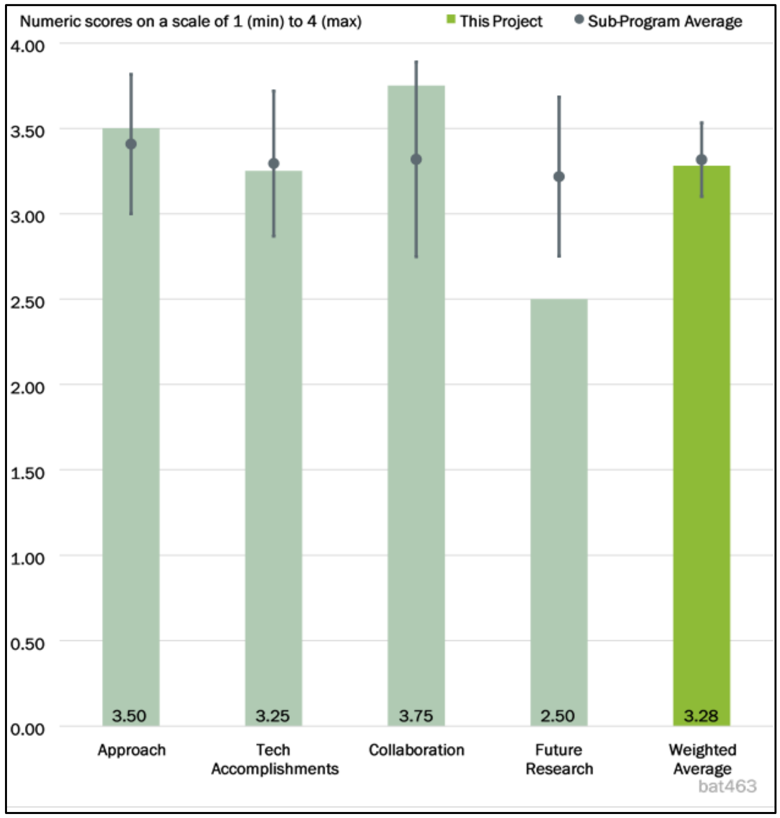


Figure 2-26 - Presentation Number: bat463 Presentation Title: eXtreme Fast Charge Cell Evaluation of Lithium-Ion Batteries (XCEL)–Effects of Extreme Fast Charging on Lithium-Ion Battery Cathode Principal Investigator: Tanvir Tanim (Idaho National Laboratory)

Presenter

Tanvir Tanim, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the approach to understanding cathode degradation due to DCFC outstanding. The experiments and the corresponding simulation work made the project well designed.

Reviewer 2:

This reviewer explained that understanding the impact of high-rate charging is an excellent idea as material properties are being understood by the project team under extreme fast charging. Effecting battery fast charging and understanding its chemistry by analytical modeling will help solve many problems including application variability as the model could capture such variations by parametric analysis. Therefore, the reviewer asserted that analytical modeling is quite critical to problem solving.

Reviewer 3:

The reviewer remarked that the project is well defined, with approaches to overcoming degradation and failure modes on the cathode side that occur during extreme fast charging.

Reviewer 4:

There is very detailed analysis using scanning electron microscopy (SEM) methods. Use of software to gain more insight into data was refreshing for the reviewer to see instead of moving to high-powered instruments.

The reviewer had a concern with the data on Slide 8, which states that cracking of particles does not lead to loss in performance, yet the entire presentation is focused on eliminating cracking and characterizing it. The reviewer suspected the conclusion of Slide 8 was made after the other work had started, but the future work should gear more toward what Slide 8 has found as a non-issue instead of developing solutions to the observation.

The reviewer said that using such a small cell (0.019 Ah) for this study may lead to misleading results. The cell's area is quite large relative to its capacity; this work should continue with larger cells of at least 5 Ah of capacity to better characterize gradients in processes, temperatures, etc., under a length scale that better represents the end use and could highlight more common issues.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that significant work related to various elements affected by fast charging have been investigated by the project team.

Reviewer 2:

According to the reviewer, the DOE work done to understand the mechanism of particle cracking and to correlate it with modeling was a good accomplishment. The project met all the objectives set at the start. However, there is still more work needed to understand how this failure can be mitigated and controlled to meet consumer objectives.

Reviewer 3:

As the PI indicated, the technical progress has been impacted by the COVID-19 pandemic. The approach of the project of considering identification of effects of XFC on cathodes seems to be well chosen. Nevertheless, it was not clear to the reviewer if the advancements identified will have a solution directly on material level and, if yes, what the approach on material level would be (e.g., choice of different production methods, additional particle or electrode coatings, and impact of particle-size distribution).

Reviewer 4:

Much of the technical work here has already been well understood prior to this study. The reviewer stated that it is nice to see a single study comparing NMC811 and NMC532, but the results are not novel. The in situ spatial XRD data are interesting, but the project team should have provided more analysis and observations on this. The true accomplishment of this work is the advanced image processing, which can be applicable across a wide range of materials and not exclusive to lithium-ion.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there was outstanding collaboration and coordination across all project members.

Reviewer 2:

The reviewer commented that the collaborations across labs and universities involved seems to be working extremely well.

Reviewer 3:

The reviewer noted many DOE labs working together on this extremely important research, which is very relevant to U.S. industries.

Reviewer 4:

It was clear to the reviewer that INL and ANL have a strong relationship on this project. It is great to see the academic support from University of Ulm on the imaging data processing, but it would be nice if the team could focus that work at a domestic lab instead of an international source. This would help strengthen the talent base for battery researchers, which is extremely limited today.

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 state project ended.

Reviewer 1:

This reviewer observed an excellent plan on many issues such as completing understanding of NMC811 aging mechanisms; planned work on cathode-related issues; quantitative methods for quantifying particle cracking and correlating with electrochemical understanding on the spatial distribution of utilization and cracking, etc. This is a great plan for future research and will allow the project team to know battery degradation caused by fast charging.

Reviewer 2:

The reviewer questioned the focus on cracking when the project team has concluded on Slide 8 that this is not causing a loss in performance. It would be useful to use the conclusions to generate future work to answer known concerns.

Reviewer 3:

The project is ending in September 2021, but the reviewer suggested that there is still a lot more future work needed as a follow up to the findings in the project.

Reviewer 4:

In the reviewer's opinion, there are still more challenges to be approached to generate full understanding of the cathode-aging mechanism in connection with XFC.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that this helps support the movement to nickel-rich cathodes, which are an enabler for lower cost EV cells.

Reviewer 2:

The reviewer asserted that the project is most relevant to the industry to make DCFC a more useful application.

Reviewer 3:

Understanding the internal details of batteries is very relevant research from this reviewer's perspective.

Reviewer 4:

The project supports the targets to identify the aging and degradation mechanisms for cathodes during XFC. However, the pathway where the contribution of these results will be allocated (charging protocols, material development, and electrode production) was not crystal 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:

According to the reviewer, the project had sufficient resources to accomplish the tasks set at the start of the project.

Reviewer 2:

This reviewer stated that the team is well resourced and the PI gets help form many DOE labs.

Reviewer 3:

The resources appeared to the reviewer to be sufficient for this project.

Reviewer 4:

These projects show a bundled cost, which made it hard for the reviewer to gauge each subsections true cost and value. The reviewer suggested that the budget for the core research in these slides be more easily stated than a blank $5.6 million for all of XCel.

Presentation Number: bat464
Presentation Title: ReCell–Direct Cathode Recycling: Material Separation and Preparation
Principal Investigator: Albert Lipson (Argonne National Laboratory)

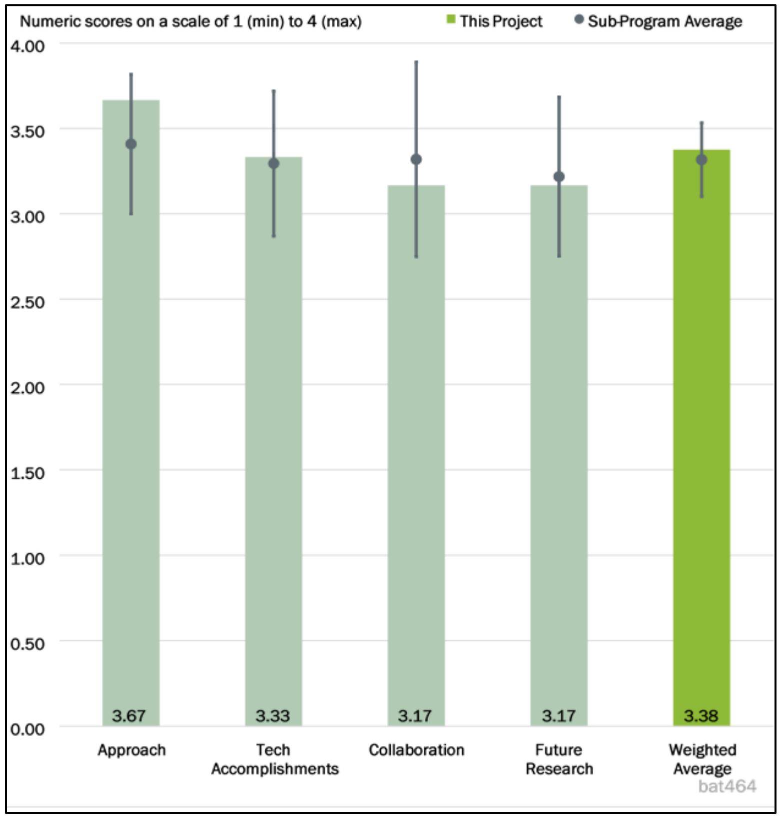


Figure 2-27 - Presentation Number: bat464 Presentation Title: ReCell–Direct Cathode Recycling: Material Separation and Preparation Principal Investigator: Albert Lipson (Argonne National Laboratory)

Presenter

Albert Lipson, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the technical barriers and milestones are clearly discussed and elegantly addressed in the initial slides.

Reviewer 2:

It is good to see the United States investing in battery recycling. The reviewer was interested in understanding how the approaches investigated here are better or different from those developed by others (e.g., Umicore). Maybe there is no need to re-invent the wheel, just make the wheel better or cheaper. However, the reviewer appreciated the variety of approaches investigated for all the components and asked if cost effectiveness is being taken into consideration on all of them.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project has shown different approaches toward recycling cathode and anode materials from scrap batteries. Significant progress has been accomplished by showing recovery of more than 90% for NMC cathode materials.

Reviewer 2:

The processes for the cathode recovery would seem to be the highest value, so the reviewer was glad to see that those were successfully developed; electrochemical results look okay so far. The reviewer asked whether the other components are worth it. The project is 90% complete and tried a lot of methods. The reviewer did not see enough data on the recovered materials to be convinced that the selected methods are good enough to scale up. It may exist but was not adequately shown in the presentation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The team appeared to the reviewer to be large, thus- allowing a lot of different methods to be investigated.

Reviewer 2:

It was not clear to the reviewer about the collaboration structure in 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer asserted that the project has elegantly planned the scale-up process to recover critical materials at high yield and high purity. Pathways for the scale-up process have been identified, and that will improve the probability of success for this project.

Reviewer 2:

The reviewer thought that the proposed future work needs to include a lot more testing and characterization of the recovered and recycled materials.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that successful recycling of EV batteries materials at reasonable cost will provide a clear path for reducing the cost of EV batteries to less than $60/kWh.

Reviewer 2:

According to the reviewer, the United States does not have an adequate secure supply of raw materials for EV batteries. A low-cost recycling program will supplement our access to the supply chain.

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 remaining resources are sufficient for the scale-up stage of the project.

Reviewer 2:

The project is almost complete and appeared to the reviewer to have achieved its milestones.

Presentation Number: bat465
Presentation Title: ReCell–Direct Cathode Recycling: Relithiation and Upcycling
Principal Investigator: Jack Vaughey (Argonne National Laboratory)

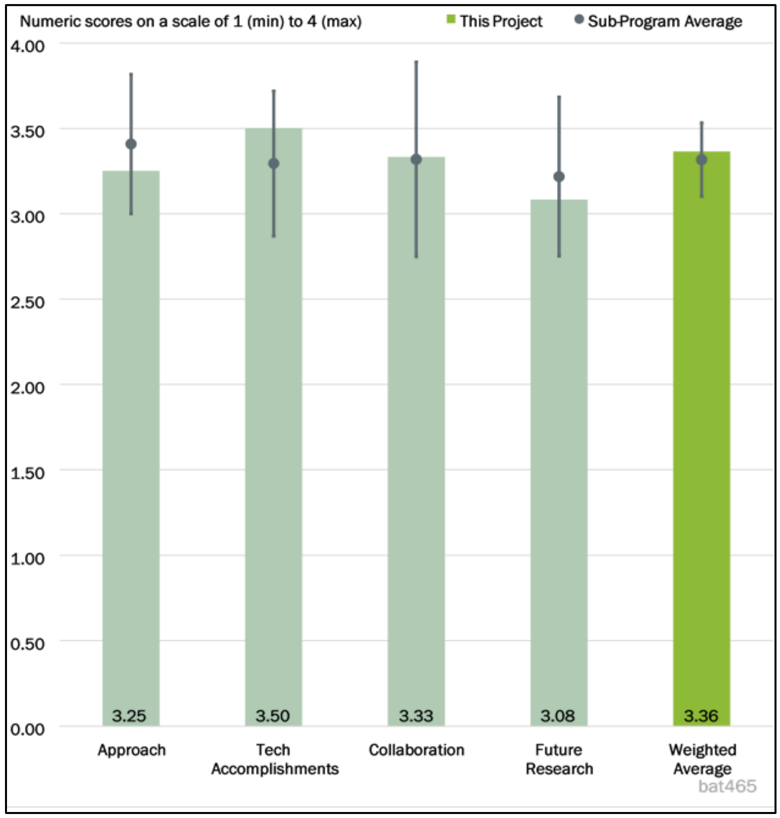


Figure 2-28 - Presentation Number: bat465 Presentation Title: ReCell–Direct Cathode Recycling: Relithiation and Upcycling Principal Investigator: Jack Vaughey (Argonne National Laboratory)

Presenter

Jack Vaughey, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 17% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the program is an important contribution to understanding how Li-ion battery cell electrodes can be recycled in a cost-effective way. The program anticipates that the desired composition of NMC will change with time and three methods for upgrading has been demonstrated. Three methods of lithiation were also demonstrated through the program. The reviewer further commented that it will be interesting to find out more performance data as the program continues to see the viability of the materials produced.

Reviewer 2:

This reviewer opined that the research team took a very good approach by assessing technical feasibility of the multiple processes for relithiation of NCM based cathode materials. It would be great to deep dive some of the promising processes by running additional performance/life tests.

Reviewer 3:

The reviewer observed a wide range of recycling issues being identified and solved in this work. The team is responsive to data and future data correlates to lab results well. The concern with this work is the overuse of EverBatt to guide research. The EverBatt and other national laboratory models are cumbersome and tend to have incorrect inputs of the true state of the art. Given how early stage some of this research is, the reviewer suggested that the team should focus on understanding processes and chemistry first instead of asking a model to predict solvents or boundary conditions for its work. Having a cost-effective process is important but if the chemistry simply will not work understanding cost up front at this level of detail is not important.

Reviewer 4:

The reviewer indicated that this is a surprisingly ambitious take on the reuse of cathode active material from recovered electric vehicle batteries. The evaluation of various aspects of regeneration of the material is very complex and this program has laid out some good program goals. This reviewer suspected that there are more "real world" challenges that exist than can be expressed in the program right now, but this early-stage evaluation is well thought out.

Reviewer 5:

Although the project is well-designed and feasible for the intended tasks, the reviewer noted that the basic focus on rejuvenation recycling does not seem practical.

Reviewer 6:

The reviewer remarked that the project takes a comprehensive approach to address the many possible avenues of reviving spent LIB materials—from hydrothermal, thermal, to ionothermal and electrochemical. The knowledge obtained is invaluable for such an emerging technological sector.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that the program has demonstrated thermal, hydrothermal, and ionothermal methods to perform lithiation and upcycling. It is early to tell the success based on the limited data available on performance, which likely results from the reduced amount of lab time because of COVID-19. However, it is good that different methods were pursued to eventually compare technical performance and cost-effectiveness of the various methods.

Reviewer 2:

This reviewer observed great accomplishment. Processes for relithiation and upcycling were thoroughly investigated, and the team was provided with information on limiting steps for some processes and suggestions to mitigate technical constraints.

Reviewer 3:

The reviewer commented that clear challenges in lithium dissolution and sintering have been identified by the team. Some of this chemistry, such as EtOH as a solvent, is well known from early NMC work. It was unclear to this reviewer whether old research was used or not, but at times the processes and chemistry feel complex and may benefit from a literature research to find some simpler starting points. However, it is clear that as challenges are found, the team is working the problem instead of focusing on characterization.

Reviewer 4:

This reviewer noted good progress on demonstrating progress on the two main technical thrusts of the program. Although it is stated that the program will not include the second use evaluation of the materials, the reviewer hoped that this is being addressed somewhere in the system as it seems critical to setting ultimate targets for success.

Reviewer 5:

The reviewer remarked that the technical accomplishments and progress are perhaps excellent from a scientific perspective, but the potential feasibility for practical implementation or at least the thinking behind it does not seem to have been demonstrated or conveyed.

Reviewer 6:

This reviewer described accomplishments and progress as satisfactory. The efficiency and feasibility of recycling and upcycling are designed effectively to face the new cathode materials that is a dynamic factor in the manufacturing and recycling of LIBs. The team displayed outstanding expertise in conducting the technical tasks.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

It appeared to this reviewer that the project team worked together very effectively in challenging times.

Reviewer 2:

This reviewer observed good collaborations among the entities, experts in each area for battery recycling process research. Expertise includes electrode material science, physical and electrochemical analysis, material recycling processes, battery manufacturing for validation tests, etc.

Reviewer 3:

The reviewer noted a multi-institutional team that closely collaborated on the various approaches. The different fronts seemed to be highly synchronized.

Reviewer 4:

The reviewer stated that this is a large collaboration team, and further commented that the program presented results as a unified set of results, which suggests a good coordination effort.

Reviewer 5:

Although collaboration and coordination are assumed to be good or better, the reviewer indicated that it was difficult to understand collaboration or coordination across the team from the presentation or other info.

Reviewer 6:

The reviewer could not tell who provided what based on provided slides and noted that the work appears to be all ANL.

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 state project ended.

Reviewer 1:

The reviewer described future work outlined as appropriate to assess the outcome of the recycling methods developed. The multiple path routes should help to mitigate risk. A little more detail about any decision points would be helpful to effectively spend the resources.

Reviewer 2:

The reviewer stated that further technical evaluation is great, but as proposed by presenter, economic feasibility study of each process will be good addition to this excellent work.

Reviewer 3:

Scale-up and industrial discussions are a great first step, but this reviewer disagreed with using EverBat at this time because the chemistry needs to be more stabilized to make modeling meaningful.

Reviewer 4:

The reviewer indicated that the initial technical goals of the program are well thought out and the future work is reflective of the current program effort. As a practical matter, this program will require notably more infrastructure development than is being addressed by this program.

Reviewer 5:

Given the work done to date, proposed future work seemed appropriate to this reviewer. Any further work to elucidate true rate capability or temperature dependence in relevant full cells versus relevant baseline full cells may be illuminating.

Reviewer 6:

In future research, this reviewer suggested that the emphasis should be placed on these scalable approaches—hydrothermal, thermal—while approaches involving the use of solvents or ionic liquids should be de-emphasized. The electrochemical, in particular, should be gradually phased out. The LIBs to be recycled in the future are in the approximate scale of MWh to GWh. Therefore, these non-sustainable approaches should be abandoned; otherwise, they will only make the process highly costly and cause more environmental and landfill problems rather than solving them.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer asserted that battery recycling is and will continue to be of key and ever-growing importance in supporting overall DOE objectives.

Reviewer 2:

The reviewer stated that this is right on target to meet DOE objectives of lowering the cost of batteries to increase market penetration.

Reviewer 3:

The reviewer remarked that this research significantly impacts on DOE’s objective of EV battery cost reduction.

Reviewer 4:

The reviewer described this project as highly necessary and should be prioritized, considering that electrification of transportation is an irreversible pathway, while consumer and other sectors’ spent LIBs are already starting to pile up.

Reviewer 5:

This reviewer indicated that recycling of active materials, particularly cathode materials, is critical to the long-term infrastructure of electric vehicles. This is a surprisingly ambitious approach to that issue and, if successful, could be a significant contribution to EV infrastructure.

Reviewer 6:

Domestic supply chain improvements and reduction in cell cost was reported by this reviewer. The authors should start to identify partners to commercialize the process before cathode manufacturing starts to build in North America so the recycling aspect can be integrated into the plant layouts.

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 devoted to the project seem sufficient and relatively appropriate within the overall DOE portfolio in the related time period.

Reviewer 2:

Based on the work reported in this year, the reviewer noted a good research team with the right expertise was formed generating very interesting data for last year.

Reviewer 3:

The appropriate amount of funding was available to carry out this work from this reviewer's perspective.

Reviewer 4:

This reviewer described resources as sufficient for now, and added that success at this level will lead to a much higher demand for resources.

Reviewer 5:

The allocation of resources seems reasonable, but this reviewer suggested that the approaches—those involving solvents/ILs and electrochemical—should be de-emphasized and phased out for long-term scalable consideration.

Reviewer 6:

This reviewer could not tell if all approximately $14 million is spent within just these 20 slides or what else is included. $580,000 per slide is a very expensive price of research and this is all the data that this reviewer has from which to evaluate.

Presentation Number: bat467
Presentation Title: ReCell–Battery Design for Recycling
Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

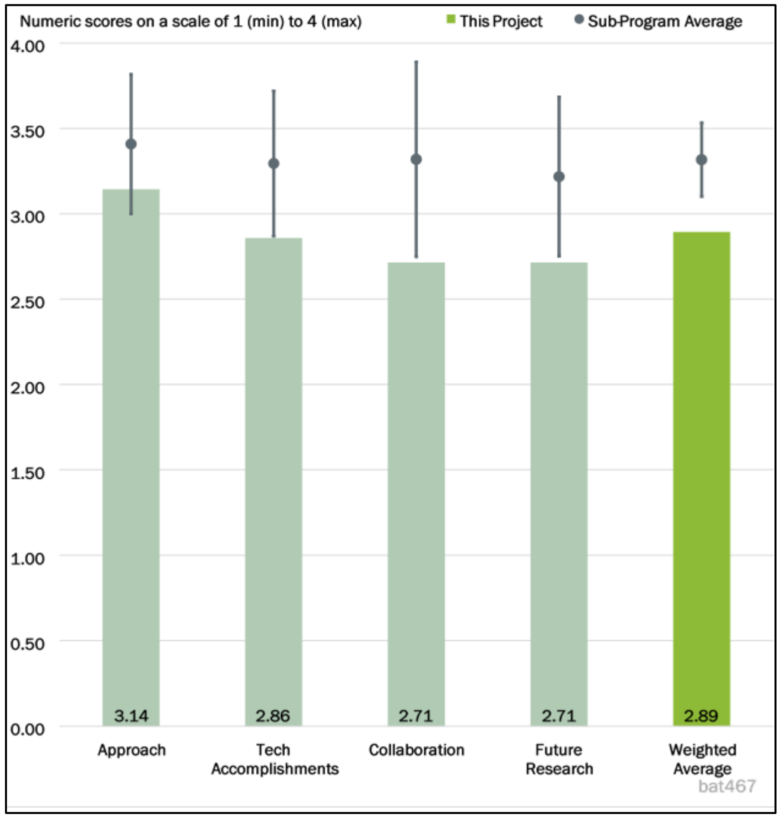


Figure 2-29 - Presentation Number: bat467 Presentation Title: ReCell–Battery Design for Recycling Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Presenter

Jianlin Li, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 57% of reviewers felt that the resources were sufficient, 29% of reviewers felt that the resources were insufficient, 14% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the investigator presented a well-researched effort. It seems that if funding is continued so as to support the work, a viable solution will result which enables efficient recycle of battery systems.

Reviewer 2:

The reviewer stated that this portion of the ReCell project focuses on battery design for recycling. Specifically, the project team is focused on new cell designs that are specifically aimed at rejuvenation/reuse in recycled applications. This reviewer further added that the project team is focused on new cell designs to allow more easy removal of SEI components and other items.

Reviewer 3:

The reviewer noted that cell design is critical for ease of recycling.

Reviewer 4:

It seemed to this reviewer that there should be more focus on understanding why the refreshing is not working before optimizing the ability to refresh. For example, it may be that this is not possible under pressure.

Reviewer 5:

The project is a good concept from this reviewer's perspective. It looks like it needs a lot more lab time to define what type of battery aging can be restored with fresh electrolyte. The reviewer explained that short project timeline limits flush and restoring electrolyte to 100-80% cycling. Electrolyte restoration may be more effective if battery was aged more. Refresh seems to benefit about 50 cycles or 2 months of real-world cycling. The reviewer hoped that the team would get a restore of 300 cycles (or an annual vehicle service) and suggested that it should explore if a reflush at later stage—70%, 60% 50%--would yield more restoration and life. This is worth it to go back to, even if the results would not be available by the end of the project. The reviewer added that the project has some minor lab barriers to solve such as the flow tube and connections.

Reviewer 6:

The reviewer observed a novel design to make it possible to remove SEI and adding fresh electrolyte to recover some capacity for spent cells. However, as well known, there are many factors leading to capacity fading of a lithium-ion battery or cell—Li-ion inventory loss due to continuous SEI growth, impedance increase, electrolyte depletion, etc. Without compensating the Li-ion inventory loss, the recovered capacity is limited. Any economic analysis to justify the approach? How does the added ports impact safety and performance? How practical is the approach for industry?

Reviewer 7:

The reviewer explained that the concept of rinsing the cell to rejuvenate it and extend the life is a novel approach that could contribute greatly to ReCell objectives. This approach also has the advantage that it could apply across the diversity of battery chemistries being developed.

The reviewer indicated that the presentation was generally poor and confusing in both the oral presentation and the slides. The project design and planning needs substantial improvement, and the technical objectives are unclear. Is the objective to remove SEI—some components and if so, which components—or is the objective to relithiate the cathode? How does this rejuvenation work and how does the project team expect it to work? The reviewer observed no systematic approach evident as to optimizing flushing procedures and details of the procedures were omitted. This seems to be a rather preliminary exploratory study from a few months of work. Technical targets were not provided. The reviewer further stated that this project is a poor execution of what would seem to be a great idea.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that progress to date seems good given the experimental nature of this research.

Reviewer 2:

This reviewer noted that the researcher demonstrated the viable potential of success for the technology via prototype development.

Reviewer 3:

The reviewer described the concept as well defined. The fresh electrolyte flush shows a short-lived effect, which proves the concept is good. However, more work is needed to get a longer effect and restoration of more capacity per flush, and the reviewer asserted that this is going to be a lot of hard work and will require new ideas. Tough to put a timeline on this as it requires an inventive leap. Even if the inventive leap is not realized immediately, a stable system for having a way to flush & replenish a battery flush would be a success as it would leave a path for the superior flush/restore to be effective when it arrives.

Reviewer 4:

Good results were noted by this reviewer, but there are still major challenges around reusing of recycled materials. Also, it was not clear to the reviewer if proposed cell designs are practical.

Reviewer 5:

The reviewer remarked that some capacity is recovered after rinse and fresh electrolyte addition, but the capacity fading becomes faster. Considering the long cycling life of EV batteries, i.e., greater than 1000 cycles, what is the target for cycling life after rinse and fresh electrolyte addition? Although relithiating spent cathode is mentioned in project goal, no related work was mentioned in the following slides. Is it feasible to combine electrolyte rinse and addition with cathode relithiation?

Reviewer 6:

Technical progress seemed sketchy to this reviewer, who added that it was hard to judge because very little information is shared on the procedures and parameters for the rinsing and new electrolyte addition. Performance indicators are not clearly presented; so, comparison of results to technical targets is not provided. How much cycle life improvement is targeted? How long does the rinsing and new electrolyte add take versus what target times?

The reviewer indicated that it is reported that the cells designed for rinsing and electrolyte refill "failed after a few days due to electrolyte loss." This is not adequate for reasonable testing of how much the cycle life can be extended. The reviewer explained that this type of mechanical development should have been successful given great resources and fabrication facilities available at ORNL, and more effort should have been expended on this. Furthermore, multiple cell designs should have been developed. This cell design is a critical component of this project.

Apparently, there was an effort to speed up the flow for rinsing and electrolyte replenishment by changing the anode active material graphite (although this reviewer did not see quantitative results on how that worked and, again, there was no technical objective). That does not seem like a great approach because it could have deleterious effects on performance or cycle life. The reviewer reported that no information on this was provided. There should be other approaches to increasing the flow independent of the active material composition including design of flow channels in the cell and perhaps microflow channels in the electrodes themselves.

This reviewer was not impressed by the technical accomplishments and progress in this project toward the novel and promising approach of the project.

Reviewer 7:

The reviewer commented that over the past year, the project moved from experiments in coin cells and into practical pouch cells. The presenter demonstrated various electrolyte washing techniques that were investigated with little success, and also highlighted challenges with modifying pouch cell fabrication with ports to try to investigate washing. It was also mentioned that the project team has not yet accomplished successful data acquisition.

Overall, much progress is needed in order to execute on the promising approach of this thrust. The reviewer believed that the approach and underlying idea behind "design for recycling" is very powerful, although it has been poorly executed in this project thus far. The reviewer can imagine alternative development pathways to improve the technical project progress, such as including active lithium inventory components into the "electrolyte wash" to compensate for lithium losses to the SEI in the existing project. The reviewer could also imagine another project focused on developing and integrating small amounts of inactive electrode additives that could be decomposed to allow for easier recycling/recovery of active materials, or other projects that could more broadly advance the "design for recycling" agenda.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

It was very clear to this reviewer that the Recell project is well defined and working on many avenues. The collaboration across the projects is clear.

Reviewer 2:

A very competent team was observed by this reviewer.

Reviewer 3:

This reviewer commented that team efforts were used to accomplish work to-date.

Reviewer 4:

The reviewer noted a great team with excellent collaborations, though an industrial partner may make the team better.

Reviewer 5:

Although this was not really mentioned, the reviewer stated that it seems like progress would be difficult without it.

Reviewer 6:

This reviewer remarked that the presenter did not mention or highlight any particular collaborations with other project team members. Some of these interactions may have occurred, although they were not highlighted beyond the boilerplate "collaboration and acknowledgements" slide.

Reviewer 7:

The reviewer indicated that there was no specific mention of any collaboration or coordination with other members of the impressive ReCell team. This project needed help in several areas; so, collaboration in the future is highly encouraged.

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 state project ended.

Reviewer 1:

The proposed future work plan was described as sound by this reviewer.

Reviewer 2:

Proposed future research is appropriate for this approach from the reviewer's perspective. Sealing of the added ports are key for safety and performance, especially after rinse and fresh electrolyte addition.

Reviewer 3:

The reviewer stated that work should be continued and proposed future efforts will continue to evolve viable recycle solutions.

Reviewer 4:

As this reviewer mentioned previously and because refreshing does not seem to be providing long-term benefits, it seems that there is a risk that this cannot be done in this form. Before continuing with doing a better job of adding ports, the reviewer suggested that it would make sense to mitigate this risk by understanding how to improve refresh performance to match the coin cell results.

Reviewer 5:

This reviewer recognized the need for a leak-free system of flushing. Without breaking this barrier, there is a hole in the project, and the reviewer offered suggestions to the author—need to design a cell network (even if it is only two cells) to better understand limits of flushing and compare front cell to second cell. The rest looked good to this reviewer.

Reviewer 6:

The reviewer commented that the presenter briefly discussed continuing to work to improve sealing of the pouch cells with the ports, although the initial data from the adjacent project has failed to demonstrate that this approach will lead to improved performance or achieve the targeted results. The presenter acknowledged that these R&D cells contain excess electrolyte at the beginning, and are therefore less likely to be improved with the electrolyte flush. The reviewer respectfully believed that the future work needs to be reconsidered.

Reviewer 7:

This reviewer explained that the proposed future work is limited to finding improved sealants for the flow cell and further investigating alternative electrode microstructures for electrodes to improve flow. The reviewer's impression was that making the flow cell work will require more than a more effective sealant and that a more comprehensive effort should be made on the mechanical design of the flow channel. This reviewer also thought that the approach of redesigning the porosity of the electrodes is risky and undesirable because that will probably affect the performance and/or cycle life, most likely having an adverse effect on both.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that enabling increased battery life would increase the viability of energy storage.

Reviewer 2:

Because these resources are mined outside of the US, this reviewer indicated that recycling makes extra sense. This is an insane amount of material, too, and toxic waste dumps popping up all over the world are not needed. Anything that can be done to extend the life of the battery is even more useful than recycling.

Reviewer 3:

The reviewer stated yes, this project supports overall DOE objectives. The life of pouch cells is a big challenge in EV application; investigating the capacity loss and finding solutions are very necessary.

Reviewer 4:

The reviewer asserted that cell designs accounting for the need to eventually recycle batteries are relevant to DOE objectives.

Reviewer 5:

DOE has a focus on battery development and viable recycle of developed technology, and the reviewer stated that this work serves to support this overarching goal.

Reviewer 6:

The reviewer indicated that yes, in theory, this project supports the DOE objective by improving the ability to recycle battery materials, which can lead to reduced costs for batteries and therefore accelerate EV adoption and reduce GHG emissions and global warming.

Reviewer 7:

The reviewer described this project concept as excellent with great promise to extend the cycle life of LIB cells with a relatively simple procedures at least in principle. Although this reviewer was unimpressed with the planning and execution of this project, the project start and funding level were unknown to the reviewer. If this was an exploratory preliminary study of several man-months, the reviewer thought it showed enough promise that this deserves a serious effort with good planning.

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 work was adequately funded.

Reviewer 2:

Sufficient resources were observed by this reviewer.

Reviewer 3:

This reviewer described a very strong team and suggested that some support from industrial partner may be very helpful.

Reviewer 4:

Although this was not described in detail, the reviewer noted that the level of effort seems adequate given the discussed scope.

Reviewer 5:

This reviewer was not clear on the resources or time allotted for this project. The result was not impressive and inadequate resources may be the reason.

Reviewer 6:

Although resources for this particular thrust were not separated from the larger program, it did not seem to this reviewer that many resources would be required to complete these results. Subsequently, the reviewer hoped that resources had been diverted to more promising approaches.

Reviewer 7:

This reviewer indicated that there are a lot of aspects of this project that need a deeper dive. Unfortunately, the timeline and resource are not allowing that in-depth look. Given the data, the project team needs some answers to go in the right direction and the IPA wash yielding greater recovery needs some understanding.

Presentation Number: bat470
Presentation Title: Process R&D Using Supercritical Fluid Reactors
Principal Investigator: Youngho Shin (Argonne National Laboratory)

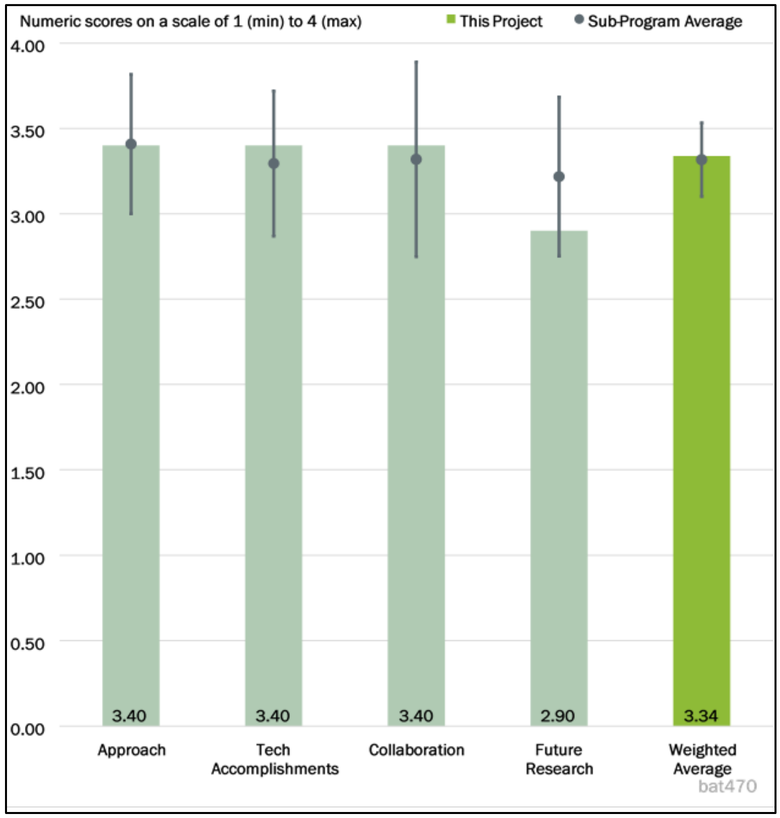


Figure 2-30 - Presentation Number: bat470 Presentation Title: Process R&D Using Supercritical Fluid Reactors Principal Investigator: Youngho Shin (Argonne National Laboratory)

Presenter

Youngho Shin, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer commented that the research team has successfully developed a hydro-solvothermal process for synthesizing single crystal NMC particles of controlled size. The particles have no grain boundaries and are more robust than polycrystalline cathode particles. The density of single crystal particles is also higher than polycrystalline powders. The reviewer indicated that this is a nice approach to making a better performing cathode.

Reviewer 2:

The reported that the project aims at one of the important aspects of synthesis—producing high quality single crystal high-Ni NMC. The technical barriers in the process development with the new HYST method has been well captured. Additionally, incorporation dopants, which is another important aspect of long-cycle and stable electrochemical performance, has been addressed as well.

Reviewer 3:

The reviewer stated that the goal of this project was to produce electrode materials through a hydrothermal synthesis approach, which the PI did effectively. Details regarding the approach with respect to the equipment were not given, but the results clearly show viable powders have been produced.

Reviewer 4:

This reviewer noted a reasonable approach that is appropriate for the materials being studied. The process approach produces unique battery materials in a flexible manner that is critical to fundamental studies. If continued beyond September 2021, the reviewer expressed interest in seeing an analysis on the feasibility of this process to realistically scale to larger quantities. If this project does produce materials that are of interest for commercialization or scale-up beyond 40 grams, it is unclear whether this process is truly scalable to a kg-scale or what the alternate process approach would be to help scale-up synthesis of the most promising materials. Is there an exit strategy for this project when a promising material is found?

Reviewer 5:

This project establishes an advance synthesis process, using supercritical fluids, able to obtain/tune such a very singular stoichiometry/composition for cathode materials, which this reviewer described as one of the main barriers to develop batteries beyond the present Li-ion battery technology. However, it is not quite clear from the information provided, why specifically a NMC96-2-2 cathode (focus of this study) would be better than, for instance, a NMC8-1-1. Are there strong differences between the $Li_{100}Ni_{96}Mn_2Co_2$ investigated in this project and the $LiNiO_2$? Are all the problems of the latter solved by including 2% of atoms of Co and Mn in the transition metal components? This reviewer pointed out that no explanation is provided. On the other hand, the supercritical technique allows, to some extent, the tuning of particle size and morphology, which are other barriers to developing new materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer reported the following technical accomplishments: synthesis of single crystal NMC with high Ni has been well established using the HYST method; the particle morphology for single crystal NMC via this route has been shown to be improved; electrochemical performance for the materials synthesized via this method is superior; and effect of dopants were addressed as well.

Reviewer 2:

The reviewer stated that this project seems to be on the right track toward overall completion. The scheduled milestones so far have been concluded successfully and those in progress are providing the expected results.

Reviewer 3:

This reviewer indicated that the PI produced nice 9622 materials. The mechanical advantages of large single crystals are not necessarily sound with respect to theory especially under electrochemomechanically induced strains and stresses, but they may have other merit. The reviewer definitely liked the way the PI benchmarked the single crystal material to a polycrystalline materials. In terms of cycle life, a small advantage is seen depending on the comparison viewed (Slide 9 versus 19). The PI should also show results for rate.

Reviewer 4:

Single crystal NMC96-2-2 results are interesting and promising from the perspective of this reviewer, who also expressed interest in seeing more electrochemical cycling data and validation of these materials. For example, on Slide 19, it is not clear why some samples were stopped before 15 cycles and others went to 20+ cycles. For the normalized capacity presented, is that self normalized to the cell you tested or the practical expected capacity of the material? The reviewer further noticed the electrode composition is quite high in binder and carbon content (70:15:15) and inquired about the reason for that. Is this the composition that the project team would need longer term for materials? If yes, how does the project team expect to overcome the Wh/kg and Wh/L impacts at scale? How do these materials perform at higher charge and discharge rates?

Reviewer 5:

The reviewer commented that the research team has shown good progress in synthesizing particles of different size. Preliminary coin cell test shows a modest improvement in gravimetric capacity retention for 80 cycles. Al- or zirconium (Zr)-doped single crystal material show better cycle life, but the number of cycles (13) was too small for a definitive assessment. The long-term cycle stability of this new cathode material needs to be established. Also, the team needs to perform cycling experiments at different (higher) C-rates. The reviewer explained that mechanical properties of single crystal versus polycrystalline particles was also evaluated. The authors write about facet control of their single crystals, but no data was presented where particle growth rates along the [100] and [111] facet directions was enhanced/altered.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The syntheses of new materials was the modus operandi of this project observed by this reviewer. These materials are sent to several labs for further analyses with extremely sophisticated instrumentation. The group is doing these collaborations very successfully with key national laboratories and excellent universities.

Reviewer 2:

The reviewer stated that this project requires a wide range of collaboration mainly because of the different techniques employed to study the structural and electrochemical properties. The range of expertise across the collaborators are well identified and the material characterizations are performed accordingly enabling a better insight of the synthesized materials.

Reviewer 3:

This reviewer noted that the PI shows a nice synergistic collaboration among national laboratory and academia for a variety of physical characterization.

Reviewer 4:

There appeared to be good collaboration and integration of project tasks across the project team from this reviewer's perspective. Results were presented from team membranes at Brookhaven, University of Wisconsin, and UC Irvine. However, the role of Hunt Energy on the project is unclear.

Reviewer 5:

Collaborations seem strong to this reviewer, who expressed interest in seeing more industrial collaboration or a path toward further material validation that goes beyond half-cell coin cells with outside 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 state project ended.

Reviewer 1:

The main concern of scaling up the material for large cell manufacturing has been addressed, however, this reviewer saw that there are no clear paths on achieving this goal. The team has to address this during their next year and clearly define how they are going to achieve this enabling a large format cell testing and validation.

Reviewer 2:

Future work is well planned, although this reviewer suggested making further analyses comparing to other stoichiometries of the NMC cathodes instead of comparing several variants of the NMC96-2-2. Certainly, it is a good idea to evaluate the doping of Al and Zr, but it should be done also comparing with similarly doped presently used NMC cathode materials.

Reviewer 3:

The reviewer stated that the PI could have expanded on process development, what unique attributes of hydrothermal can further differentiate it from state-of-the-art manufacturing techniques. Also, there should be a plan for fabricating a material that can benchmark this technique versus state of the art in a one to one comparison to show the advantages.

Reviewer 4:

The reviewer noted that future plans seem like a natural continuation of what was presented. For electrochemical testing, are there any plans to test the NMC96 2 2 cathode materials at higher charge and discharge rates? For the future nanoindentation work, it is not clear how much these results will translate to eventual macro-scale electrode performance (both mechanical and electrochemical). While these tests are important for basic material property quantification, it was unclear to this reviewer if any macro scale tests or composite electrode tests will eventually need to be performed. For the samples provided to external collaborators for evaluation, will there be a feedback loop wherein industrial or academic collaborators provide input on the utility of the synthesized materials?

Reviewer 5:

The reviewer recommended that future work should focus more on the performance of cathode material in pouch cells. Long term cycling needs to be performed at different C-rates; 20-80 cycles is insufficient to determine if single crystal particles are superior to polycrystalline powders. When synthesizing new single crystal powders, the PI should establish and justify a targeted set of properties. Why do the current doped particles require further improvement? What is the targeted capacity loss after 300, 500, and 1,000 charge/discharge cycles? An economic analysis of the hydrothermal process is also needed. What is the extra cost for single crystal particle synthesis versus the benefits of employing such particles in a Li battery cathode? Would it be possible to perform bench-scale continuous flow reactor experiments?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project supports DOE objectives in examining an alternative processing technique for electrode materials and identifying whether advantages exist.

Reviewer 2:

The reviewer observed an interesting approach that supports DOE’s current objectives as a path toward higher energy density batteries.

Reviewer 3:

The reviewer reported that overall aims of this research project are to improve the performance and loading of Li battery cathodes. The work may have spin-off implications/applications for other battery materials.

Reviewer 4:

This reviewer described this project as well aligned with DOE’s goal of developing high quality Ni-rich, low Co containing NMCs. However, the presentation has no clear mention on the economics of this method compared to the traditional Single crystal synthesis methods.

Reviewer 5:

This project supports DOE objectives; however, in the opinion of this reviewer, the project should also consider the theoretical limitations of strongly increasing the amount of Ni in NMC materials. Without such an analysis, the reviewer is not fully convinced that the materials being developed are going to be of importance for DOE. The mayor question is: what is the difference between a 98-1-1 from a 99-1-0, 99-0-1, 100-0-0, and the like?

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 a well-aligned team to understand multiple aspects of the material properties.

Reviewer 2:

This reviewer observed an appropriate funding level for the work presented.

Reviewer 3:

The reviewer noted adequate resources for the project.

Reviewer 4:

Resources seemed sufficient to this reviewer.

Reviewer 5:

Without LOE or burn rate, this reviewer could not comment on this. However, funding seems adequate especially as much of the characterization is done collaboratively by others.

Presentation Number: bat472
Presentation Title: Behind-the-Meter-Storage (BTMS)–Materials
Principal Investigator: Kyusung Park (National Renewable Energy Laboratory)

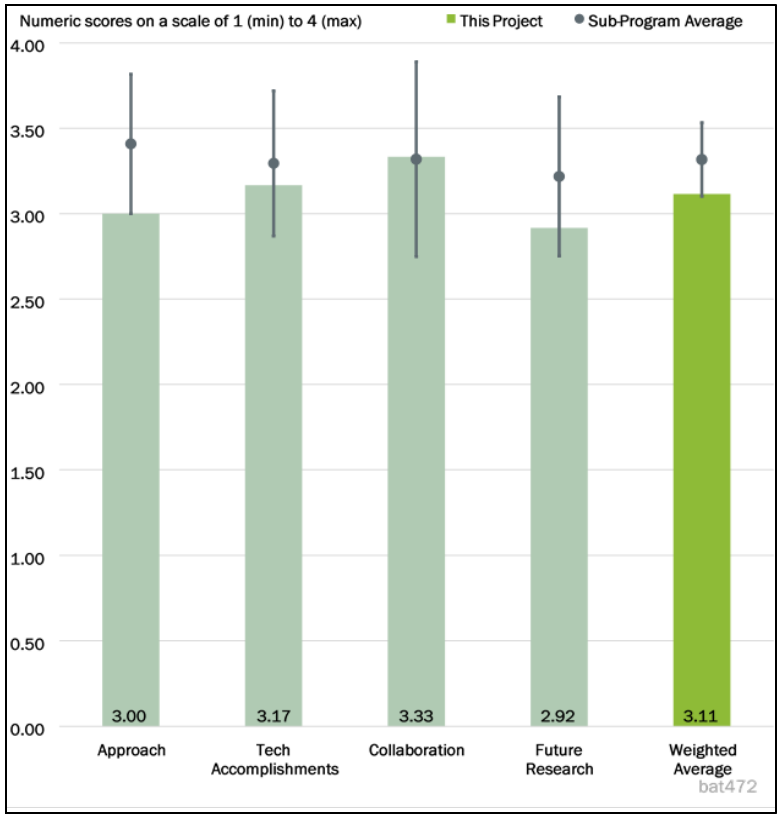


Figure 2-31 - Presentation Number: bat472 Presentation Title: Behind-the-Meter-Storage (BTMS)–Materials Principal Investigator: Kyusung Park (National Renewable Energy Laboratory)

Presenter

Kyusung Park, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the work is meaningful and addresses DOE VTO goals of developing a total battery focused energy system. Storage is paramount to success and the work accomplished stated goals.

Reviewer 2:

The reviewer indicated that using locally-sourced battery materials is an important step in broader adoption of battery technologies.

Reviewer 3:

The reviewer reported that key barriers were identified as battery cost, cycle life, sustainable materials, and energy density for behind-the-meter-storage (BTMS) batteries. These generally make sense, but it would be useful to have specific quantitative technical targets for BTMS and show gap analysis for commercially existing batteries. Certainly, cycle life and cost (and sustainable materials as a subset of cost) are key issues for BTMS. However, energy density is less clearly a critical barrier. For stationary applications, this reviewer explained that the energy density targets are not as challenging as for EVs. This may be implicitly understood since LTO batteries are lower in energy density than EV battery targets. Higher energy density is still useful however in reducing cost, which is a very critical barrier. The reviewer agreed that safety is perhaps a more critical barrier for large BTMS batteries inside buildings.

This reviewer noted that good approaches were developed to address these barriers including designing electrolyte for safety, using high-rate, high cycle life LTO battery technology and focusing on cycle life development. The focus on thick electrodes was said to be aimed at improving energy density, which would not seem to be a critical barrier. However, this would have more of a favorable effect on lowering cost which is a critical barrier. Again, it would help to have quantitative technical targets.

The starting battery cathode chemistry is excellent in its lack of critical materials (no Co and no Ni). Thus, why there were efforts into studying LiNiMn oxides and LiNiMnCo oxides was a little puzzling to this reviewer. The reviewer further commented that this project does address the technical barriers and the project is well-designed and feasible.

Reviewer 4:

The reviewer stated that the critical-material-free chemistries should be investigated for many applications; so, this reviewer was glad to see this project. Is it necessary to be concerned about the flash point of the electrolyte with relatively low energy safe active materials? The reviewer asked whether there is any SEI or lithium plating to worry about, or any oxygen release from the cathode. Also, a requirement to prelithiate a system where you already have lithium in both your cathode and anode seems inefficient. This reviewer was unconvinced that LTO is the way to go here. Why not graphite? Perhaps, this is just for learning, not a commercial product. The reviewer further indicated that Mn dissolution from LMO is well known and there are many solutions/mitigations that should be implemented.

Reviewer 5:

The reviewer stated that the LMO/LTO is not a great approach or starting point. Both LMO and LTO have been well developed in industry. For example, LMO has been widely used as cathode in two-wheeler batteries because it is cheap and has a life of about 500-700 cycles. Due to the Mn dissolution, its cycle life is very limited. LMO’s capacity is also low comparing to other cathode materials. The reviewer explained that LTO has also been well developed in industry and has magnificent stability. However, its high cost and high operating voltage compared to graphite anode is very limited in its applications.

In this project, there are also a lot of ongoing efforts on thick electrode investigation that are not very useful in a national laboratory or university because more depends on processing and equipment. The reviewer asserted that it is a must for every battery company to develop a process that makes good thick electrodes based on its equipment capability.

LTO anode makes it possible to use sole PC or EC as electrolyte solvent. However, this reviewer recommended that efforts should be made to develop the electrolyte for normal temperature operation, not at 40°C.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed excellent progress/accomplishments made based on the existing plan, and noted that very detailed results were presented.

Reviewer 2:

This reviewer noted the work met stated standards as described in original project and the investigative work has led to a functional approach to energy storage. Further efforts may yield viable technology to support next generation energy infrastructure.

Reviewer 3:

The reviewer reported that the team has demonstrated feasibility of LT/LMO cells.

Reviewer 4:

The reviewer stated that this project shows substantial progress with excellent technical accomplishments aimed at overcoming barriers. An improvement would be to include specific quantitative technical targets.

The reviewer described cycle life result of 98% capacity retention after 1000 cycles of 1C rate charge-discharge for the prelith EC as impressive and consistent with the excellent 99.99% coulombic efficiency. The detailed study of degradation modes is also excellent and shows approaches to further improve cycle life. Further insight from XPS and TOF-SIM depth profiles is also impressive. The reviewer asserted that this is first class R&D work.

The reviewer did not quite understand the motivation for the additional work on Ni and Co containing cathode materials if LMO works so well.

This reviewer commented that pouch cell evaluation results on Slide 13 do not look as promising as the cycle life results on Slide 7. The results on Slide 13 show a strong dependence of performance and cycle life on electrode thickness. Slide11 also shows a dependence of performance on vendor. There is probably a big dependence on processing techniques and this reviewer suggested that things like dry electrode processing may be beneficial for thicker electrodes.

Reviewer 5:

It seemed to this reviewer that there are many problems—the LMO has Mn dissolution and the LTO thick electrodes do not work well. The evaluation of LNMO (higher voltage)/LMO can improve energy density, but requires a high voltage electrolyte. It is not clear where this project is going until 2025.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that this project does a very good job of working in teamwork with partners and those collaborations have been detailed.

Reviewer 2:

This reviewer indicated that the team at NREL is effectively using CAMP and INL for their specific expertise.

Reviewer 3:

This reviewer observed a competent team is competent and effective collaboration.

Reviewer 4:

The reviewer noted that team coordination was necessary to accomplished presented work. It seems that all involved performed as expected and required to yield successes reported by the researcher.

Reviewer 5:

This reviewer recommended seeking industrial collaboration on the thick electrode development and large pouch cell manufacturing.

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 state project ended.

Reviewer 1:

Future plans are sound from this reviewer's perspective.

Reviewer 2:

The reviewer described proposed future research as great based on the existing plan. However, as previously indicated, LMO/LTO is not a great approach; LMNO could be a great alternative.

Reviewer 3:

This reviewer asserted that work needs to continue, and further commented that storage capability of generated energy is of paramount importance to complete a total renewable energy system. Proposed future efforts need to be supported and addressed.

Reviewer 4:

This reviewer indicated that the proposed future research plan is excellent and further focuses on cycle life. Again, the reviewer did not understand the continued focus on layered oxides if the LMO spinel materials with no Ni and no Co work. Furthermore, this reviewer highly recommended development of targeted quantitative technical targets for energy density, cost, and cycle life. It would also be good to develop technical targets for safety for the BTMS applications.

The reviewer also recommended a cost analysis including not only the materials cost, but also some estimate of the manufacturing cost and cost comparison of existing LIB battery products including LTO batteries. LTO batteries are theoretically inexpensive. However, in practice there are complex and troublesome issues with formation and other manufacturing processes that are reflected in current pricing of these batteries.

Reviewer 5:

This reviewer did not see approaches proposed to solve the problems that have been encountered. These are “old” chemistries and the problems are well known. The reviewer asked what the team is doing differently to solve them.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that yes, this project is relevant to DOE objectives in the area of BTMS, which should help the proliferation of fast-charge stations. The overall BTMS initiative is excellent and this project provides excellent support and development of batteries aimed at this application. Within the BTMS initiative it would also be useful to examine the suitability of existing battery products in detail.

Reviewer 2:

The reviewer commented that evaluation of chemistries that do not require critical materials is essential for U.S. energy dependence during the transition from hydrocarbons to electricity, which requires batteries.

Reviewer 3:

The reviewer stated that non- or low-Co chemistries would support the overall DOE objectives due to very limited Co resources and very high demand of LIB in EV and ESS markets. The development of non- or low-Co chemistries would be critical for the independence of the U.S. LIB industry.

Reviewer 4:

This reviewer asserted that the work presented definitely supports DOE VTO efforts to enable a total renewable energy system.

Reviewer 5:

Developing BMT technology that does not use critical materials is relevant to DOE objectives from this reviewer’s perspective.

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 this project does a very good job of utilizing existing resources through collaboration.

Reviewer 2:

The reviewer commented that industrial collaboration is critical for the thick electrode development and evaluation, as well as large format pouch cell manufacturing.

Reviewer 3:

Funding appeared adequate to support current and proposed work from this reviewer's perspective.

Reviewer 4:

Resources were described by this reviewer as sufficient.

Reviewer 5:

This is hard to answer as the reviewer could not tell what the future proposed efforts entail. Therefore, the reviewer concluded that there are sufficient resources.

Presentation Number: bat473
Presentation Title: Behind-the-Meter-Storage (BTMS)–Analysis
Principal Investigator: Margaret Mann (National Renewable Energy Laboratory)

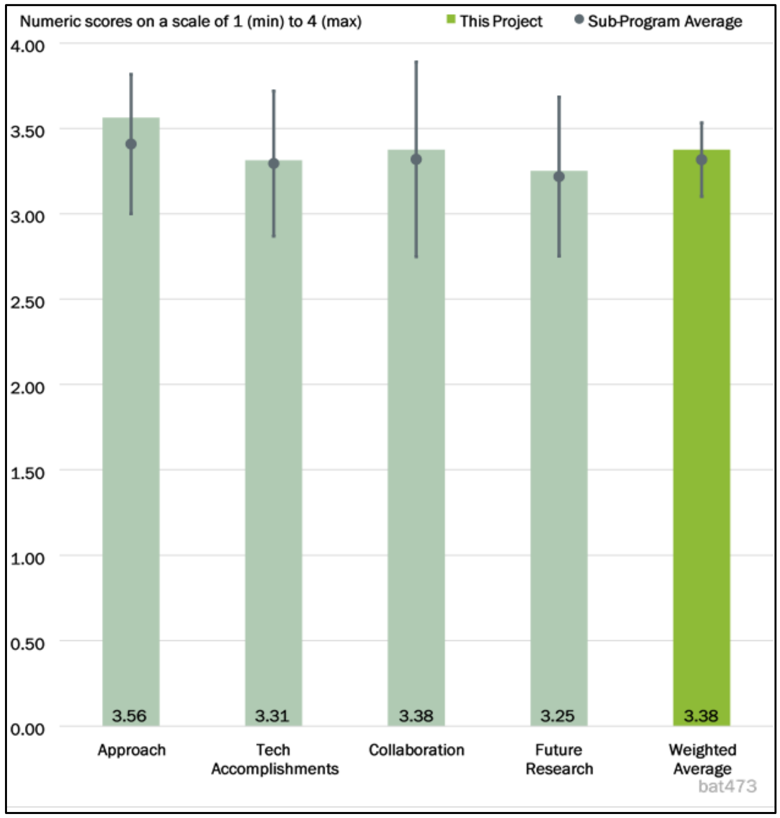


Figure 2-32 - Presentation Number: bat473 Presentation Title: Behind-the-Meter-Storage (BTMS)–Analysis Principal Investigator: Margaret Mann (National Renewable Energy Laboratory)

Presenter

Margaret Mann, National Renewable Energy Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this looks like an excellent project with excellent potential.

Reviewer 2:

This reviewer indicated that BTMS analysis is a critical need for understanding how both vehicle charging (especially DC fast charge) and increased use of rooftop solar impact the grid and how BTMS can be optimized to manage that impact. The selected analytical methods and models appear sound and the reviewer looked forward to seeing how this project progresses.

Reviewer 3:

The reviewer indicated that BTMS optimization is good idea as it is based on a detailed, physics-based model. Predictive control of BTMS could solve cost and grid impact issues. Sensitivity analysis for variability faced by BTMS is part of the approach and this reviewer asserted that it is a good idea to consider effects variability in the BTMS operation.

Reviewer 4:

The reviewer stated that this project focuses on examining how behind-the-meter systems can minimize unexpected charging costs and enable fast EV charging applications. This thrust proposes to use physics-based modeling and predictive controls to evaluate the potential for BTMS to address charging costs and grid impacts of fast EV charging. The project team is developing a detailed, physics-level understanding of the interaction of the various components and systems to optimize BTMS design and operation. In particular, the project team is looking at the analysis sensitivity, impact of new research achievements, iterative feedback modeling, and potential energy savings as inputs to its model among other variables.

Reviewer 5:

The technical barriers of the energy storage and generation behind the meter are well addressed from this reviewer's perspective. It is suggested that technical goals such as the specific power density, power density, etc., can be further detailed so the researchers can work toward them.

Reviewer 6:

This reviewer remarked on the importance of determining the cost-benefit ratio in doing DCFC. The approach to model the best strategy to meet DCFC demands at a grid level is well designed.

Reviewer 7:

The reviewer observed a very complex but necessary task to analyze the Behind-The-Meter-Storage (BTMS) system. Extensive analysis is needed to understand the trade-offs between the dynamic loads, on-site generation and BTMS energy storage affected by various parameters listed in Slide 8—climate region, battery lifetime, efficiency of EVs. The proposed EnStore model on Slide 9 that integrates existing underlying models, e.g., battery lifetime model, is a good approach to analyze the complex task. Levelized cost of charging (LCOC) was proposed as the metric to measure efficiency of the BTMS system. However, metrics are also needed to quantify the reliability and resilience of the BTMS system.

Reviewer 8:

This reviewer acknowledged lacking enough knowledge in the topic to give it an outstanding rating. Nevertheless, all ratings in this review are awarded on technical merits. The reviewer indicated that the technical merits of what is needed in this project were fully addressed and described the data as invaluable and insightful. It shows where and what problems need to be addressed in densely populated city areas. While good to see that addressed, rural areas should be addressed as well. Rural areas are the last problem to solve as it serves the least number of people, but farm equipment serves all people; so, it too will need to be addressed, but the reviewer expected a stripped or mobile BTMS system will be implemented in rural America.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that the EnStore model provided examples of peak power profile and dynamic loads for specific scenarios and illustrated the complexity of the BTMS system. Optimized LCOC was also modeled for different climate regions at various utility rates, successfully illustrating the feasibility of the EnStore model.

Reviewer 2:

This reviewer reported that Slide 15 indicates that the project has made great progress.

Reviewer 3:

The reviewer stated that this looks good and appears to be ahead of schedule.

Reviewer 4:

It seemed to this reviewer that the plan is ahead of schedule.

Reviewer 5:

Impressive technical achievements were noted by this reviewer. As a comment to the overall BTMS project, it is unclear how this project leverages previous activities such as battery research efforts funded by DOE for numerous years.

Reviewer 6:

The reviewer indicated that there are some amazing accomplishments that were made in collecting data and information to feed the model. However, there is still notably more that needs to be done to make it more relevant and applicable to real world conditions.

Reviewer 7:

This reviewer stated that the project has developed an EV Charge Profile and predictive control model to better model energy flows within the BTMS system. It was challenging to understand the scale of the overall technical accomplishments, although the presenter did show that BTMS can reduce costs of fast EV-charging for two specific scenarios (PG&E and ConEd) by 30-40%, which is impressive. The reviewer explained that it will be critical to see how well this process can be generalized to other scenarios and to understand what the return on investment (ROI)/payback period would be for the large battery storage infrastructure costs.

Reviewer 8:

The reviewer remarked that the project is still near the very beginning, but the analytical methodology appears to be sound.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaborations across the team members appeared excellent to this reviewer.

Reviewer 2:

The reviewer observed outstanding collaboration and coordination across all project teams.

Reviewer 3:

This reviewer reported that this project is part of a wider collaboration between five national laboratories and appears to have sufficient collaboration and coordination between project institutions.

Reviewer 4:

This reviewer noted that complexity of the BTMS system necessitated collaboration with other DOE offices such as the Office of Electricity (OE), Building Technologies Office (BTO), and Solar Energy Technologies Office (SETO).

Reviewer 5:

Although this was not discussed in detail, the reviewer indicated that this seems good based on other presentations.

Reviewer 6:

The reviewer stated that many DOE offices and labs are working together.

Reviewer 7:

Rather than relying solely on sensitivity analysis for the battery costs for BTMS, the reviewer thought that collaboration with ANL could be improved. The ANL BatPaC model appears to be capable of modeling bill of materials and costs for all of the cathode/anode chemistries under consideration for BTMS. Subsequently, the reviewer recommended incorporating BatPaC modeling into the project team’s cost analyses and identified the primary POC for BatPaC at ANL, Shabbir Ahmed.

Reviewer 8:

This reviewer stated that the data is clearly coming from the utility industry in different areas. This is supposed to be a joint project between VTO, BTO, OE and SETO and a five-laboratory team including SNL, ANL INL, and PNNL, and the reviewer emphasized that it probably is. Slide 27 finally is explicit about who is doing what. The reviewer could not identify where the collaboration and coordination come from in Slides 3-26 given the unfamiliarity with the project. Slide 10 does credit data sharing, but this reviewer was unsure if this is related to the collaboration in the overview slide.

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 state project ended.

Reviewer 1:

This reviewer indicated that proposed future research topics include (1) running scenarios for three of five building types, four of six climate regions, battery costs, PV costs, battery lifetime, and battery chemistry impacts; (2) public-facing visual interface for exploring the potential of BTMS under changing scenarios; and (3) GHG emissions savings compared to no BTMS at locations across the United States and at different levels of EV deployment. These activities will be quite helpful to understand BTMS far better than the present state of know-how on this topic.

Reviewer 2:

The proposed analytical blueprint for future work is sound from this reviewer's perspective.

Reviewer 3:

Although this was not discussed in detail, the reviewer indicated that this project has an achievable plan for future work.

Reviewer 4:

This reviewer stated that the proposed future research was largely focused on more data analysis and fancier ways of displaying data—in the other proposed research and beyond the scope of the contract. The reviewer expressed interest in seeing a more science-based project; there is no here are proposed theories or ways of testing those theories, or the project team does not have a model for X and we need to create it. The proposed research is limited to Engineering-Fiscal studies of tabulating with and without BTMS and EV usage, and calculating more accurate constants in the energy flow models, of which all are useful.

Reviewer 5:

This reviewer indicated that there are too many variables that need to be applied to the model to make it more applicable. That requires lot more effect and time that is available to complete the project. The focus needs to be updated or more time and resources needs to be provided.

Reviewer 6:

The reviewer observed well-illustrated barriers for future work. It is suggested that supercapacitors be considered in BTMS analysis considering its super power capability and long cycle life, though its low energy density may be a drawback.

Reviewer 7:

The reviewer reported that the project proposes to run scenarios for the remaining building, climate regions and for various battery and photovoltaic (PV) inputs. Most interesting would be potential future partnerships with charging and vehicle industries to rollout this model and learning to provide cost advantages to companies and individuals.

Reviewer 8:

This reviewer explained that the stationary battery is needed to buffer against instability to the grid from XFC charging. The project team should use its model to provide guidance on BTMS stationary battery's energy density and power density targets. The BTMS team should publish the energy density and power density targets for the stationary battery. The reviewer asked whether the BTMS battery needs to have very high energy density (per BAT472 talk by Park) and indicated that a higher energy density battery usually has lower cycle life and shorter calendar life. A high-power stationary battery with medium energy density may be sufficient as a BTMS battery. Given the complexity of the energy flow in the BTMS system, future research should focus on validating the energy flow modeling results.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that this study is clearly needed. This reviewer could see the advantages of a BTMS on delivering enough fast charge to the consumer and minimizing costs to the utility supplier. Given that demand will go way up, it looks like the model will not be undercut by savings being used to justify rate hikes. It also looks like this work will provide the necessary work for building owners to justify investments in BTMS systems. Recognizing the resulting model is not a one-size-fits-all makes it even more invaluable. This work is clearly a pillar in its area.

Reviewer 2:

This reviewer highlighted that it is very important to optimize the grid-level approach to DCFC to make it more applicable to consumers.

Reviewer 3:

The reviewer remarked that this project does support the overall DOE objective because it targets a reduced cost of ownership for EVs, thereby increasing adoption and lowering GHG emissions and potentially improving U.S. energy independence.

Reviewer 4:

This reviewer indicated that these analyses will be critical in developing full assessments of EV DCFC costs and challenges.

Reviewer 5:

The reviewer opined that good understanding of the BTMS is critical for success of the EV ecosystem.

Reviewer 6:

Understanding BTMS effect on electric grid itself is quite relevant to Americans from this reviewer's perspective. Then BTMS' usefulness in reliable EV charging without impacting grid due to availability of local charging by renewable sources could make BTMS quite relevant and attractive.

Reviewer 7:

This reviewer stated that reducing the cost of charging would benefit electrification.

Reviewer 8:

This reviewer explained that a detailed physics-level understanding of the interaction of various components and systems—including energy storage, PV, etc.–is needed to economically optimize the design and operation of BTMS.

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 more resources are needed for the BTMS analysis given the complexity of the BTMS system.

Reviewer 2:

The reviewer commented that more time and resources need to be provided to complete the objectives set at the start of the program.

Reviewer 3:

The reviewer asserted that the team is well resourced. Many DOE offices and DOE labs are working together and contributing to this project's success.

Reviewer 4:

This project is ahead of its time (as opposed to last minute), which the reviewer described as good because it provides timely data before future action is past due.

Reviewer 5:

The reviewer observed appropriate resources assigned to this project.

Reviewer 6:

The reviewer described project resources as sufficient to achieve the stated milestones.

Reviewer 7:

Although this was not discussed in detail, funding seemed sufficient to this reviewer.

Reviewer 8:

The project appears to be on schedule, and this reviewer remarked that there was no indication that resources were a significant issue.

Presentation Number: bat475
Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes
Principal Investigator: David Wood (Oak Ridge National Laboratory)

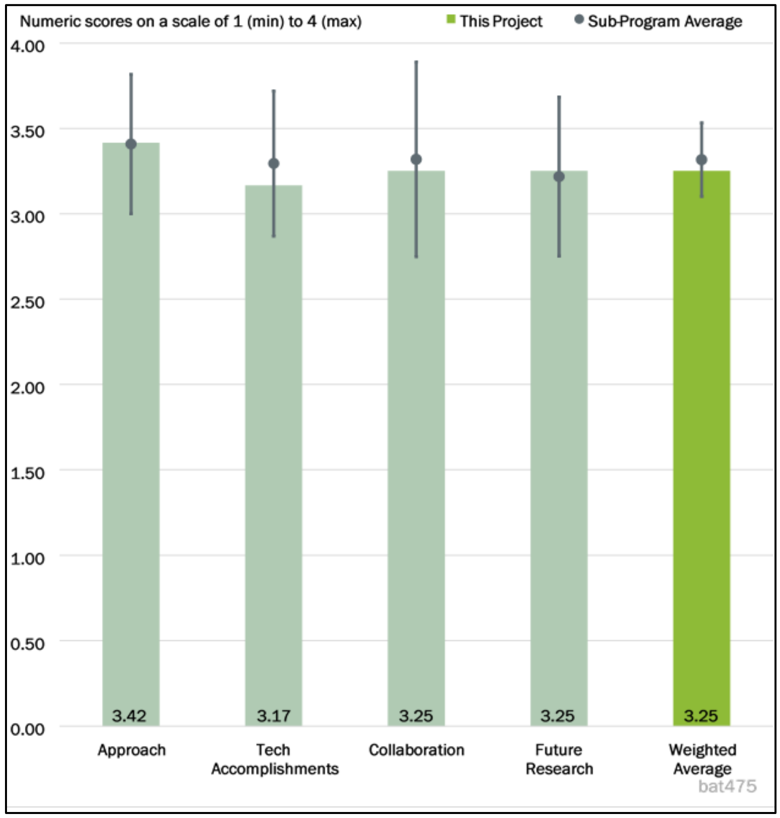


Figure 2-33 - Presentation Number: bat475 Presentation Title: Towards Solventless Processing of Thick Electron-Beam (EB) Cured Lithium-Ion Battery Cathodes Principal Investigator: David Wood (Oak Ridge National Laboratory)

Presenter

David Wood, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer explained that EB curing is one of the novel methods that can efficiently implement solvent free dry electrode fabrication method and the project has critically approached this task. Electrode loadings of approximately 30 mg/cm^2 is the need of the hour to achieve high energy density. The reviewer asserted that practicing this approach with NCM811 is extremely important. Novel approach of EB curing has been validated at pilot scale, which demonstrates the serious efforts undertaken by the team.

Reviewer 2:

The reviewer observed a novel approach novel that can be tailored for designing different cell components, including cathodes and solid electrolytes. The team has also evaluated the electrode performance with its internally developed V2 electrolyte.

Reviewer 3:

The reviewer commented that the research team has developed an interesting and effective approach to cathode fabrication that does not involve an electrode drying step. Preliminary electron beam (EB)-cured cathodes worked well in terms of capacity retention during charge/discharge cycling, but the cathode contained binder oligomers with some solvent during curing. The reviewer explained that electron-beam curing is fast and the method can be incorporated into roll-to-roll processing schemes. The research team has shown that EB curing may be economically attractive in terms of manufacturing cost.

Reviewer 4:

The reviewer asserted that EB curing was a innovative approach for low cost and high energy Li-ion electrode production. The approach could enable thick electrode production, unlike ultraviolet (UV) ray, the high energy of EB can cure a thick electrode. It seemed to this reviewer that a slot die was still used to cast electrode slurry. Is this a solventless process?

Reviewer 5:

This reviewer indicated that the project is generally effective and contributes to overcoming the barriers in the development of cathodes with little or no solvent using EB curing, which can significantly reduce the drying/fabrication time for electrodes compared to conventional solvent-based electrodes. The reviewer explained that this will enable the fabrication of dense (with high active material loading corresponding to 4 mAh/cm^2) cathodes with faster processing speeds, reduced footprint and infrastructure for the (drying) equipment, and thus, a reduction in overall cost. Subsequently, the project addresses the two significant barriers of current EV batteries, i.e., specific energy and cost. With little or no solvent in the fabrication process, the EB curing method minimized or even eliminates environmentally incompatible solvents (e.g., NMP) and the problems associated with its use. The reviewer stated that the method looks promising for the current Li-ion battery technology using metal oxide/phosphate cathodes and may also be extended to the fabrication of composite cathodes for solid-state batteries with conducting polymer as a binder.

As a weakness, and with promising results from the last two years, it was surprising to this reviewer that there has not been as much interest from the major Li-ion cell manufacturers. What is the reason for this lack of interest from the commercial battery manufacturers? Secondly, why is this not being extended to the fabrication of graphite anode instead of composite solid electrolyte films?

Reviewer 6:

The concept of EB based coatings is one worth exploring from this reviewer's perspective. The machines can be notably more compact than coating machines based on solvent evaporation, thus having a smaller foot print in the manufacturing setting. This could lead to lower cost more environmentally-friendly methods.

Several items that still need to be addressed were identified by this reviewer. The method in current development still uses approximately 10% solvent. Further minimizing or removing the solvent would be important in order to facilitate scale-up. Additionally, the reviewer indicated that details on the speed that would be possible for full-scale manufacturing need to be provided. Is there a limit on electrode thickness based on the ability of the EB to penetrate the coating? The reviewer also reported that nitrogen is currently used as a cover gas, and that careful quantification of nitrogen consumption is important for a final cost analysis

A technical comment is that while the group explored the bulk characteristics of the active material after exposure to the EB, the reviewer suggested that the project team should also look into the surface condition of the material. This could be done by soft XAS depth profiling or possibly some information could also be gained from XPS analysis.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that project investigators have studied the electrode fabrication process using EB curing method at very high loading with the next generation cathode material. Additionally, high speed coating of the electrodes using the method has been well validated at a pilot scale level. The project has also looked into any side reactions because of the exposure of the electrode to the EB and have established a systematic study in understanding the cation mixing at various energy levels of the EB.

Reviewer 2:

The reviewer stated that the progress is adequate and the prospect is clear. The team has established the fabrication capability at this point, which will help accelerate the next phase of research.

Reviewer 3:

The reviewer noted good progress has been made toward the projective objectives. Specifically, the Roll-to-roll (R2R) EB curing pilot line for cathode fabrication has been successfully installed at ORNL to add to the capabilities of the laboratory. Thick cathodes of NMC 811 were demonstrated, which showed impressive capacity retention during cycling. EB Radiation does not seem to impact the crystalline properties of the active material, though there is increased cation mixing at high radiation levels. This reviewer expressed surprise that performance of the EB-cured cathode was demonstrated in different electrolytes, but a direct comparison with the conventional solvent-based cathode has not been provided. Finally, this technique has been demonstrated Li ion conducting polymer as a binder for composite cathode with stable cycling. Cost analysis were made which show substantial operating and capital cost reduction with EB Processing. There is a good possibility for the technology transfer because of the significant electrode production cost reduction, and impact on cell energy density.

Although not weakness per se, the reviewer suggested that it is probably an appropriate time to investigate the applicability of this method to “Beyond Li-ion Technologies,” specifically, Si anode sulfur cathode.

Reviewer 4:

A pilot level demonstration coater with EB curing was set up on schedule as observed by this reviewer. The coated electrodes were tested, and adequate results were demonstrated. It seemed to the reviewer that the electrodes shown in the photo on Slide 7 were not roll-to-roll production.

Reviewer 5:

Good progress has been made in demonstrating the process. As noted previously, the boundary conditions in terms of electrode thickness, web speed, material damage, and nitrogen consumption still need better definition in order to transition to large scale manufacturing.

Reviewer 6:

Although research progress is very good, this reviewer highlighted that the research team has yet to show that EB curing will work when there is no solvent in the oligomeric binder. Was the solvent providing sufficient oligomer mobility (plasticization) for proper crosslinking? The reviewer explained that without solvent, the efficiency and extent of crosslinking will be reduced. The PI did not indicate whether the use of a binder with 10% solvent will require a drying oven with the EB reactor in a roll-to-roll process scheme. Also, there is still the need for calendaring and it is not clear if this step was included in the economic analysis of EB manufacturing cost. This reviewer also noted that there was no discussion of the reproducibility of EB cured cathodes.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the team is highly collaborative and has involved multiple companies in their network. The team has also established collaboration with their neutron source.

Reviewer 2:

Collaborations appeared effective to this reviewer, who also noted that the project has involved material manufacturers and equipment suppliers among others. The project team has an appropriate diversity of engaged partners.

Reviewer 3:

It appeared to the reviewer that the PI collaborated with both equipment suppliers, raw material manufacturers, and battery manufacturers well.

Reviewer 4:

The reviewer stated that the team is well crafted across different battery material, cell, and equipment manufacturers. Given that the project is 84% complete, the roles of individual collaborators are not clearly mentioned during the presentation. Charting out the individual contributions will be very helpful to understand the scope of the collaboration.

Reviewer 5:

Ongoing collaborations with equipment suppliers were reported by this reviewer, including PCT EB and Integration, Keyland Polymer, B&W MEGTEC, and Eastman Kodak; battery manufacturers including XALT Energy and Navitas Systems; and raw materials suppliers including BASF, Allnex, Keyland Polymer, Superior Graphite, and Denka

As a weakness, the reviewer commented that the collaboration is non-specific and the commercialization opportunities are not bright with these collaborators. A more useful partnership would be with a major cell manufacturer, if possible.

Reviewer 6:

There was little discussion of collaborative work in the AMR presentation observed by this reviewer, and it was not clear how equipment suppliers and battery manufacturers are contributing 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that proposed future studies will focus on extending the EB curing to graphite anodes (this is quite appropriate) and to EB/UV R2R polymer electrolyte and composite cathode for solid state lithium cell and demonstrate high energy density and good cycle life. This project has effectively planned its future work in a logical manner by incorporating appropriate technology metrics, considering barriers to the realization of the proposed technology and, adopting suitable approaches to progress toward project objectives.

Reviewer 2:

This reviewer noted future research has been clearly stated, with some battery performance metrics stated as well.

Reviewer 3:

The reviewer stated that the research team needs to demonstrate that EB curing can be carried out with no solvent in the binder. The project team needs to show reproducible cathode performance. The PI showed that an EB cured cathode works well at high C-rates, but this might be due to the use of a newly developed electrolyte. The reviewer explained that the team needs to identify if EB curing produces a better electrode morphology, or it just eliminates the need for large drying ovens (with long residence times) in a roll-to-roll process. The economic analysis should include capital equipment and equipment replacement costs, not just manufacturing costs. What is the lifetime of the EB reactor? Will this be an issue that might affect the economic analysis?

Reviewer 4:

The reviewer remarked that future research is in three categories—EB curing of anodes, EB/UV for polymer electrolyte, and understanding of processing-microstructure-performance relationships. For a process development project like this one, Design-of-Experiment is a good tool to understand the interaction of many parameters. This reviewer suggested that instead of expanding the EB to many systems, more attentions should be focused on item 3 on Slide 14.

Reviewer 5:

The reviewer commented that future work proposed focused on breadth rather than depth. For example, the project team wants to demonstrate coating of anode materials and solid-state batteries. While these are of interest and worthy under takings, it would be of interest to fully define the cathode parameters such that most questions are answered. This may facilitate transition to a manufacturing company. Thus, the reviewer indicated that there may be a short-term trade-off of depth versus breadth of the technique. It may prove that short-term investment in detailed understanding will provide benefit for future processes as well.

Reviewer 6:

The reviewer explained that studying anode is another important aspect of battery research and establishing the cycle life of EB cured electrodes will be very helpful to understand the benefits of this technique. The plan to study long cycle performance of the high energy density cell with EB/UV cured solid electrolyte and electrodes is an important milestone to meet, mainly to see the benefit of this technique of fabricating battery grade electrodes and electrolytes. The proposed study to understand the electrode microstructure is significant; it will answer the effect of making electrodes with this technique on fast-charge capability of the cell incorporating the electrodes using this novel method.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that proposed research could enable the manufacture of low-cost and high energy thick electrodes. Such advanced production processes will not only produce high energy density Li-ion batteries, but also make U.S. production more competitive.

Reviewer 2:

This project supports overall DOE objectives because it supports cell design targeting higher energy density; lowers $/kWh because of the cost reduction; and envisions a universal approach on fabricating anode, cathode, and electrolyte, which has merit in incorporating this method across the board of battery manufacturing process.

Reviewer 3:

The reviewer indicated that the project supports the overall DOE objectives by developing a novel, low-cost and environmentally friendly fabrication using EB/UV curing for dense and high areal capacity cathodes for improving specific energy and reducing the cost of LiBs. Overall, the reviewer asserted that this is relevant to DOE VTO’s battery programs and supports its objectives.

Reviewer 4:

The reviewer stated that the process is able to make thicker electrodes with lower cost and environmental friendliness. These are important factors for battery manufacturing and clearly relevant to DOE missions.

Reviewer 5:

The reviewer remarked that the overall aims of this research project are to decrease the processing time and simplify the processing steps to manufacture Li-battery electrodes. Both objectives are important and worthwhile.

Reviewer 6:

This project paves a lower cost environmentally friendly path, and if the questions previously posed can be resolved, then the reviewer opined that this meets DOE objectives nicely. A focus on deeper understanding and more quantitative results prior to moving to other systems would be useful. The reviewer acknowledged the possibility that the team may already have the results and did not wish to present the details to a broad audience.

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 resources are commensurate with the scope of the project and adequate to achieve the stated milestones.

Reviewer 2:

This reviewer commented that resources appeared sufficient for the proposed projects.

Reviewer 3:

Adequate project resources were noted by this reviewer.

Reviewer 4:

This reviewer stated that the team has established fabrication capability to move the project forward.

Reviewer 5:

As mentioned previously, this reviewer observed the collaboration team enables a wide range of resources and the outcome because of this larger collaboration that has not been highlighted in the presentation.

Reviewer 6:

The reviewer remarked that the PI has access to more than adequate resources to complete the proposed milestones.

Presentation Number: bat478
Presentation Title: Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes for Solid State Lithium Batteries
Principal Investigator: Steve Martin (Iowa State University of Science and Technology)

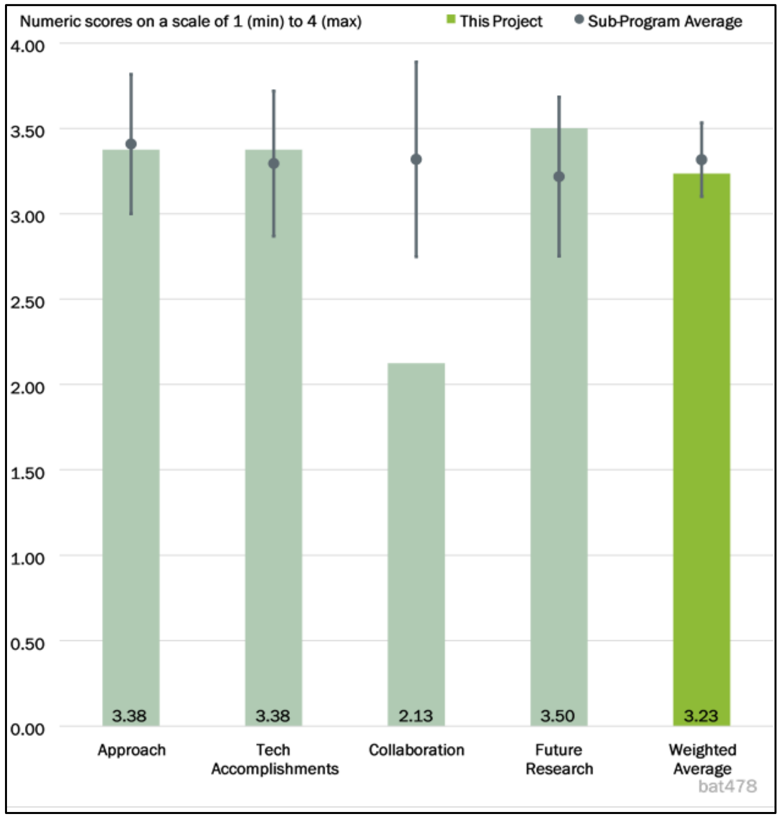


Figure 2-34 - Presentation Number: bat478 Presentation Title: Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes for Solid State Lithium Batteries Principal Investigator: Steve Martin (Iowa State University of Science and Technology)

Presenter

Steve Martin, Iowa State University of Science and Technology

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Development of the glassy solid electrolyte is an effective way to improve the Li-anode/electrolyte interface, which this reviewer described as critical for the performance of all-solid-state batteries. The team has demonstrated its ability to make thin and Li-impenetrable glassy solid electrolytes (GSEs).

Reviewer 2:

This reviewer referenced "Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes (GSEs) for Solid State Lithium Batteries," and asserted that the presentation is very clear and very well organized with clear milestones. The project seems to have met the milestones for 2019 and 2020. The remaining challenges are well defined, and a clear path forward is set.

Reviewer 3:

Well-designed work starting with GSE composition development was observed by this reviewer, followed by thin film forming and finished by assembling asymmetric and symmetric cells LM|GSE|SS for stability testing and cycling.

Reviewer 4:

The reviewer explained that glass technology has a significant technical and economic potential for solid electrolyte Li metal batteries. The compositional space affords flexibility and opportunities to design for a range of metrics. Regarding the approach, it seemed to this reviewer that some industrial partnerships could help. Why not partner with a glass company who could provide the type of engineering and technician support for the glass draw? The reviewer could imagine that getting that equipment up and running, and getting students trained and operating a piece of equipment like that is both challenging and requires a significant period of time.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer commented that the team has demonstrated several technical accomplishments and progress in the overall project. The project is in a great shape in terms of milestones and publications. Stability of the new electrolyte is well characterized in respect to temperature, air exposure, and operating potential window. The reviewer explained that what is missing is more insights into chemical stability of the electrolyte in contact with metallic Li. Looks like observed interfacial reactivity is self-limiting and beneficial resulting in increased electronic resistivity and decreased interfacial resistivity. Because dramatic change in SEI resistivity is already observed in contact with Li disk even without external pressure applied, this reactivity will be amplified with evaporated Li and should be carefully characterized. The reviewer further suggested that evolution of interfacial layer/reactivity upon electrochemical cycling should be followed.

Reviewer 2:

Project milestones for 2019 and 2020 seemed to have been met from this reviewer's perspective, and the milestones were clearly indicated in the results section. This reviewer offered additional questions and/or comments about the presentation.

Referencing Slide 8, the reviewer asked if there are any other characterization methods to assess stability with air. Would it be possible to say something about the mechanism of ionic transport that is in these materials (GSE)? Weak electrolyte or strong electrolyte? Any anisotropy effects in these materials, due to processing? Need to make sure that the properties of GSE are uniform across the film to warrant cell to cell reproducibility.

Concerning Slide 9, this reviewer reported that impedance plots show stability. More comments on the actual magnitudes of the impedances on the slides would be very welcome. Are they high?

Regarding Slide 11, the reviewer inquired about whether it would be possible to elaborate a little more on why liquid electrolyte is being adding. Would the liquid electrolyte deplete with time/cycling? The reviewer also referenced stability test goals for high voltage (full cell). Why LFP?

Highlighting Slide12, the reviewer asked why the efficiency increases with cycling.

Reviewer 3:

The reviewer stated that the project team has all milestones for FY2020, but no progress report for the first quarter of FY2021. The project team's targeted stability with LM anode did not seem impressive—100 cycles with less than 20% degradation. However, the team has done a good job in the composition development of GSE.

Reviewer 4:

The presenter showed several compositions, and different compositions are used, in some cases this reviewer believed, to report against different milestones. A single composition should be compared against all of the milestones.

The reviewer observed "very modest" cycling performance as the presenter stated, but the reasons for this are not clear. It would be very helpful for the presenter to share some failure analysis for the samples. Otherwise, the audience is left wondering about the huge gap between the potential for glass SE technology and the demonstrated performance in a battery.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although there are no collaborations with other institutions so far, this reviewer indicated that new collaborations are planned. The topics selected for the collaboration are well defined.

Reviewer 2:

This reviewer observed no partners so far; however, new partnerships are programmed.

Reviewer 3:

No collaboration currently exists, but the reviewer opined that planned collaboration with ORNL on Evaporated Lithium on ISU GSEs to investigate LM/GSE interface and cycling performance will be excellent addition to this project. This reviewer recommended collaborating as well with someone doing DFT calculations as this might help to explain the chemistry a little better.

Reviewer 4:

As previously mentioned by this reviewer, there are no partners formally on the project, and it seems the PI is pursuing a "go-it-alone" approach. This is likely to be very slow, and not draw on the expertise of others to overcome challenges.

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 state project ended.

Reviewer 1:

A Clear path toward full cell assembly and characterization was noted by this reviewer.

Reviewer 2:

This reviewer stated that proposed future work is in-line with the project needs and should improve the performance of the GSE proposed in this project. New challenges might arise from the optimization process, given inter-dependence of the different parameters.

Reviewer 3:

The reviewer indicated that the important areas to work on are listed in future work. However, there is a question about how much progress a single PI at a university can make on a project like this within a few years.

Reviewer 4:

The reviewer described the project team's future tasks on GSE composition optimization and thin-film forming as well planned. The team has more work to do in cell forming and testing, which should be its first priority.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that "Development of Thin, Robust, Lithium-Impenetrable, High-Conductivity, Electrochemically Stable, Scalable, and Low-Cost Glassy Solid Electrolytes (GSEs) for Solid State Lithium Batteries" is certainly in-line with DOE mission and objectives. The development of new materials at a competitive cost for energy storage is greatly needed and supports the overall DOE objectives.

Reviewer 2:

GSE is an important part to make the all-solid-state-battery (ASSB), which this reviewer stated is currently one of the main approaches in making better LIBs. The project supports the DOE objective to promote electric drive vehicles.

Reviewer 3:

This reviewer asserted that the project supports main DOE goals—high conductivity, stability to air, industrial scale processing.

Reviewer 4:

Glass solid electrolyte technology has very good potential from this reviewer's perspective.

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 PI already seems to have the necessary equipment and expertise to carry on with the project. Materials cost and manpower seem to be covered with the current level of funding.

Reviewer 2:

Resources and expertise seem sufficient to achieve proposed milestones from this reviewer's perspective.

Reviewer 3:

The reviewer observed the team has sufficient technical resources in making the proposed GSEs, although the team probably needs help via collaboration in cell testing.

Reviewer 4:

The reviewer remarked that the project spans glass composition development, battery making and evaluation, and glass draw. A single PI doing this with students at a university is not sufficient resourcing to make significant progress.

Presentation Number: bat479
Presentation Title: Composite Solid Ion Conductor with Engineered Lithium Interface
Principal Investigator: Kyler Carroll (Wildcat Discovery Technologies)

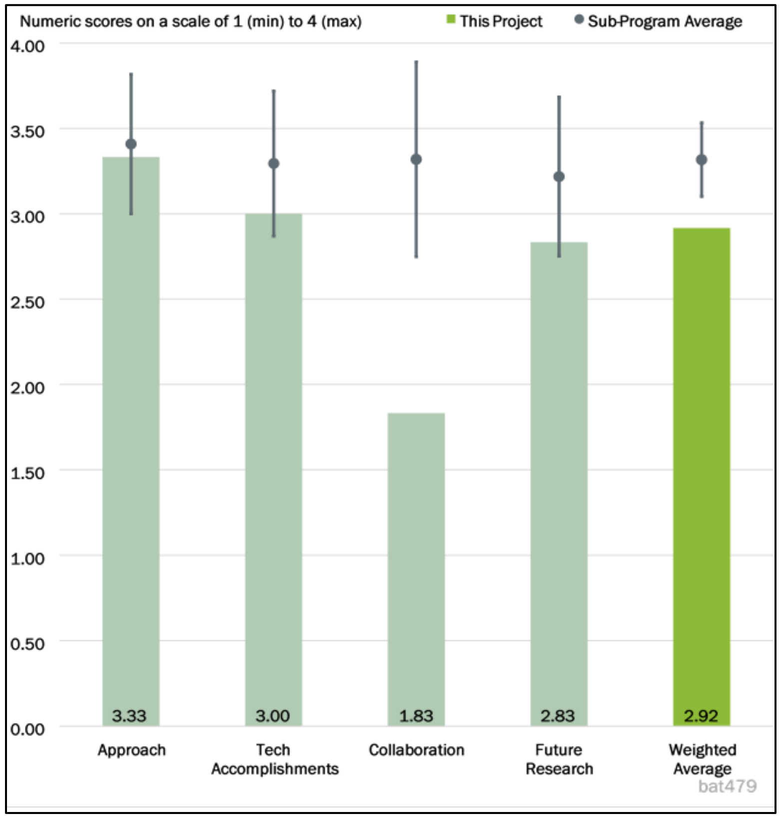


Figure 2-35 - Presentation Number: bat479 Presentation Title: Composite Solid Ion Conductor with Engineered Lithium Interface Principal Investigator: Kyler Carroll (Wildcat Discovery Technologies)

Presenter

Kyler Carroll, Wildcat Discovery Technologies

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that Wildcat is very good at developing approaches for high throughput screening. The reviewer mentioned that the approach for screening the catholyte is good, but was not so sure about using a liquid to screen the protected lithium anode interface. The reviewer added that the project team’s overall approach of finding a surface stabilizing treatment of the anode and developing a high voltage polymer/inorganic solid conductor composite for the cathode, is a good one.

Reviewer 2:

The reviewer stated that the work approach has enabled the evaluation of greater than 5000 variations, and that the trilayer approach enabled a quick metric to determine promising interfacial treatments.

Reviewer 3:

The reviewer said that testing and optimizing many different materials is a terrific approach to improving battery performance.

Reviewer 4:

The reviewer stated that the PI uses two approaches for improving solid state battery performance: solid electrolyte optimization and lithium metal protection. The reviewer remarked that for the solid electrolyte, the PI uses surface-treated inorganic ceramics to be integrated with polymers in forming composite electrolyte that shows balanced performance in ionic conductivity, mechanical and electrochemical stability, and interfacial contact. The reviewer added that for lithium metal protection, the PI uses coating on lithium metal anode to suppress dendrite formation. The reviewer wrapped up by acknowledging that these approaches are in line with the state-of-the-art understanding of the key challenges facing solid state batteries.

Reviewer 5:

The reviewer mentioned that developing polymer ceramic composite electrolytes helps to improve the interfacial contact between electrolyte and electrodes including both Li metal anode and high voltage cathode. The reviewer added that there are also some key challenges:

- Organic components are typically not chemically stable with Li metal and 4-volt (V) cathodes. Thus, this approach usually introduces interface resistance in this regard.
- The ionic conductivity of composite electrolyte without a liquid component is low.
- It is still an open question whether the composite electrolyte performs better to suppress dendrite formation than inorganic solid electrolytes.

The reviewer said that this project aims to address some of the key challenges by screening the ceramic electrolyte, polymer electrolyte (in the bulk electrolyte layer and in the cathode composite), and interfacial layer on Li metal. The reviewer stated that it is not clear whether the study on SEI formation from liquid electrolytes is necessary and can be transferred to the interlayer design in this project. The reviewer expressed that there are already a large number of published results to reveal the composition and structure of SEI formed in liquid electrolyte batteries.

Reviewer 6:

The reviewer stated that although “mechanically stable interfaces” is one of the objectives, the project does not have any quantitative criteria for and measurements of interfacial mechanical stability. The reviewer added that SSE target properties, such as greater than or equal to 8.4 gigapascal (GPa), Lithium compatibility “stable”, and processability “standard” are ill-defined.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the work to improve the interface revealed promising approaches to reduce the impedance. The reviewer added that the ability to protect the Li and also protect the electrolyte from reduction is an important accomplishment enabling more design flexibility.

Reviewer 2:

The reviewer said that surface treatment is shown to greatly reduce or even eliminate the interfacial resistance between the inorganic component and the polymer component in the solid electrolyte. The reviewer added that the PI has identified chemical approaches (formula not specified probably because it is proprietary information) to protect the lithium metal anode. The reviewer noted that composite electrolyte and lithium anode protection enable a solid-state battery cell that delivers around 180 mAh/g capacity in the voltage range of 4.3V-3V for around 20 cycles. The reviewer mentioned that the composite electrolyte showed ionic conductivity in the order of 10^{-5} Siemens per centimeter (S/cm) which needs some improvement, and that the mechanical stability of the composite electrolyte may also need to be strengthened.

Reviewer 3:

The reviewer stated that the ionic conductivity of around 10-5 S/cm was achieved by compositing $Li_{1.3}Al_{0.3}Ti_{1.7}(PO_4)_3$ (LATP) with a polymer. The reviewer added that the ionic conductivity is not high compared with data available in the public literature, and that further efforts should be done to improve the ionic conductivity. The reviewer mentioned that LATP is not stable with Li metal, and questioned whether an interfacial layer between LATP and Li can effectively suppress the reaction between LATP and Li. The reviewer thought the solid-state full cell is still run at a low rate of 0.05C at 60°C.

Reviewer 4:

The reviewer stated that the project team makes excellent progress compared to their base case. However, the reviewer pointed out that the team does not compare its best results to what others have already achieved, and the reviewer sees no evidence that the team's results are better than the best previously reported results.

Reviewer 5:

The reviewer stated that a negative interface resistance is non-physical. The reviewer could not evaluate the accomplishments based on the code names—A, B, C, ..., and M for the additive families. The reviewer questioned what the discovered "chemistry trends" are that can be used to seek further improvements.

The reviewer noted that the mechanical strength measurement method, e.g., tensile or compression, should be disclosed. The reviewer added that the decreasing Young's modulus with increasing inorganic content is counter intuitive based on the upper- and lower-bound estimates for the elastic modulus of ceramic-polymer composites. The reviewer mentioned that the Young's modulus and yield strength values for the composite solid electrolytes are too low—much below the 8 GPa modulus target.

Reviewer 6:

The reviewer noted that it is hard to measure the accomplishments of this project as there is not much discussion on C-rate or capacity per cm^2. The reviewer stated that there is no mention of addition of carbon to the cathode, and finally, with just 20% of the project left, there is no discussion of full cell cycleability, which is the hardest thing to accomplish with this chemistry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project was 20% funded by Wildcat, which is trying to develop intellectual property (IP). So, it is of little surprise that the project team does not have collaborators.

Reviewer 2:

The reviewer stated that only one company was involved.

Reviewer 3:

The reviewer remarked that the project team does not have partners.

Reviewer 4:

The reviewer noted that the project team stated that there are no collaborators.

Reviewer 5:

The reviewer observed that the PI indicated that no collaboration is involved, but that this is due to proprietary concerns.

Reviewer 6:

The reviewer encouraged the project team to collaborate with other institutions on 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that an appropriate path forward was outlined.

Reviewer 2:

The reviewer mentioned that the degradation mechanism of the full cell performance will need to be studied to identify the component that leads to cell failure. The reviewer added that the interfacial resistance may not be the only and the main reason for cell degradation. The reviewer suggested that the project team should also consider dendrite formation as one reason for full cell failure, as some full cells are clearly shorted by dendrite formation.

Reviewer 3:

The reviewer stated that the PI has proposed future research in further optimizing composite electrolyte, especially in improving the mechanical strength. The reviewer noted that the PI also proposed further research in lithium metal anode protection and has already made some progress in the project but indeed needs further improvement.

The reviewer suggested that the PI can consider further improving the ionic conductivity of the composite electrolyte as mentioned in previous comments. The reviewer encouraged the PI to also consider increasing the current density used in testing the solid-state battery cell—it is now 0.06 mA/cm^2 which may be too low.

Reviewer 4:

The reviewer remarked that the proposed future research is vague and does not have quantitative measures and goals to “Optimize incorporation of the SSE (catholyte) into the cathode” and to “Further reduce resistance between SSE and coated lithium.”

Reviewer 5:

The reviewer noted that the project team is still screening surface agents, and that it is not clear the team will be able to make a decent cell by the end of the program. The reviewer added that the project team is not sharing what it learned.

Reviewer 6:

This reviewer indicated that proposed future work is sensible, and there is promise.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that this project supports the overall DOE objectives in providing clean energy solutions. The reviewer added that specifically, the beyond Li-ion battery option has higher energy density and better safety characteristics than the conventional liquid electrolyte-based Li-ion batteries.

Reviewer 2:

The reviewer stated that if successful, the work could play a role to lower cost on a $/kWh—an important metric for the DOE.

Reviewer 3:

The reviewer mentioned that the DOE would like to see an advancement in solid state batteries as they offer high energy density.

Reviewer 4:

The reviewer agreed that the project supports the overall DOE objectives.

Reviewer 5:

The reviewer stated that yes, the project enables the utilization of lithium metal anode for high-energy density batteries.

Reviewer 6:

The reviewer remarked that better solid-state batteries is 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 stated that the project is right on target and amount of funding.

Reviewer 2:

The reviewer mentioned that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 3:

The reviewer noted that the project team has sufficient resources.

Reviewer 4:

The reviewer declared that the project has the adequate resources.

Reviewer 5:

The reviewer noted that the resources are sufficient as they match what Wildcat was willing to put forward. The reviewer added that Wildcat will have a better understanding of the difficulties of this chemistry and possible paths forward when the project concludes.

Reviewer 6:

The reviewer mentioned that the project team does not seem to have the capability to quantify “Mechanically stable interfaces.”

Presentation Number: bat480
Presentation Title: Physical and Mechano-Electrochemical Phenomena of Thin Film Li-Ceramic Electrolyte Constructs
Principal Investigator: Jeff Sakamoto (University of Michigan)

Presenter

Jeff Sakamoto, University of Michigan

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

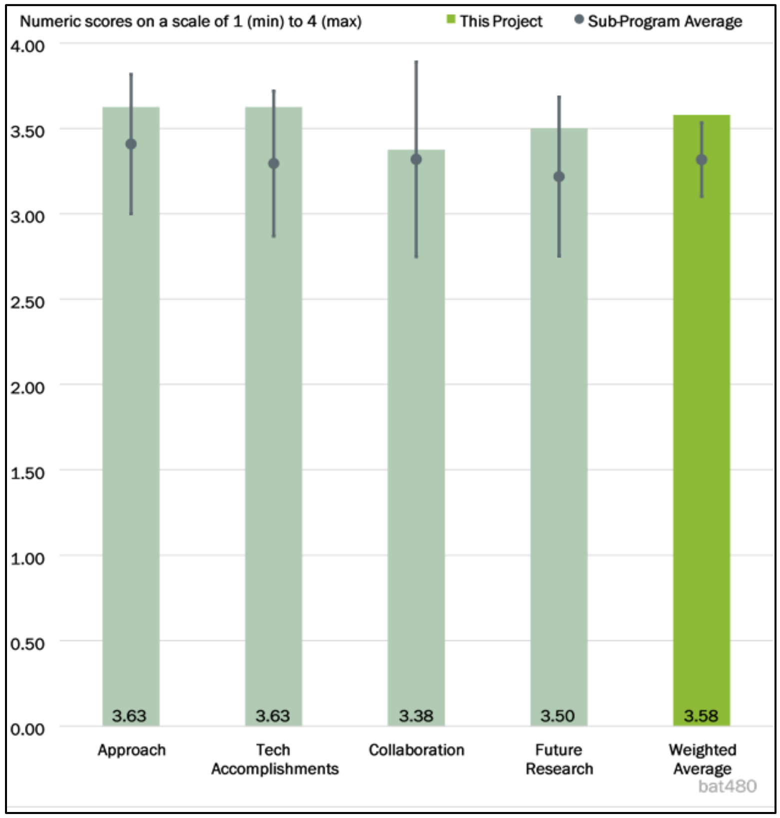


Figure 2-36 - Presentation Number: bat480 Presentation Title: Physical and Mechano-Electrochemical Phenomena of Thin Film Li-Ceramic Electrolyte Constructs Principal Investigator: Jeff Sakamoto (University of Michigan)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the work was excellent. The reviewer added that it is critical that the battery scientific community starts to understand and account for the differences in material and cell properties when using non-commercial type materials, like very thick Li or very thick solid electrolytes. The reviewer declared that it is excellent that Professor Sakamoto is doing a comprehensive study of the impacts of thickness, pressure, and current density on the stripping and plating of Li metal. The reviewer encouraged the project team to quickly incorporate studies of very thin LLZO electrolyte. The reviewer suggested that the large differences seen in behavior between thick (700 micron) and thin (20 micron) Li metal could be equaled or exceeded by changes seen in the behavior of cells using thick and thin LLZO. The reviewer noted that Professor Sakamoto correctly pointed out the radically different mechanical property of traditional glass sheets and the much thinner glass used in optical fibers.

The reviewer commented that the Battery500 program has found that pressure can extend Li metal (liquid electrolyte) cell cycle life by two times, and mentioned that understanding the quantitative role that pressure plays in Li metal cells could be critical.

Reviewer 2:

The reviewer stated that the approach of this project, as performed by Sakamoto and co-workers, aims to bridge fundamental and applied battery research in order to better understand how SSB designs (and packaging) affect the overall performance, especially with Li metal anodes. The reviewer noted that the main technical barriers addressed in this project are 1) performance (e.g., enabling Li metal anodes to achieve greater than 1000 Watt-hour per liter (Wh/L) and 2) cost (e.g., enabling Li free manufacturing to achieve less than $100/kWh). The reviewer declared that the first approach includes operando visualization analysis of in situ Li metal growth on Li garnets, while the second approach includes studying the stripping behavior of thin Li (e.g., thickness of 10 microns). The reviewer concluded that overall, this systematic approach has a great impact on the SSB community, as the plating behavior of thin and thick Li is drastically different and can also influence the cycle life of full SSB cells.

Reviewer 3:

The reviewer said that operando cell allows direct visualization of the lithium behavior upon plating and stripping, under different pressures. The reviewer remarked that it is a nice design and will facilitate the fundamental understanding of thin lithium.

Reviewer 4:

The reviewer stated that the integration of thin Li anode is important to further improve the energy density of SSBs. The reviewer mentioned that this project evaluated the Li plating/stripping behaviors in operando and observed the stacking pressure effect on the Li nucleate morphology. The reviewer added that the project provides knowledge from the anode side to address long term stability issue of SSBs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project "Physical and Mechano-Electrochemical Phenomena of Thin Film Li-Ceramic Electrolyte Constructs" reports a number of important technical accomplishments. The reviewer added that the project 1) provides important insight towards in situ Li anode formation, 2) highlights structure-property relationships of the Li metal/Li garnet interfaces, 3) compares the impact of thick versus thin Li metal, and 4) discusses the overall mechanical behavior of commercially-relevant Li metal thicknesses (10-20 microns). The reviewer explained that while these technical accomplishments are impressive, more attention should be given to approaches that prevent de-wetting of Li metal anodes, especially approaches that may overcome the apparent need to have relatively high stack pressures. The reviewer concluded that special attention should be given to the proposed solid-state Li-S prototypes.

Reviewer 2:

The reviewer noted that the project mainly focused on the fundamental understanding of thin lithium behaviors, but not the device performance. For example, it was not clear how far it is from the technology readiness level (TRL) 6 project goal.

Reviewer 3:

The reviewer said that the project team gained knowledge of the Li plating/stripping behaviors in a Li/LLZO/Cu. The reviewer added that this information will guide future adoption of methods for better utilization of Li reversibly. The reviewer noted that it is not clear what tools will be evaluated in future work to address the issue.

Reviewer 4:

The reviewer stated that the work was excellent, and that very good progress has been made toward goals. The reviewer was a bit nervous about conclusions being drawn using very thick LLZO. The reviewer understood the practice issues with obtaining thin (20 micron) and defect free LLZO, but felt like that should become a priority soon.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer mentioned that the project team appears to have close, appropriate collaborations as well as coordination with the PI's startup, Zakuro Inc. The reviewer added that this project also includes important collaborations within the lead PI's home institution, the University of Michigan. The reviewer concluded by saying that overall, the work and the team appear to be well coordinated by the PI.

Reviewer 2:

This reviewer had no comments.

Reviewer 3:

The reviewer stated that it was not clear how the team collaborates with the partner Zakuro Inc.

Reviewer 4:

The reviewer questioned what Zakuro Inc. contributes to this project, and encouraged more collaborations across project teams.

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 state project ended.

Reviewer 1:

The reviewer stated that future work looks good.

Reviewer 2:

The reviewer mentioned the PI listed very clearly the future research directions. The reviewer commented that addressing the void formation/dewetting issue is critical for the adoption of Li-free or thin Li anode.

Reviewer 3:

The reviewer stated that the project "Physical and Mechano-Electrochemical Phenomena of Thin Film Li-Ceramic Electrolyte Constructs" will end on September 30, 2022, and is approximately 50% complete. The reviewer added that the proposed future work includes further work with "Li free" manufacturing; further work with cycling thin Li metal anodes (presumably between 10-20 microns in thickness); work with cathode integration (e.g., Li-S batteries); and a continuation to link project findings with vehicle electrification needs. The reviewer suggested that while these four areas are incredibly important, special attention should be given to approaches to prevent de-wetting during Li metal stripping. The reviewer noted that overcoming this hurdle can significantly improve the utilization of thin Li metal anodes in batteries with specific energies greater than 350 Wh/kg.

Reviewer 4:

The reviewer said that Professor Sakamoto seemed to agree that studying behavior using commercially relevant LLZO thicknesses was critical although the reviewer did not see this mentioned in the project's future plans.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that it is highly relevant.

Reviewer 2:

The reviewer mentioned that this project has strong relevance to DOE. The reviewer added that the objective of this project is to overcome the performance and cost barriers associated with all-solid-state batteries by specifically understanding the physical and mechano-electrochemical phenomena at solid-solid interfaces. The reviewer noted that these results have direct implications to the electric vehicle market. The reviewer remarked that this project aims to provide a far-reaching understanding of how thick Li (e.g., thickness greater than 50 microns) and thin Li (e.g., thickness 10-20 microns) perform in all-solid-state batteries. The reviewer commented that these results have far-reaching implications for practical cells that will most likely use only 10-20 microns of Li.

Reviewer 3:

The reviewer stated that this research focuses on decreasing the thickness of lithium metal anode, which is critical for solid-state battery.

Reviewer 4:

The reviewer said that one of DOE's objectives is to improve energy density and safety of battery technology. The reviewer mentioned that this project, if successful, will enable the use of thin Li or Li-free anode for solid state batteries, which can further improve the energy density and increase battery 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 remarked that the project team was able to meet most of its proposed milestones despite COVID-19. The reviewer added that the team has the proper equipment and resources to carry out this research, and has a number of active collaborations both internally (through the University of Michigan) and externally (with Zakuro, Inc.). The reviewer noted that the team has expertise in thin film coatings, and has the resources to complete work related to exploring possible approaches to prevent de-wetting during Li metal stripping (e.g., possibly an interlayer). The reviewer concluded that overall, the project team completed great work despite setbacks from COVID-19 and met most of its milestones to date.

Reviewer 2:

The reviewer commented that the resources at the University of Michigan are great.

Reviewer 3:

The reviewer noted that the funding level is sufficient to conduct the proposed experimental work.

Reviewer 4:

The reviewer remarked that funding should increase, if possible, and the scope of work needs to be expanded.

Presentation Number: bat481
Presentation Title: Li Dendrite-Free Li7N2I-LiOH Solid Electrolytes for High Energy Lithium Batteries
Principal Investigator: Chunsheng Wang (University of Maryland, College Park)

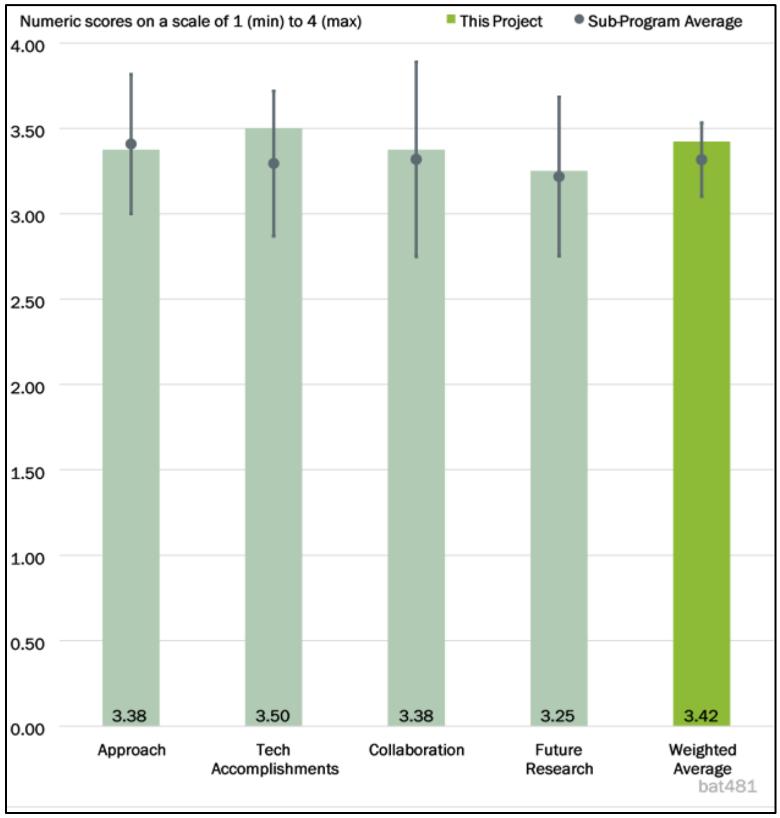


Figure 2-37 - Presentation Number: bat481 Presentation Title: Li Dendrite-Free Li7N2I-LiOH Solid Electrolytes for High Energy Lithium Batteries Principal Investigator: Chunsheng Wang (University of Maryland, College Park)

Presenter

Chunsheng Wang, University of Maryland, College Park

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project team developed several techniques to address the Li-anode/electrolyte interface problems. The reviewer added that the team developed doped Li-M alloy to enhance diffusivity at the SSE interface, and several interface layers to suppress Li dendrite growth. The reviewer noted that the electrochemical tests show promising interfacial stability.

Reviewer 2:

The reviewer mentioned that the project team developed great work and publications. The reviewer remarked that the idea of mixing lithiophobic and lithiophilic electrolytes to try to prevent Li dendrite growth while maintaining good ionic conductivity, is worth pursuing. The reviewer questioned whether this approach is really preventing Li growth or just delaying it. The reviewer commented that Li can eventually find a path via the lithiophilic phase.

Reviewer 3:

The reviewer stated that there was a good outline for the plan, but that it was somewhat limited in scope.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer mentioned that the LiF-C-LixM interlayer with mixed ionic/electronic conductivity shows good capacity retention at up to 450 cycles.

Reviewer 2:

The reviewer stated that the project is moving forward and is on target, with several good results presented. The reviewer added that the approach seems to provide some improvements with respect to performance. The reviewer noted that more microscopic characterizations might be needed to show dendrite mitigation and improved interface.

The reviewer posed a few questions about the presentation. Regarding Slide 6, the reviewer asked whether the project team can provide some details on how magnesium (Mg) addition into Li increases the Li diffusivity? If so, what is the mechanism of Li diffusion within the alloy? Additionally, the reviewer explained that alloying Li with Mg impacts some other mechanical properties. Which property is important for this system, mechanical or Li diffusivity (if really changed)?

Regarding Slide 7, the reviewer inquired about the experimental data that supports the density functional theory (DFT) results—"Li reservoir during cycling without Li-metal formation"? The reviewer asked whether high interface energy (lithiophobic electrolyte) and Li-ion conductivity are antagonistic, resulting in the need to mix-in a lithiophilic electrolyte.

This reviewer inquired about the property that was calculated to reach the conclusion on Slide 9—"First-principles calculation indicates Li_7N_2I-LiOH is stable against Li metal."

Referencing "Lithiophobic-lithiophilic gradient & ionic conductive LiF-LixMg interlayer" on Slide 11, the reviewer asked if the Li-Mg alloy is stable with Li and with the lithiophobic Li fluoride (F) phase? Are there any theoretical calculations or experimental evidence?

Reviewer 3:

The reviewer stated that the project team has demonstrated several technical accomplishments and showed progress in the overall project. The reviewer mentioned that the project is in good shape in terms of milestones and publications. The reviewer remarked that the team developed in-situ formation of a mixed electronic/ionic conductive and lithiophobic-lithiophilic gradient layer between Li and solid-state electrolyte to suppress Li dendrite growth.

The reviewer posed the following questions:

- Is the cycling necessary to form this lithiophobic-lithiophilic gradient or can it be formed with heating as well?
- Is there separate precondition cycling step that is required for the creation of this interlayer or is it happening during the first cycle?
- Is dimethyl ether (DME) liquid electrolyte completely decomposed/evaporated at the interface during cycling?
- How thick is the whole interface layer if LiF alone is approximately 200 nanometers (nm)?
- Can the thickness be further minimized with all three components preserved?
- Has the project team tried a liquid electrolyte mix without $Mg(TFSI)_2$?

- Can porous and approximately 200nm thick LiF alone protect $Li_{10}GeP_2S_{12}$ (LGPS) and serve as Li reservoir during cycling?
- What is the difference in dendrite protection by in-situ-formed LiF compared to pressed solid powder?
- When the 200-micron thick lithiophobic porous LiF-lithium nitride (Li_3N) electrolyte was used as interlayer for Li dendrite suppression, Li was penetrating approximately 10 microns deep. Is that saying that the lithiophobic component is critical for design of effective thin interlayers?

The reviewer concluded by stating that the formation process can be followed with EIS, and suggested that the role of each of the lithiophobic and lithiophilic component on the interfacial resistivity should be studied.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer mentioned there are good and effective collaborations with national laboratories and industry.

Reviewer 2:

The reviewer remarked that there is little collaboration apparent so far, but noted that the collaboration with the National Institute of Standards and Technology (NIST) and BNL is a good direction.

Reviewer 3:

The reviewer stated that there was good collaboration, but it was not clear from the presentation how much contribution was in fact present. The reviewer added that there were good and appropriate characterization techniques from two of the listed collaborators, but that the project team should better support the claims presented in this work.

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 state project ended.

Reviewer 1:

The reviewer stated that the project team is aware of the critical remaining challenges, and that it proposed future research that includes mechanical property improvement and incorporating the SSE/interphase to the NMC811 and Li_2S cathodes.

Reviewer 2:

The reviewer said that there was clear work proposed towards dendrite/critical current density (CCD) investigation but was unclear about cathode side protection.

Reviewer 3:

The reviewer observed that the proposed future work is certainly in line with the project, but that at the same time it was a little generic and mainstream. The issues to solve and phenomena set to understand are the issues the research community is striving to solve. The reviewer suggested that more specific and achievable goals would serve the project better.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the development of high-energy rechargeable Li metal all-solid-state batteries for future vehicle electrification is part of the DOE objectives.

Reviewer 2:

The reviewer mentioned that the development of new stable solid-state electrolytes will support the overall DOE objectives, and noted that new approaches such as the one presented in this work are worth pursuing.

Reviewer 3:

The reviewer commented that this project clearly adds to the understanding of the correlation between Li dendrite formation and the intrinsic properties of solid-state electrolytes such as lithiophobicity, solid electrolyte interphase, porosity, thickness, and ionic and electronic conductivity.

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 team has strong capabilities and technical resources to accomplish the project.

Reviewer 2:

The reviewer stated that the resources seem to be sufficient to cover extra materials and research needed for this project.

Reviewer 3:

The reviewer remarked that the resources and expertise seem sufficient to achieve proposed milestones.

Presentation Number: bat482
Presentation Title: Hot Pressing of Reinforced Lithium Nickel Manganese Cobalt Oxide (Li-NMC) All-Solid-State Batteries with Sulfide Glass Electrolyte
Principal Investigator: Thomas Yersak (General Motors, LLC)

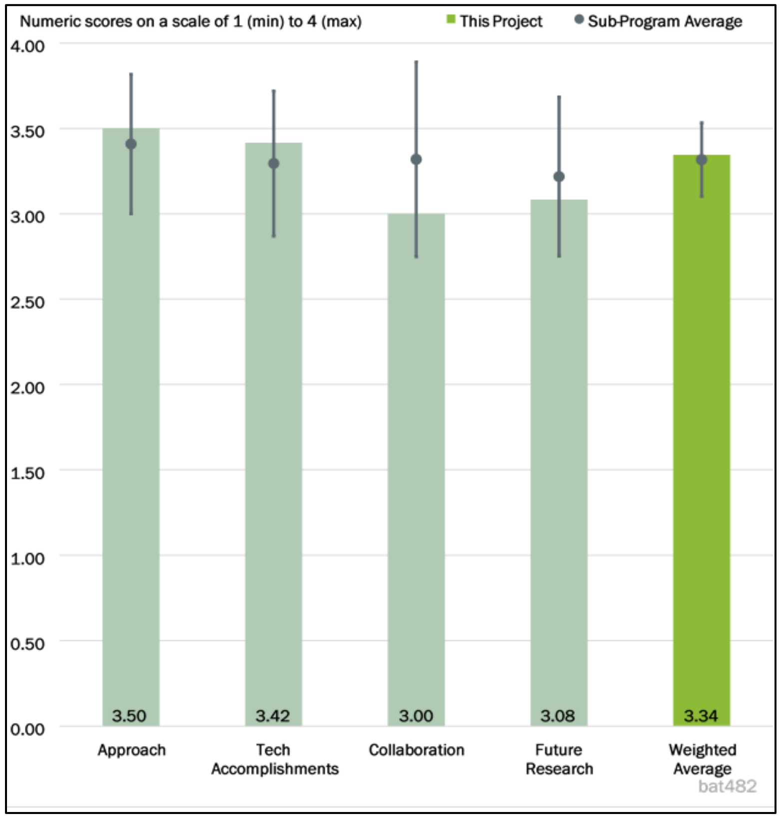


Figure 2-38 - Presentation Number: bat482 Presentation Title: Hot Pressing of Reinforced Lithium Nickel Manganese Cobalt Oxide (Li-NMC) All-Solid-State Batteries with Sulfide Glass Electrolyte Principal Investigator: Thomas Yersak (General Motors, LLC)

Presenter

Thomas Yersak, General Motors, LLC

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach is sound for R&D, and that it is good to see a study of cathode/SSE optimization.

Reviewer 2:

The reviewer said that the approach is to use hot pressing of glasses to reduce porosity and hence improve energy density, which seems like a reasonable approach. The reviewer added that since high temperature may lead to decomposition, the project team will look for additives to stabilize the electrolyte.

Reviewer 3:

The reviewer said that being able to hot-press sulfide-cathode composites using realistic pressures is a critical barrier to enabling ASSBs. The project is well-thought-out in terms of aiming for practical applications.

Reviewer 4:

The reviewer noted that the PI applies General Motors' (GM) hot-press technology to combine coated NMC and glass electrolyte together, in an effort to form a catholyte with reduced porosity and hence increased energy density. The reviewer remarked that such a feasibility test is needed for the possible application of hot-press in solid state batteries, especially from the industry point of view.

Reviewer 5:

The reviewer stated that it is highly questionable whether the objective of eliminating porosity in the cathode is achievable or even beneficial since some level of porosity may help accommodate the volume change of the positive electrode materials during electrochemical cycling. The reviewer commented that since NCM microcracking is likely caused by both thermal and diffusion induced stresses, the project should include approaches to address both, as opposed to just one (thermal).

Reviewer 6:

The reviewer affirmed that hot pressing cathode composite certainly helps to improve the physical contact between solid electrolytes and electrodes. The reviewer added that the possible sintering of solid electrolyte would also increase the ionic conductivity of solid electrolyte, which will also contribute to the kinetic performance of the cell. The reviewer commented that the main challenge would be how to mitigate the chemical stability between the cathode and solid electrolyte at elevated temperatures. The reviewer thought that the team is well aware of the challenge and proposed a detailed study on thermal stability.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this work does an outstanding job trying to deeply understand all of the features that were observed, such as how porosity is affected by component properties, how cracking occurs, how ionic conductivity is affected by hot pressing, and even identifying a new phase in the catholyte. The reviewer noted that this work also incorporates and takes advantage of an understanding of glass short range structure.

Reviewer 2:

The reviewer mentioned that the PI was able to look at variations on the catholyte and found one that works considerably better than others. The reviewer noted that the density was improved, and that there was relatively good charge/discharge demonstrated. The reviewer remarked that the lithium bromide (LiBr) addition strongly improves the performance and is a promising result.

Reviewer 3:

The reviewer stated that the project team showed that beta-Li_3PS_4 reduces the differential scanning calorimetry (DSC) heat overall and does not require coatings for improvements. The reviewer noted that the Li_6PS_5Cl does require a protective layer to reduce reaction with the cathode active material. The reviewer added that that hot pressing does reduce the porosity, but results in a loss of capacity if the cathode material is not protected. The reviewer remarked that the addition of carbon black can reduce the microcracking seen with high temperature pressing, but can lead to more surface reaction. The reviewer said that the project team selected a catholyte combination that includes hot pressing, and that the team has shown progress throughout.

Reviewer 4:

The reviewer stated that the project team identified the optimized mixing process for the cathode composite and demonstrated that the hot-pressed cathode showed better cycling performance than the cold-pressed one. The reviewer added that the team also did a comprehensive investigation on the thermal stability between cathode and electrolyte.

Reviewer 5:

The reviewer mentioned that the PI verified the possibility of utilizing cathode support for GM's hot pressed, reinforced sulfide glass separators. The reviewer added that a full cell using NMC and sulfide based catholyte, sulfide electrolyte, and indium anode was demonstrated. The reviewer noted that hot-press did show the capability of decreasing the porosity in NMC cathode.

The reviewer remarked that indium, not lithium, is used as anode in the full cell testing, which suggests that the incompatibility between the sulfide electrolyte and lithium metal is not addressed. The reviewer stated that hot-press has some side effect such as partially damaging the NMC particles, and suggested that these areas need to be improved.

Reviewer 6:

The reviewer stated that the plasma-focused ion beam PFIB image on Slide 11 suggests poor utilization of the SSE particles because they are too large and do not form percolating paths for lithium-ion transport. The reviewer added that the "Processed image" on Slide 11 shows NCM particle cracking, but does not have sufficient resolution to show interface cracking between NCM and SSE particles. The reviewer said that the latter may be more detrimental to the degradation of the positive electrode.

The reviewer suggested that the project should explore the size and volume distribution of the SSE particles in the composite electrode. The reviewer remarked that the cycle life of the composite electrodes is quite poor (Slide 14). The reviewer proposed that this is likely caused by fracture at the interface between SSE particles and NCM particles due to volume change of the NCM particles. The reviewer recommended that the project should address this fundamental challenge that is inherent in all solid-state-batteries.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer mentioned that the project seems well coordinated.

Reviewer 2:

The reviewer stated that external collaboration with researchers at Michigan Technological University and Iowa State University is planned.

Reviewer 3:

The reviewer mentioned that the project team is planning several collaborations.

Reviewer 4:

The reviewer stated that the PI collaborated with Michigan Technological University and Iowa State University.

Reviewer 5:

The reviewer noted that the existing data are mainly collected solely by the proposer, and that some collaborations with Michigan Technological University and Iowa State University are included in the plan.

Reviewer 6:

The reviewer noted some collaboration, but not much.

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 state project ended.

Reviewer 1:

The reviewer stated that the future proposed work and plan is appropriate.

Reviewer 2:

The reviewer mentioned that with the cathode chemistry and processing set, the project team will now turn to the separator processing. The reviewer noted that the team has reasonable goals.

Reviewer 3:

The reviewer mentioned that the project team has plans to greatly reduce the required pressure for hot-pressing.

Reviewer 4:

The reviewer stated that the PI proposed to limit the thickness of solid electrolyte to within 40 µm as future research, and carry out more specific test for the cell performance. The reviewer noted that both of these are indeed needed.

Reviewer 5:

The reviewer stated that the fundamental premise of eliminating porosity in the composite positive electrode is questionable because of the diffusion-induced volume changes and, consequently, stresses. The reviewer also remarked that the fracture at the interface between SSE and NCM particles, as well as the delamination at the interface between the composite electrode and the separator, should be addressed. The project should also explore the size and volume distribution of the SSE particles in the composite positive electrode.

Reviewer 6:

The reviewer said that it is expected that the side reaction between cathode and electrolyte highly depends on temperature. The reviewer suggested that the team should study the effect of temperature to identify the optimal temperature that can enable good interfacial contact, but avoid severe side reactions. The reviewer added that the mechanical stability of the hot-pressed cathode composite should also be carefully studied, as mechanical degradation such as contact loss and crack formation is one main reason for the limited cycling life of solid-state cathodes, even for the cold-pressed one.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer confirmed that this project supports the overall DOE objectives in providing clean energy solutions, specifically, the beyond Li-ion battery option that has higher energy density and better safety characteristics than the conventional liquid electrolyte-based Li-ion batteries.

Reviewer 2:

The reviewer said that this work supports the goal to achieve a higher energy density cell, which can lead to lower $/kWh.

Reviewer 3:

The reviewer stated that the project team is trying to develop an all-solid-state system, which is of interest to DOE.

Reviewer 4:

The reviewer remarked that the effort will enable safe, high energy density solid state batteries.

Reviewer 5:

The reviewer noted that the project is a good, new approach for enabling cost-effective ASSBs.

Reviewer 6:

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 stated that the program is funded appropriately.

Reviewer 2:

The reviewer stated that the project team has excellent resources.

Reviewer 3:

The reviewer said that the project team has good track record on solid-state battery development, and that it has sufficient resources.

Reviewer 4:

The reviewer remarked that a galaxy of high-quality technologies is being applied to this problem.

Reviewer 5:

The reviewer declared that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 6:

The reviewer mentioned that solid state is a challenging technology. The reviewer noted that the project team is making reasonable progress, but that there is no guarantee this will be successful.

Presentation Number: bat483
Presentation Title: Low Impedance Cathode/Electrolyte Interfaces for High Energy Density Solid-State Batteries
Principal Investigator: Eric Wachsman (University of Maryland, College Park)

Presenter

Eric Wachsman, University of Maryland, College Park

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

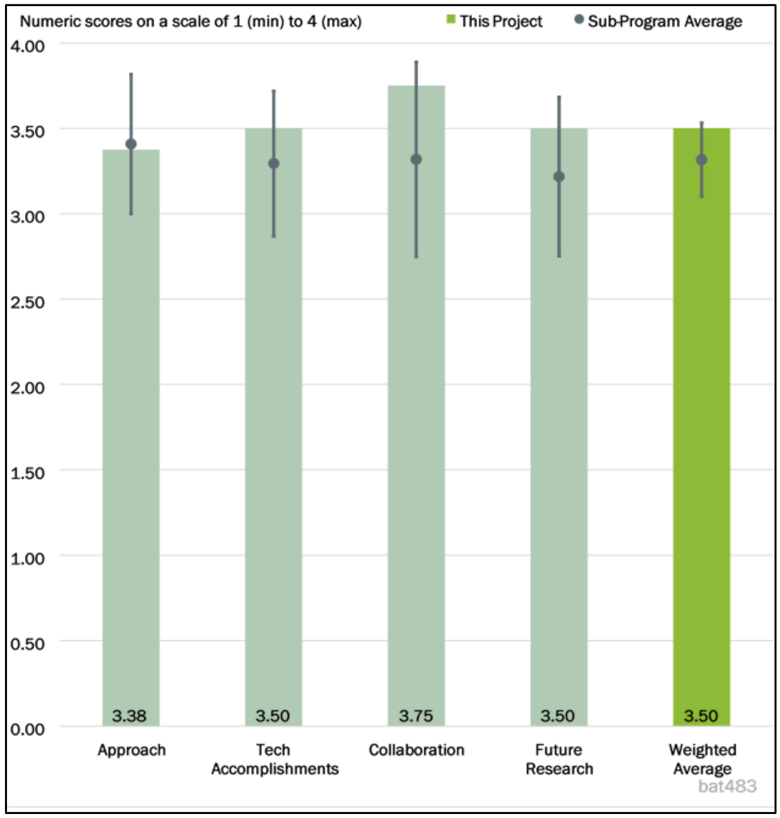


Figure 2-39 - Presentation Number: bat483 Presentation Title: Low Impedance Cathode/Electrolyte Interfaces for High Energy Density Solid-State Batteries Principal Investigator: Eric Wachsman (University of Maryland, College Park)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project team's approach is systematic and builds on its demonstrated expertise with garnet-solid-state battery. The reviewer mentioned that the team proposes to first engineer interfaces to overcome high NMC/LLZ interfacial impedance and interfacial degradation. The reviewer continued that the team will then develop processing and fabrication techniques to achieve high loading NMC/LLZ composite cathodes with low resistance and high cyclability and integrate them into all-solid-state Li-metal/LLZ cells to achieve high energy density batteries.

Reviewer 2:

The reviewer said that the project team's approaches are concentrated in the NMC/LLZ interface. The reviewer stated that the team tries to add interphase by co-sintering the interface-coated LLZT/NMC cathode. The reviewer added that the team also adopts high-throughput computation to identify coating materials, and some advanced materials characterization techniques, such as X-ray tomography, to examine the effect of structure on performance.

The reviewer remarked that in general, these are proper approaches to the research objectives, however, the team needs better understanding on the NMC materials to find the proper conditions for sintering the interface layers.

Reviewer 3:

The reviewer stated that the presentation and the path forward were very clear, and that there were great results, both from the theory as well as from the preliminary experimental data.

The reviewer commented that the first project objective focusing on identifying interfacial layers to achieve low-impedance and stable NMC/LLZ interfaces relied on the results of DFT calculations of reaction energies between LLZ and NMC cathodes as well as potential coatings. The reviewer added that the calculations are based on known stable bulk compositions and assume complete reaction. The reviewer noted that this assumption provides a limit towards complete reaction of the reactants to the pre-defined products. The reviewer said that although they are a very good indicator of possible chemical reactivity of the components, the experimental results show possible phases at the interface not predicted by the model.

The reviewer stated that from XRD results $La_2Ni_{0.5}Mn_{0.5}O_4$ and $La_2Ni_{0.5}Co_{0.5}O_4$, seem to be the reaction products for all NMCs. The reviewer emphasized that there is no dependence on NMC composition, and that it is not present in the table of reaction products in the DFT screening results. The reviewer also stressed that for coatings, Li_2CO_3 seem to be a good candidate, and that there is then no need for complicated coatings.

The reviewer posed the following questions:

- How much delithiated NMC (d-NMC) is left?
- Can delithiation trigger instability within the cathode materials itself without even invoking the interface with lithium lanthanum zirconate (LLZO), i.e., decompose by itself?
- Can the project team provide more information about $LiNiO_2$ and $LiMnO_2$ results in the table? Have there been any reactions with LLZO?
- Regarding screening under voltage, how does one distinguish between 3V and 5V for LLZO? Does Li chemical potential change in LLZO?
- Supposing that 3V for NMC would correspond to a certain SOC and 5V to higher SOC, which NMC is used in the approach slide?
- In an earlier slide the project team mentioned more Mn leads to lower interfacial stability. In a later slide “Thermal Stability of LLZO with Different NMC Compositions,” it is mentioned that, “the increase in Ni content increases NMC/LLZO reactivity.” Does this mean that both Mn and Ni lower the interfacial stability?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that starting with computational screening based on DFT for possible stable interfaces (solid state electrolyte, cathode, and cathode-coating), is helpful in eliminating obvious unstable compounds. The reviewer remarked that the DFT results are comprehensive within the proposed approach, and that the approach and calculations are simple and straightforward, but quite effective.

Reviewer 2:

The reviewer stated that the project team has reported results of calculations and materials characterizations. The reviewer added that the initial electrochemical test shows some effects of the interlayer, but the performance is far from the targeted standards.

Reviewer 3:

The reviewer noted that the campus was closed for three months due to COVID-19 and has only partially reopened, thus experimental results were limited resulting in a six-month no-cost extension (NCE). The reviewer added that the project team has demonstrated several technical accomplishments and progress in the overall project. The reviewer mentioned that the project is in good shape in terms of milestones and publications.

The reviewer stated that computationally and experimentally, the team determined the interfacial stability between LLZ solid electrolytes and NMC cathode and performed high-throughput computations of promising coating materials to determine appropriate compositions to stabilize the LLZ-NMC interface, guiding next stage experiments.

The reviewer said that the team demonstrated that percolating lithium film is necessary to enable low area-specific resistance (ASR) of the Trilayer. The reviewer added that the model indicated gradient porosity structure will perform better and the team fabricated gradient porosity structure and characterized by X-ray tomography.

The reviewer remarked that the team demonstrated interfacial layer that can stabilize LLZ-LCO interface to enable fast Li-ion transfer, but did not give more details on the interface layer chemistry or microstructure.

The reviewer noted that the team identified the elements and compositions with the widest stability range as promising coating candidates for interfacial stabilization. What is the desired thickness of an atomic layer deposition (ALD) coating? How does the team plan to address the mechanical damage and the formation of cracks, especially in the Ni-rich materials, due to large volume change during cycling? To be preserved, how thick can the coating be, if with poor ionic conductivity, to still be beneficial for overall cell performance?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project team collaborated with national laboratories and other universities in the US and Germany. The reviewer remarked that the collaboration is quite productive.

Reviewer 2:

The reviewer said that this team is a great example of collaborative experimental and computational work.

Reviewer 3:

The reviewer said that there is great collaboration between theory and experiment. The reviewer suggested that more feedback between the two could improve the overall understanding and outcome of the project. The reviewer noted that this last point is in fact mentioned in the future work already.

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 state project ended.

Reviewer 1:

The reviewer remarked that the excellent future work plan focuses on interface design by coating, co-sintering and fabrication of a trilayer cell with composite NMC-LLZ to achieve desired performance metrics.

Reviewer 2:

The reviewer mentioned that the proposed future work is certainly appropriate for the continuation of the project. The reviewer said that the project team has several challenges ahead, however, it is well equipped for the challenge.

Reviewer 3:

The reviewer stated that the project team's major challenge is the thermochemical stability of the sintering process. The reviewer noted that it seems like the team has recognized the challenges but did not present details of the plan to address them.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the research supports DOE objectives.

Reviewer 2:

The reviewer noted that designing new stable SSE-cathode and cathode-coatings-SSE is the goal for better performing SSB. The reviewer added that this project supports the overall DOE objectives, and that the use of computing techniques and power available at DOE facilities is also a plus.

Reviewer 3:

The reviewer mentioned that the objectives to develop novel processing techniques to fabricate NMC/LLZ composite cathodes with low interfacial resistance and enable high-performance ASSBs with an energy density of 450 Wh/kg and 1400 Wh/L and negligible degradation for 500 cycles, support overall 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 noted that the project team has sufficient resources to conduct the work.

Reviewer 2:

The reviewer said that the resources and expertise seem sufficient to achieve the proposed milestones.

Reviewer 3:

The reviewer stated that the project, being both computational and experimental, requires manpower (theorists and experimentalists) as well as equipment and materials.

Presentation Number: bat484
Presentation Title: Developing an In-Situ Formed Dynamic Protection Layer to Mitigate Lithium Interface Shifting: Preventing Dendrite Formation on Metallic Lithium Surface to Facilitate Long Cycle Life of Lithium Solid State Batteries
Principal Investigator: Deyang Qu (The University of Wisconsin-Milwaukee)

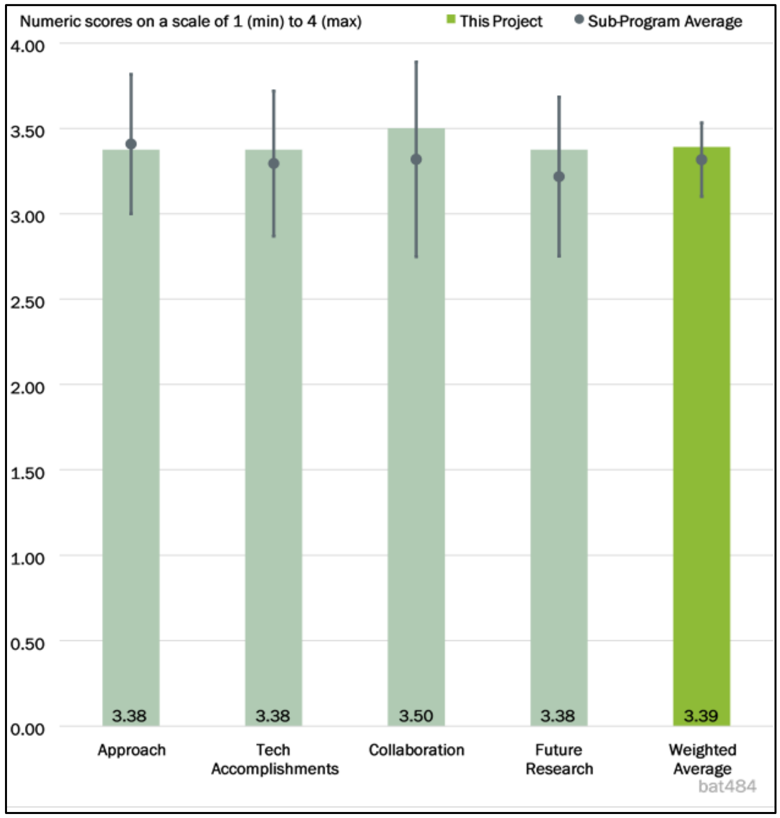


Figure 2-40 - Presentation Number: bat484 Presentation Title: Developing an In-Situ Formed Dynamic Protection Layer to Mitigate Lithium Interface Shifting: Preventing Dendrite Formation on Metallic Lithium Surface to Facilitate Long Cycle Life of Lithium Solid State Batteries Principal Investigator: Deyang Qu (The University of Wisconsin-Milwaukee)

Presenter

Deyang Qu, The University of Wisconsin-Milwaukee

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the team addresses Li dendrite growth issue in solid state batteries by incorporating in situ formed dynamic protection layer on metallic Li. The reviewer declared that the approach includes synthesis, in situ monitoring, and cell performance test, which are well designed and feasible. The reviewer mentioned that the underlying physics shall be better understood in the later stage of the project.

Reviewer 2:

The reviewer stated that the project team has a very good approach for working to stabilize the very reactive Li interface and react with and destroy Li dendrites. The reviewer added that polymer coating that is formed in situ appears to inhibit Li dendrite growth, and doing that in situ means (in principle) that any reactive Li surface is coated with this polymer. The reviewer was somewhat surprised that the layer is not chewed up in the process of holding onto some of the Li.

The reviewer encouraged Professor Qu to start using much thinner solid-state electrolytes. The reviewer remarked that Professor Sakamoto showed the dramatically different mechanical properties of thin and thick Li and it is suspected that similar large differences will be seen in the behavior of thin versus thick SSEs.

Reviewer 3:

The reviewer said that the approach of this project, as performed by Qu and co-workers, aims to assess the performance of beyond Li-ion cells with Li metal anode by 1) gaining new knowledge about Li filament growth, 2) investigating new inter-layers for Li metal anodes, 3) developing a pouch cell with greater than 400 Wh/kg at C/3 for greater than 200 cycles, and 4) fabricating Li anodes with greater than 2Ah/g gravimetric energy density. The reviewer stated that the team's approach includes the development of an in situ and operando cell to observe Li dendrite growth, formation of dynamic protection layers on metallic Li anode surfaces, and assessment of full Li metal cells with NMC811/SSE/Li cells and dimethoxy benzoquinone (DMBQ)/SSE/Li cells. The reviewer noted that while the first year of this project aims to develop the benchmark tests for these materials, the approach needs to have more focus towards fabricating thinner solid-state electrolytes as well as addressing possible interdiffusion between the sulfide-based solid-state electrolytes and the oxide-based NMC cathodes.

Reviewer 4:

The reviewer noted that the in-situ diagnostic tools are very powerful in studying the dendrite problem of lithium metal, and that the project is well-designed. The reviewer stated that the fundamental mechanism for the dynamic protection layer can be more clearly identified in the presentation—for example, by explaining how the protection layer evolves during cycling.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated there was very good progress and excellent work. The reviewer questioned the value of using low capacity and low voltage cathodes to enable sulfide electrolytes. The reviewer mentioned that the 250mAh/g, 2V cathode used here is good for showing progress on the Li side, but it's unclear if this can be performance or cost-effective when compared to NMC cathodes that provide 220mAh/g and 3.7V—almost 60% higher energy density.

The reviewer remarked that it was not clear if this polymer passivation layer also results in a coulombic efficiency needed for long term cycling. The reviewer mentioned that the 100 cycles shown is too short to see any clear CE shortfall, and added that the scale on the CE plot is 0-100, so even 99% (which is much too low) looks good.

Reviewer 2:

The reviewer stated that the project "Developing an In-Situ Formed Dynamic Protection Layer to Mitigate Lithium Interface Shifting: Preventing Dendrite Formation on Metallic Lithium Surface to Facilitate Long Cycle Life of Lithium Solid State Batteries" reports a number of important technical accomplishments, including assembly/testing of the new operando electrochemical cells; and the formation of new protective layers on Li metal anodes (e.g., organic and inorganic). The reviewer said that the performance of the cells is approaching the project goals, yet the project team still needs a relatively high stack pressure to cycle the as-assembled cells. The reviewer suggested that in the coming years, special attention should be given to fabricating thinner solid-state electrolytes; cycling at higher current densities with thin Li metal anodes (10-20 microns in thickness); and understanding the effect of the stack pressure on the electrochemical performance. The reviewer noted that the combination of these three thrusts will help achieve batteries with higher total specific energies.

Reviewer 3:

The reviewer noted good progress in this reporting period, however, it seems that the cycle life of the protected Li is still very far from the overall objective, in particular the pouch cell.

Reviewer 4:

The reviewer stated that the team developed an in-situ formed dynamic protection layer to prevent or reduce the Li dendrite formation. The reviewer added that the project team has tried conductive polymer, red P, indium (In)-Li alloy and LPSCl to prevent direct contact of halide with Li. The reviewer noted that some materials may reduce the Li dendrite growth judging from in situ/ex situ optical imaging. The reviewer said that significant cycling stability improvement has been found with the protection. The reviewer remarked that in some slides such as Slide 12, it is unclear what protection layer the team refers to. The reviewer mentioned that cycling stability data from polymer and red P protection approaches seem to be needed in the follow-up studies.

The reviewer said that the halide/LPSCl dual electrolyte work seems to be less relevant to the in situ formed protection layer, and that it is not clear if additional protection layer was used on metallic Li and what was used.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted no issues, and remarked that there are good interactions with Millpore, national laboratories, and universities.

Reviewer 2:

The reviewer stated that the project team appears to have close, appropriate collaborations, especially with labs outside of the University of Wisconsin - Milwaukee. The reviewer said that specifically, the PI works with the University of Washington, Cornell University, PNNL, BNL, as well as Millipore Sigma. The reviewer notes that some work was completed in collaboration with Wuhan University in China (to develop the spectroscopy-based techniques). The reviewer said that the combination of these individuals will ensure a thorough understanding of the new interlayers as well as the performance of the solid-state batteries.

Reviewer 3:

The reviewer noted that there are multiple collaborations with universities and national laboratories.

Reviewer 4:

The reviewer reported that the contributions from collaborators have been clearly shown in Slide 15.

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 state project ended.

Reviewer 1:

The reviewer noted good future research.

Reviewer 2:

The reviewer remarked that the proposed future research looks logical.

Reviewer 3:

The reviewer stated that for future work, the project team will optimize and down select the Li protection layer, fabricate pouch cell, and understand the fundamental mechanisms. The reviewer agreed that this is very logical planning, and if successful, it will be a big step in addressing the electrolyte-Li interfacial stability issues.

Reviewer 4:

The reviewer stated that the project "Developing an In-Situ Formed Dynamic Protection Layer to Mitigate Lithium Interface Shifting: Preventing Dendrite Formation on Metallic Lithium Surface to Facilitate Long Cycle Life of Lithium Solid State Batteries" will end on September 30, 2022, and is approximately 50% complete. The reviewer reported that the proposed future work includes further experiments to elucidate dendrite/filament growth in the as-assembled all-solid-state batteries; demonstration of the effectiveness of the organic protection layers towards Li plating and suppression of filaments; optimization of material processes as well as cell fabrication procedures; and fabrication of 1 Ah pouch cells for final deliverables. The reviewer noted that while this proposed work is ambitious, this work relies on the funding levels and coordination among the multiple researchers that contribute to this project. The reviewer urged the project team to down select the materials to focus on the best performing solid-state electrolyte/cathode combination, in order to mitigate the risk. The reviewer added that once identified, the team can focus on establishing degradation models to better guide optimization studies. The reviewer suggested that once the materials are down selected, the team dedicates efforts to form thin solid electrolyte films (e.g., 20-40 microns in thickness) of the chosen solid-state electrolyte.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the work is very relevant, as stabilizing the Li interface is the number one problem in battery R&D and success would enable a new class of high energy inexpensive EV batteries.

Reviewer 2:

The reviewer stated that this project has a strong relevance to DOE. The reviewer remarked that specifically, the objective of this project is to overcome the performance barriers associated with all-solid-state batteries by specifically diagnosing electrochemical phenomena at solid-solid interfaces and by forming dynamic surface protection layers on Li metal anodes. The reviewer said that these results have obvious and direct implications to the electric vehicle market.

Reviewer 3:

The reviewer noted that protecting lithium anode is critical for developing solid-state batteries.

Reviewer 4:

The reviewer said yes, and added that solving the interfacial stability issue will enable the use of highly conductive and easy processing halide and sulfide electrolytes for high-energy-density high-safety all-solid-state batteries. The reviewer concluded that it thus will support the DOE objectives in clean energy storage and utilization.

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 no issues.

Reviewer 2:

The reviewer stated that the project has sufficient resources.

Reviewer 3:

The reviewer said that the resources are adequate for the scope of the work.

Reviewer 4:

The reviewer stated that the project team was able to meet most of its proposed milestones even despite COVID-19. The reviewer added that the team has the proper equipment and resources to carry out this research, and that it was able to build new facilities and capabilities in order to enable this work. The reviewer remarked that this team has a number of active collaborations (University of Washington, Cornell University, PNNL, BNL, as well as Millipore Sigma), which can ensure the success of the project moving forward. The reviewer suggested that the team should focus on making thin solid electrolyte membranes in the near future, which may require additional equipment. The reviewer concluded that overall, this team appears to have sufficient resources to complete this work.

Presentation Number: bat485
Presentation Title: Molecular Ionic Composites: A New Class of Polymer Electrolytes to Enable All Solid-State and High Voltage Lithium Batteries
Principal Investigator: Louis Madsen (Virginia Polytechnic Institute and State University)

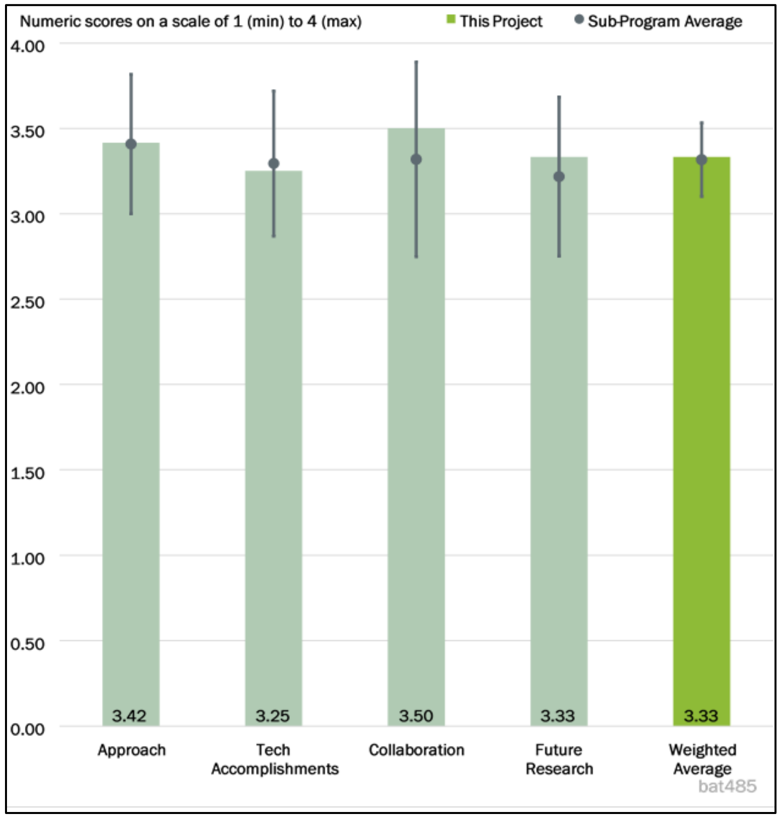


Figure 2-41 - Presentation Number: bat485 Presentation Title: Molecular Ionic Composites: A New Class of Polymer Electrolytes to Enable All Solid-State and High Voltage Lithium Batteries Principal Investigator: Louis Madsen (Virginia Polytechnic Institute and State University)

Presenter

Louis Madsen, Virginia Polytechnic Institute and State University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the PI uses molecular ionic composite as the solid electrolyte to meet the general requirements of high ionic conductivity, good mechanical strength, and high voltage stability. The reviewer said that the PIs shows clear understanding of state-of-the-art of solid-state batteries and the challenges to be addressed. The reviewer noted that the proposed molecular ionic composite is a new material that was not or little explored previously.

Reviewer 2:

The reviewer mentioned that the approach is sound and novel, and that the technical barriers have been addressed for the most part.

Reviewer 3:

The reviewer said that the project team is developing a new class of SE, which is a bull’s eye for an important barrier. The reviewer noted that the project exacerbates low temperature performance.

Reviewer 4:

The reviewer stated that in the “Approach” section, the project team indicates that it will develop the electrolyte, evaluate it electrochemically, and measure and understand the transport properties. The reviewer added that in reality the team was performing a lot of testing at elevated temperatures and at currents considered low for Li-ion (less than 1 mA/cm^2). The reviewer remarked that the team then tested it with $LiFePO_4$ as a cathode and just the polymer as the binder. The reviewer said that with NMC, the project team uses a combination of binder and, what looks like ionic liquid to make a cell but does not provide cycling data.

Reviewer 5:

The reviewer noted that the targeted elastic modulus of greater than 1 GPa seems too low to overcome lithium dendrite penetration.

Reviewer 6:

The reviewer remarked that the team aims to develop better polymer electrolytes based on molecular ionic composites. The reviewer noted that combining highly rigid and charged polymers such as Li-PBDT with lithium salt and additive can help improve the performance while maintaining good mechanical strength of the polymer electrolyte. The reviewer stated that the key challenges would be the low Li transference number and the limited oxidative stability of the proposed polymer electrolytes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the development of a new polymeric electrolyte is a significant accomplishment in itself. The reviewer added that the challenge seems to be to deal with a somewhat low transference number, at least compared to ceramic single ion conductors. The reviewer noted that there is a great benefit relative to ceramics in processability. The reviewer remarked that it is somewhat surprising that the interface should cause poor low temperature performance, as it would be expected to be less of problem for a polymer system.

Reviewer 2:

The reviewer stated that using molecular ionic composite (MIC) as a binder for the positive electrode seems quite speculative since the mechanical properties of the MIC, including the adhesive strength, are either unknown or lower than PVDF. The reviewer added that the active material NMC to binder/carbon black (CB) ratio, NMC 811:CB:MIC= 8:1:1, is too low compared to the state-of-the-art.

Reviewer 3:

The reviewer mentioned that high ionic conductivity of 10^{-3}/cm has been achieved at room temperature. The reviewer noted that this number is very high for polymer electrolytes. The reviewer remarked that the Li transference number is only 0.12 which is lower than the mainstream liquid electrolytes. The reviewer stated that the project team also demonstrated excellent cycling data for the Li-Li symmetrical cell at various temperatures. The reviewer added that the interfacial resistance between polymer and Li seems to be high compared with that of other polymer electrolytes. The reviewer said that the current full cell (Li/LFP) data shows that the electrolyte would need to be cycled at elevated temperatures greater than 60^{o}C. The reviewer concluded that including the comparison of this data with polyethylene oxide (PEO)-based polymer cells will be helpful to evaluate the progress of this project.

Reviewer 4:

The reviewer stated that the cell runs great at 150^{o}C, and that the project team is looking into potential applications at such temperatures. The reviewer added that if the team can find such applications, it would benefit by being able to develop the technology.

The reviewer mentioned that it can be made using low-cost, scalable processes, which is a major plus. The reviewer said that the fact that it needs moderate to high temperatures is a significant downside, however, and limits its applicability. The reviewer remarked that considering that the material is made up largely from ionic liquids, there is doubt that the team can lower the temperature.

Reviewer 5:

The reviewer stated that the PI has been very productive in terms of publications, including several high impact papers. The reviewer added that the synthesized molecular ionic polymer electrolyte shows high ionic conductivity (up to 1.5mS/cm) at room temperature.

The reviewer noted that the transference number is still low at this point (0.12) and needs solid improvement. The reviewer reported that it seems that $LiFePO_4$ is the only cathode used for all the tested cells, and that the NMC is mentioned in the slide, but no electrochemical performance is shown.

Reviewer 6:

The reviewer stated that the synthesized composited electrolytes consist of ionic liquids and a polymer to form self-standing, transparent films. The reviewer noted that the project team measured the conductivity as a function of temperature and the diffusion coefficient. The reviewer did not know what is meant by the diffusion coefficient of the anion and the cation. The reviewer added that the team measured its mechanical properties, and measured the cycleability in a Li symmetric cell at different temperatures and different current densities. The reviewer noted that the highest current density at room temperature was 0.15 mA/cm^2 with an overvoltage of 200 mV, which is a resistance of 1333 $ohm.cm^2$ (not great). The reviewer said that the team achieved 800 cycles while passing 0.05 mAh/cm^2 per cycle (not that impressive). The reviewer declared that the team made a cell with $LiFePO_4$ as cathode and achieved 350 cycles before irregularities appeared in the coulombic efficiency, and that there was no mention of the area specific capacity of the cell. The reviewer mentioned that the team made a cell with NCM as the cathode and did not provide any cycling data.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration is good across the team.

Reviewer 2:

The reviewer mentioned that the project team used SLAC and universities to characterize material and synthesize material.

Reviewer 3:

The reviewer stated that the collaboration between the PI and co-PI appears to be highly effective and productive.

Reviewer 4:

The reviewer said that the project team has a strong collaboration with Pennsylvania State University (PSU), University of North Carolina (UNC), and Stanford Synchrotron Radiation Lightsource (SSRL).

Reviewer 5:

The reviewer remarked that the PI collaborated with both national laboratories and universities.

Reviewer 6:

The reviewer noted moderate collaboration aimed at supporting the main work at Virginia Tech.

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 state project ended.

Reviewer 1:

The reviewer stated that appropriate work is outlined to further develop this project.

Reviewer 2:

The reviewer mentioned that appropriate goals for future work have been laid out.

Reviewer 3:

The reviewer said that the PI is aware of aspects that need to be improved such as decreasing electrolyte thickness, increasing transference number, and increasing the cathode voltage (from $LiFePO_4$ to NMC). The reviewer noted that the PI proposed specific measures to address them in future research.

Reviewer 4:

The reviewer said that the project team is now going to start optimizing its chemistry for NCM cells. The reviewer added that the team is planning to do what most solid-state systems need to do, which is to address stability at the cathode, develop a technique for making a thinner separator of the electrolyte, and improve the ionic conductivity, all with no clear plan to do any of them.

Reviewer 5:

The reviewer stated that the mechanical property measurements can be further enhanced, including the measurement of interfacial properties between MIC and the active materials, and that between the electrode and the current conductors.

Reviewer 6:

The reviewer noted that more research should be done to understand the reason for the limited Li transference number. The reviewer said that the project team will also need to study in detail the interfaces between Li anode and polymer electrolyte, as the current interfacial resistance is large for an electrolyte with a 10-3 S/cm ionic conductivity. The reviewer also recommended comparing the data with PEO-based cells using the same electrodes. The reviewer was unclear on how the team will improve the oxidative stability of the polymer electrolytes to enable 4V or even 5V cathodes, even though the co-PI slightly mentioned some promising results.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the processability and potential low cost directly support the DOE objectives.

Reviewer 2:

The reviewer noted that the DOE sees value in investigating Li based cells, and that this project team is working in that direction.

Reviewer 3:

The reviewer remarked that the project is highly relevant to the overall DOE objectives.

Reviewer 4:

The reviewer confirmed that the efforts will enable high voltage polymer based solid-state batteries.

Reviewer 5:

The reviewer said yes, the project team is aiming at an important goal, finding a new class of SEs.

Reviewer 6:

The reviewer remarked that this project supports the overall DOE objectives in providing clean energy solutions. The reviewer added that specifically, the beyond Li-ion battery option has higher energy density and better safety characteristics than the conventional liquid electrolyte-based Li-ion 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 mentioned that the project is resourced appropriately.

Reviewer 2:

The reviewer noted that the project team has excellent resources both internally at Virginia Tech and through the collaborators.

Reviewer 3:

The reviewer mentioned that the resources are sufficient.

Reviewer 4:

The reviewer observed sufficient resources.

Reviewer 5:

The reviewer noted that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 6:

The reviewer stated that this is in line with the other projects, and that it is risky research funded at an 80% level by DOE. The reviewer remarked that one needs to balance promise with reality.

Presentation Number: bat486
Presentation Title: All Solid State Batteries Enabled by Multifunctional Electrolyte Materials
Principal Investigator: Pu Zhang (Solid Power, Inc)

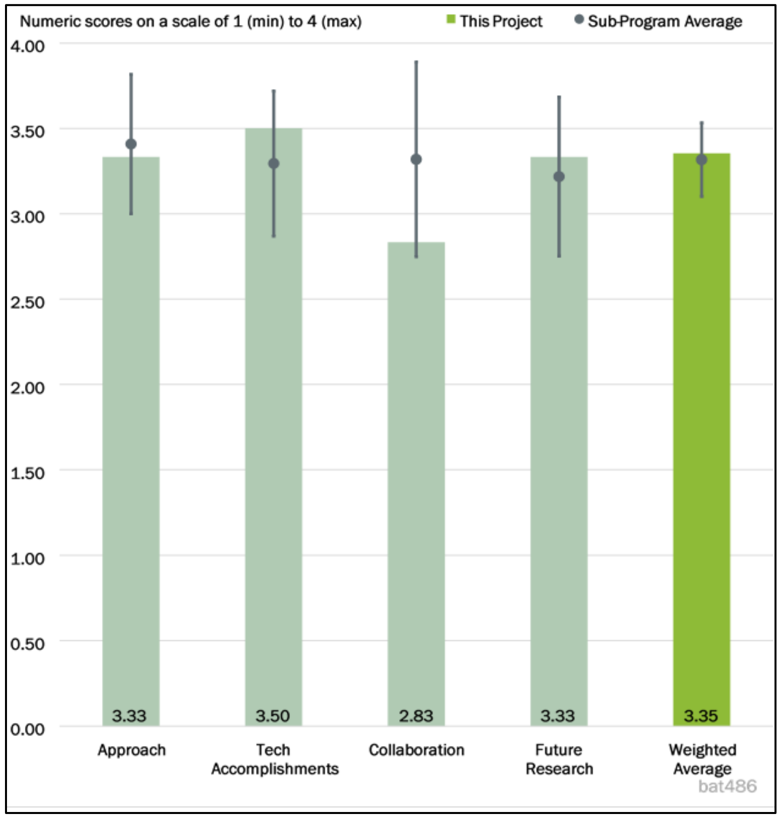


Figure 2-42 - Presentation Number: bat486 Presentation Title: All Solid State Batteries Enabled by Multifunctional Electrolyte Materials Principal Investigator: Pu Zhang (Solid Power, Inc)

Presenter

Pu Zhang, Solid Power, Inc

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach of this project, as performed by Zhang and co-workers, aims to develop solid-state electrolytes to enable high energy density solid-state batteries by using roll-to-roll-processes. The reviewer added that the general approach encompasses the formation of slurry-based deposition of cathode composites followed Solid Power's proprietary solid electrolyte. The reviewer mentioned that this approach is both economical as well as effective, as it requires the same (general) equipment that Li-ion battery manufacturing requires, so transfer from Solid Power to other production lines is expected to be relatively quick. The reviewer said that in terms of the performance, this approach yields cells that retail 93% of their capacity after 200 cycles. The reviewer concluded that overall, the approach of Zhang and co-workers addresses the technical barriers, and their team is on track to meet their goal in the coming fiscal year.

Reviewer 2:

The reviewer remarked that the project team develops highly conductive sulfide-based electrolyte for the assembly of solid-state pouch cells using R2R methods. The reviewer said that it will address the scaling up barriers for solid-state batteries for commercial applications.

Reviewer 3:

The reviewer stated that it is very difficult to assess the approach, given the lack of detailed technical data. The reviewer mentioned that the main issue with sulfide electrolytes is their instability at voltages above 3.5V, but that it is not clear how Solid Power is addressing this. The reviewer noted that the speaker said it is doing so with surface coatings and SSE dopants, but that is too vague to assess.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project "All Solid-State Batteries Enabled by Multifunctional Electrolyte Materials" reports a number of important technical accomplishments, including 1) roll-to-roll processing of solid-state electrolytes as films, and 2) the formation of solid electrolyte-cathode interfaces that ensure charge-transfer at C/5 and C/2 rates. The reviewer noted that as of now, the team is on track to meet FY 2021 goals and is on track to meet FY 2022 goals. The reviewer reported that though the performance of the solid electrolyte/cathode interface retains greater than 93% of the capacity after 200 cycles, the degradation pathway of the cathode/solid electrolyte interface is not entirely clear.

Reviewer 2:

The reviewer said that the project team has accomplished the set milestones and made great progress. The reviewer added that ionic conductivity of 4.5 x 10-3 S/cm at room temperature (RT), CCD greater than 6 mA/cm^2, and 93% capacity retention after 220 cycles were achieved, which leads to one step further towards commercial application.

Reviewer 3:

The reviewer said that the results to date look reasonable but to assess the high V stability of this sulfide SSE, the PI should conduct some longer-term calendar life studies at 100% SOC and monitor the capacity and impedance of the cell. The reviewer added that it is very nice that Solid Power has gotten its SSE to 70 microns, which is at least in the range of where commercial SSEs will need to be.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that SP has the University of California San Diego (UCSD) on its research team, but that it was not very clear what contribution UCSD made in these results, as there was no discussion of "material characterization or cell failure analysis."

Reviewer 2:

The reviewer remarked that this team appears to have close, appropriate collaborations between team members as well as its sub-contractors at UC San Diego. The reviewer added that specifically, the synthesis, profess development, cell assembly, and cell testing is completed in house at Solid Power, while the material characterization and cell failure analysis is completed at UC San Diego. The reviewer said that both teams appear to work synergistically on this project.

Reviewer 3:

The reviewer indicated that the collaboration seems to be on schedule.

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 state project ended.

Reviewer 1:

The reviewer remarked that it is good that Solid Power is moving toward even thinner SSEs and is planning to build and test 300 and 350Wh/kg cells. The reviewer noted that silicon cells are currently achieving 300-

350Wh/kg and over 1000 cycles. The reviewer encouraged SP to add calendar life studies here to demonstrate the stability of their system at 4xV.

Reviewer 2:

The reviewer noted that the project "All Solid-State Batteries Enabled by Multifunctional Electrolyte Materials" is anticipated to end in September 2022 and is approximately 60% complete. The reviewer said that proposed future work includes (1) demonstrations of solid-state cells with 500 cycles in a 300 Wh/kg design by Q8 and (2) fabrications of prototype pouch cell greater than or equal to 2 Ah with 1000 cycles, 350 Wh/kg by Q12. The reviewer mentioned that this future work will encompass the fabrication of thinner solid electrolytes in order to improve the specific capacity of the battery. The reviewer stated that in terms of future work, more time will need to be dedicated to the fabrication of thinner solid electrolyte separators (e.g., 20-40 microns in thickness) through the exploration of new slurry formulations. The reviewer added that the Solid Power team plans to explore the cell operation at room and decreased temperatures. The reviewer reported that such studies are important to enable batteries that will perform well over a wide range of temperatures. The reviewer remarked that in order to deliver pouch cells with greater than 350 Wh/kg, Solid Power is exploring NMC-based cathodes with greater than 80% Ni content (validation pending). The reviewer declared that if these cathodes perform as intended, Solid Power is on track to meet their targets this upcoming fiscal year. The reviewer concluded that collectively, the proposed future research is appropriate considering the barriers noted.

Reviewer 3:

The reviewer stated that the project team proposes to further improve the performance and the cell level capacity. The reviewer mentioned that it is not clear how the team addresses the electrode-stability issues for the sulfide system, which many research groups are struggling with.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer mentioned that Li metal SSB are clearly relevant to future EV plans.

Reviewer 2:

The reviewer reported that this project has a strong relevance to DOE, specifically when it comes to the objective of this project which is to overcome processing and performance barriers associated with all-solid-state batteries. The reviewer noted that the Solid Power team is addressing these batteries by developing roll-to-roll processes of sulfide-based electrolytes that can be directly cast to form dense cathode/solid electrolyte layers that can, in turn, be integrated in next-generation batteries. The reviewer concluded that these results have obvious and direct implications to the electric vehicle market.

Reviewer 3:

The reviewer said that solid state batteries developed by the project team are probably the closest ones for large scale commercialization.

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 was able to meet most of its proposed milestones in FY 2021. The reviewer noted that the team has the proper equipment and resources to carry out this research, and that the team was able to sub-contract some of the materials characterization as well as the failure analysis. The reviewer concluded that overall, the team appears to have sufficient resources to complete the proposed work in a timely fashion.

Reviewer 2:

The reviewer remarked that the budget is adequate for the proposed experimental work including cell development and failure mechanism studies.

Reviewer 3:

The reviewer had no comments.

Presentation Number: bat487
Presentation Title: Developing Materials for High-Energy-Density Solid State Lithium-Sulfur Batteries
Principal Investigator: Donghai Wang (Penn State University Park)

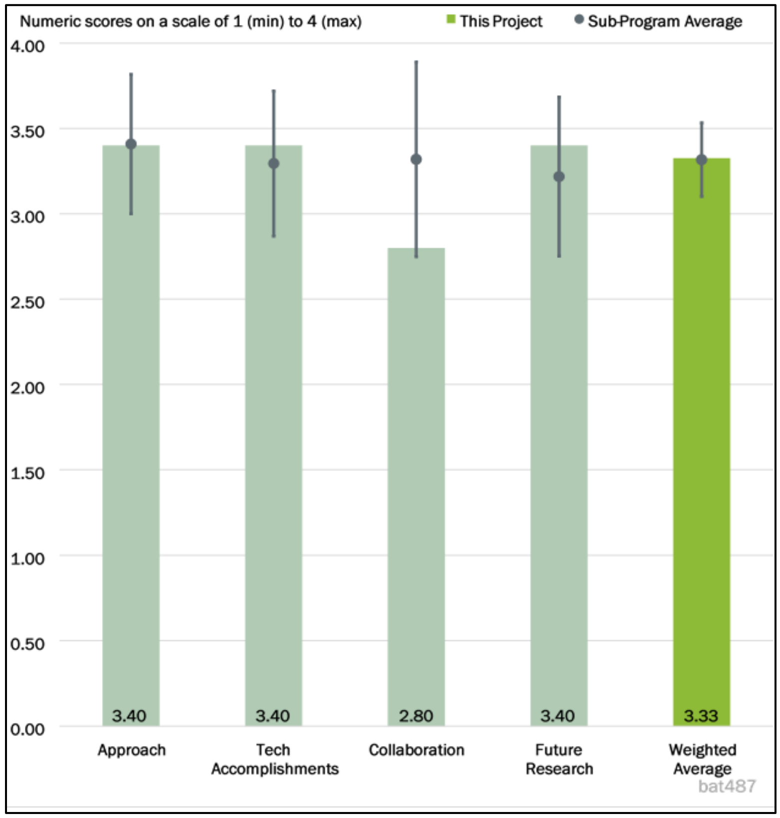


Figure 2-43 - Presentation Number: bat487 Presentation Title: Developing Materials for High-Energy-Density Solid State Lithium-Sulfur Batteries Principal Investigator: Donghai Wang (Penn State University Park)

Presenter

Donghai Wang, Penn State University Park

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project is very well designed and that all proposed, ambitious goals are feasible.

Reviewer 2:

The reviewer stated that overall, it looks like the project team is working hard on solid state Li/S and solid electrolyte development. The reviewer added that full-cell testing with Li-In is a question for the project team's approach. The reviewer pointed out that the team obviously is not able to cycle against Li metal yet, but that should remain front and center as the target. The reviewer noted that it is good to see that the team is going for high weight fraction of sulfur in cathodes, and also reasonable electrode loadings.

Reviewer 3:

The reviewer remarked that the project team worked on both high ion conductivity solid electrolytes and high sulfur content cathodes. The reviewer mentioned that these approaches are quite effective in achieving the team's objective to make high energy density solid-state Li-S batteries.

Reviewer 4:

The reviewer said that the PIs clearly address the key technical barriers such as Li ion conductivity and stability of solid-state electrolyte against Li metal of Li-S all solid state batteries. The reviewer remarked that the approaches such as novel solid state electrolyte design, synthesis and composition optimization of glass ceramic solid state electrolyte and argyrodite thiophosphate with targeted Li ion conductivity greater than 3 mS/cm, and development of high S loaded Li-S solid state batteries, are novel and innovative. The reviewer added that the in-situ pressure monitoring of the cell in real time to understand fundamental mechano-electrochemical property during charge/discharge process will open the new fundamental science on performance degradation mechanism of the solid-state Li-S battery system. The reviewer noted that the experimental work is well designed and feasible to address the major issues of all solid-state batteries.

Reviewer 5:

The reviewer declared that building on previous experience on glass-ceramic solid electrolytes, the project team optimized the composition (amount of Al_2S_3) in the SSE1 for maximum performance. The reviewer added that new formulations were presented (SSE2 and SSE3) that show improved performance. The reviewer assumed that the new formulations are based on SSE1, and noted incremental progress toward the goal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the work on solid electrolytes appears to be going well. The reviewer explained that the use of a Li-In alloy helps with the results, but that it is not envisioned in the milestones. The reviewer added that it looks like the project team still needs to reach its June 2021 milestone in terms of greater than 1000 mAh/g for the sulfur cathode.

Reviewer 2:

The reviewer expressed that the project team's accomplishments are quite impressive—achieved greater than 1000 mAh/g capacity with the developed sulfur cathode (at 0.3^{o}C and 60^{o}C), and several solid electrolytes with ionic conductivity approximately 4 mS/cm at 25^{o}C.

Reviewer 3:

The reviewer noted that excellent progress has been made both on technological and fundamental scientific point of view. The reviewer said that excellent cyclability of all solid-state Li-S batteries at 60^{o}C is an excellent achievement of the PIs. However, the PIs need to demonstrate the feasibility to achieve energy density of ^{3}500Wh/kg of Li-S cell using the Li-In metal host anode and high S loaded cathode at room temperature and below.

Reviewer 4:

The reviewer stated that the project progress is on schedule, with good conductivities achieved, and performance at room temperature and 60^{o}C remaining in progress.

The reviewer posed a few questions about the presentation. Regarding Slide 6, why is there an optimum amount of Al_2S_3 in the solid electrolyte? What happened for compositions x greater than 12? Which Li is mobile or more mobile in the following formulation—"Glass-ceramic solid electrolytes aLi_2S-bP_2S_5-cLi_3N-xAl_2S_3"?

Referencing Slide 14, the reviewer asked the project team to elaborate on better performance (capacity) with initial cycling. Concerning Slide 15, the reviewer inquired as to whether the crack in the cathode that is extended and parallel to the interface could be due to outside pressure.

Reviewer 5:

The reviewer stated that two new thiophosphate solid electrolytes were successfully synthesized using solid-phase and liquid- phase synthesis, demonstrating impressive ionic conductivity greater than 4 mS cm^{-1} at 25^{o}C. the reviewer added that the project team developed new carbon materials and solid-state electrolytes for high-energy sulfur cathode with high sulfur utilization (approximately 1400 mAh g^{-1} at 0.1°C) and stable cycling for 1000 cycles at 2°C (800-950 mAh g^{-1}). The reviewer remarked that the project is in great shape in terms of milestones, but that publications are not reported.

The reviewer reported that the chemical environment of $aLi_2S\text{-}bP_2S_5\text{-}cLi_3N\text{-}12Al_2S_3$ (SSE-1) was studied by x-ray photoelectron spectroscopy (XPS). The reviewer added that chemical and electrochemical stability against lithium metal anode should be further evaluated with XPS and improved, if necessary. The reviewer stated that the electrochemical stability against lithium metal anode at higher current densities should be studied since polarization resistance is already increasing at 0.75 mA cm^{-2}. The reviewer said that the cycling stability issue of sulfur cathode at high areal sulfur loading (greater than or equal to 5 mg sulfur cm^{-2}) needs to be resolved, and that room temperature performance needs to be achieved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer declared that the PI has good collaborations with University of Illinois at Chicago colleagues for theory and modeling work.

Reviewer 2:

The reviewer stated that the project is mainly at PSU, but there is a partner at the University of Illinois at Chicago (UIC).

Reviewer 3:

The reviewer said that the project is conducted by the Pennsylvania State University team, with their UIC partners, and that no other collaboration is shown in the report. The reviewer encouraged the project team to expand its collaborations with national laboratories and industry.

Reviewer 4:

The reviewer noted that the results presented so far are from the lead institution only.

Reviewer 5:

The reviewer remarked that little collaboration from theory group at UIC is 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed future work is effectively planned with clear and important goals.

Reviewer 2:

The reviewer noted that the project team should also consider adding future work on use of Li metal rather than Li-In.

Reviewer 3:

The reviewer stated that the project team realized the remaining challenges and has identified concrete steps in future research. The reviewer reported that the major challenge is to lower the operating temperature of the Li-S battery from 60°C to RT, while keeping the high capacity. The reviewer added that since the objective of the project is to develop the high energy density Li-S ASSBs, the team should report the energy density in addition to the charge capacities of the batteries, especially since Li-In is being used as anode.

Reviewer 4:

The reviewer stated that the future work target to improve electronic conductivity of the SSE greater than 5 mS/cm, as well as the development of high S loading electrode and using dendrite free Li as an anode, is well planned to address the key barriers of all solid-state Li-S based battery.

Reviewer 5:

The reviewer remarked that the proposed future work should address the remaining challenges and milestones, and that more characterizations are needed to show dendrite mitigation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that it is addressing the battery barriers.

Reviewer 2:

The reviewer noted that Li-S ASSBs are one of the major routes to realize all-electric vehicles by 2030.

Reviewer 3:

The reviewer said that the development of novel solid-state electrolyte of high ionic conductivity along with identification of high S loaded electrode configurations (^{3}6mg/cm^2) for use in all solid-state Li-S batteries at room temperature, can meet the DOE targeted energy density greater than or equal to350 Wh/kg and cycle life approximately 1000 cycles for the next-generation EV applications.

Reviewer 4:

The reviewer mentioned that the development of new stable solid-state electrolytes that can mitigate Li dendrite growth while maintaining good performance, certainly supports the overall DOE objectives.

Reviewer 5:

The reviewer confirmed that this project's goals are in line with DOE goals to develop novel solid-state electrolytes with high ionic conductivity and good stability against lithium metal, and demonstrate safe, low-cost, high performance Li-S ASSBs with high energy density, high sulfur content and long cycle life (greater than 1000 cycles).

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 adequate.

Reviewer 2:

The reviewer said that the current resources are sufficient to achieve the project targets.

Reviewer 3:

The reviewer declared that the amount of work needed to accomplish the tasks is consistent with the current funding.

Reviewer 4:

The reviewer noted that the resources and expertise seem sufficient to achieve proposed milestones.

Reviewer 5:

The reviewer mentioned that the project team has efficient resources to conduct the project, but that it is still encouraged to develop more collaborations with other institutions.

Presentation Number: bat488
Presentation Title: Fundamental Understanding of Interfacial Phenomena in Solid State Batteries
Principal Investigator: Xingcheng Xiao (General Motors, LLC)

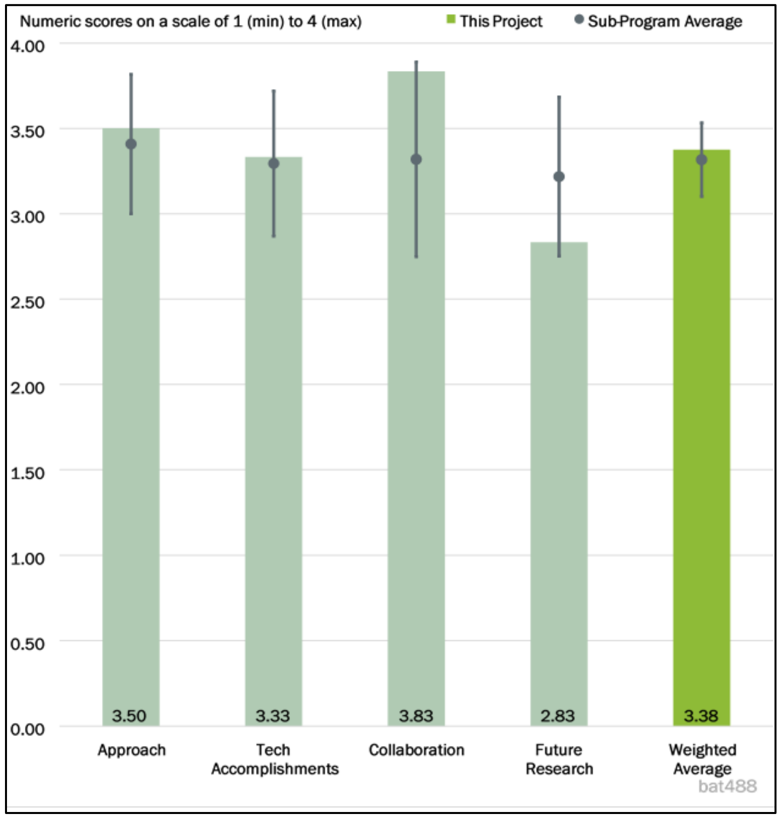


Figure 2-44 - Presentation Number: bat488 Presentation Title: Fundamental Understanding of Interfacial Phenomena in Solid State Batteries Principal Investigator: Xingcheng Xiao (General Motors, LLC)

Presenter

Xingcheng Xiao, General Motors, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach of this project, as performed by Xiao and co-workers, aims to develop a fundamental understanding of dynamic phenomena in solid-state batteries. The general approach encompasses multilayer model systems; in situ characterization of critical chemo-mechanical and transport properties; postmortem analysis; and interface engineering to form improved interfaces in next-generation batteries. The reviewer remarked that the combination of these approaches is expected to elucidate charge-transfer at interfaces and yield important strategies to improve the long-term cyclability in next-generation all-solid-state batteries. The reviewer concluded that overall, the approach of Xiao and co-workers addresses the outlined technical barriers, and that the team is on track to meet its goal in the coming fiscal year.

Reviewer 2:

The reviewer stated that the project team uses the Li|LLZO|Li symmetric cell as the model system, develops in situ mechanical monitoring techniques to reveal the dynamic change of interface contact, and then evaluates nanocomposite interfacial layer to enhance both mechanical and chemical stability. The reviewer added that the team also investigates void/vacancy formation using simulation methods. The reviewer noted that the approach is appropriate to address the interfacial issues in solid state batteries.

Reviewer 3:

The reviewer voiced his support of investigating stabilizing surfaces on Li metal interfaces, but said that the use of a very thick LLZO that is of poor quality poses the question on the value of the improvements seen here. The reviewer mentioned that the improvement being provided by the coating might indeed be smoothing out the current density inhomogeneities introduced by the very large defects in these LLZO samples, but questioned how it is relevant when applied to a cell using a thin and nearly defect-free LLZO? The reviewer was concerned the project team might be fixing an irrelevant issue.

The reviewer added that even the more fundamental aspects of this project, like investigating interface phenomena and the stress evolution on early cycling, could be very strongly impacted by the thickness and quality (or lack thereof) of the LLZO and Li. The reviewer hoped that the techniques developed will translate to systems with thin Li and LLZO.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer mentioned that a very large number of results was presented, and that the volume of work was impressive. The reviewer remarked that it was nice to see more work on understanding the impact of pressure on cycling of Li metal anodes. The reviewer reported that the stabilizing interlayer developed and shown on Slide 17 is a good improvement over the team's baseline performance.

Reviewer 2:

The reviewer stated that the project "Fundamental Understanding of Interfacial Phenomena in Solid State Batteries" reports a number of important technical accomplishments:

- Developed reliable model systems and in situ techniques to investigate interface dynamic phenomena.
- Developed a model system to investigate the stress evolution in solid electrolyte at initial stage.
- Developed and integrated in situ nano-indentor to investigate mechanical behaviors of Li garnets.
- Investigated vacancy formation along the interfaces between Li and different compounds.
- Developed a nanocomposite interlayer for Li metal/solid electrolyte interfaces.

The reviewer added that overall, the large number of accomplishments from FY 2021 clearly demonstrates the capability of the project team and the coordinated approach to improve interfacial charge-transfer in solid-state batteries. The reviewer declared that as of now, the team is on track to meet FY 2021 goals. The reviewer agreed that there are some technical challenges facing this work in FY 2022, namely, it is difficult to characterize the interfacial fracture strength between Li metal and solid-state electrolytes. The reviewer added that further correlation between experiment and theory will need development in the coming fiscal year.

Reviewer 3:

The reviewer mentioned that the project team has made very nice progress. The reviewer said that the team discovered Li plating induced compressive stress accumulation likely arising from the metallic Li nucleation in the LLZTO near the Li plating side. The reviewer remarked thar it seems to be dependent of current density, but that more well-designed experiments are needed to determine the correlation. The reviewer noted that the simulation on vacancy formation tendency with various materials is intriguing, and that it would be great if those findings can be compared with experimental observations. The reviewer stated that the critical current density of the nanocomposite coated LLZO is still very small, only 6.4 uA. The reviewer asked if the team can comment on how to further improve the CCD to a more practical value.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there was good collaboration.

Reviewer 2:

The reviewer noted that the project team has demonstrated close, appropriate interactions between team members as well as their collaborators at Brown University, University of Kentucky, Massachusetts Institute of Technology (MIT), and PNNL. The reviewer added that these efforts are exemplified by the large number of accomplishments shown from FY 2021.

Reviewer 3:

The reviewer stated that the collaboration across the team is great, based on the publications produced together.

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 state project ended.

Reviewer 1:

The reviewer stated that future work is reasonable. The reviewer encouraged the project team to redouble its efforts to do this work on commercial relevant materials, meaning thin (30-50 micron) Li and reasonable quality and thickness (30-50 micron) LLZO. The reviewer added that, if not already planned, it might be interesting to theoretically investigate LLZO surface dopants that would enable strong chemical bonding to Li metal and/or cathode/binder particles. The reviewer said that, as is well known, interfacial impedance is generally a major challenge in solid state cells.

Reviewer 2:

The reviewer remarked that the project "Fundamental Understanding of Interfacial Phenomena in Solid State Batteries" is anticipated to end in December 2022 and is approximately 45% complete. The reviewer stated that the proposed future work includes investigating different crystal orientations and comparing various properties in Li garnets; understanding the mechanisms responsible for the observed changes in mechanical properties of solid electrolyte and developing effective mitigation strategies to maintain mechanical integrity; and optimizing experimental techniques to better enable fundamental measurements. The reviewer declared that the combination of this future research is expected to better overcome the noted technology barriers. The reviewer added that while the technical challenges are apparent, it is not entirely clear how these challenges will be overcome in future experiments (e.g., what specific experiments/milestones and go/no-go points will be used in the coming fiscal year).

Reviewer 3:

The reviewer mentioned that the team did not show future work in the slides, although it did present the remaining challenges and barriers.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that as with other SSB research projects, this work is highly relevant.

Reviewer 2:

The reviewer stated that this project has strong relevance to the DOE, specifically in that the objective of this project is to develop an understanding underpinning the degradation modes at electrode solid electrolyte interfaces, particularly mechanical and chemical degradation. The reviewer added that such degradation at interfaces compromises the cyclability of next generation batteries. The reviewer remarked that here, the team, led by GM, investigates dynamic evolutions of the mechanical/transport properties and structure/composition of the interfaces in solid-state batteries. The reviewer concluded that these results have obvious and direct implications to the electric vehicle market.

Reviewer 3:

The reviewer mentioned that mechanical stability is a critical issue for all solid-state Li batteries, and that it is important to pin down the stress evaluation during battery testing, the effect of packing pressure on cell performance, and to investigate methods to alleviate the problem of improving the cycling stability of ASSLBs.

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 no issues with resources.

Reviewer 2:

The reviewer stated that the project team was able to meet its proposed milestones in FY 2021. The reviewer commented that the team has the proper equipment and resources to carry out this research, and that GM was able to establish stronger collaborations with Brown University as well as with the University of Kentucky. The reviewer added that this team also worked with PNNL and MIT on in situ transmission electron microscopy (TEM) investigations as well as the synthesis of Li garnet-based structures. The reviewer concluded that overall, the team appears to have sufficient resources to complete the proposed work in a timely fashion.

Reviewer 3:

The reviewer indicated that the funds are appropriate compared to the scope of the work, and that the project team has a variety of experimental tools for synthesis and characterization. The reviewer noted that as the team mentioned, finite element simulation might be needed to quantify the stress evolution.

Presentation Number: bat489
Presentation Title: Multidimensional Diagnostics of the Interface Evolutions in Solid-State Lithium Batteries
Principal Investigator: Yan Yao (University of Houston)

Presenter

Yan Yao, University of Houston

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

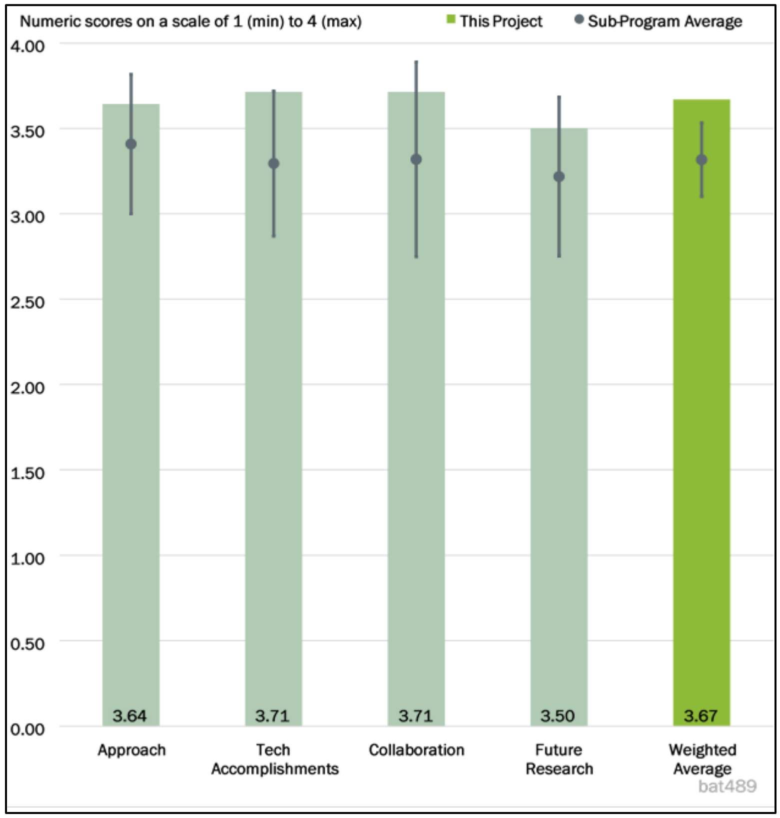


Figure 2-45 - Presentation Number: bat489 Presentation Title: Multidimensional Diagnostics of the Interface Evolutions in Solid-State Lithium Batteries Principal Investigator: Yan Yao (University of Houston)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the work is very impressive in developing methods for studying solid state batteries, and that a very useful tool set has been thus far developed.

Reviewer 2:

The reviewer stated that the solid electrolytes being developed are air sensitive and known to react at the cathode and the anode. The reviewer remarked that the plan is to develop a transfer device that allows one to perform a number of diagnostics to a sample without ever exposing it to air.

Reviewer 3:

The reviewer declared that the air-free vessel appears to be too bulky to fit into, e.g., an ion mill to make cross section samples of tens of micrometer in dimension for SEM, XRD, and electrochemical characterization.

Reviewer 4:

The reviewer commented that developing air-free vessel and cell designs are critical to understanding many fundamentals (structural, chemical and mechanical) of solid-state batteries, given that many components of the cell such as electrolytes, Li anode, interphases are highly sensitive to air.

Reviewer 5:

The reviewer was impressed with the overall comprehensive effort to use a suite of diagnostic techniques on micro- and nano-cells. The reviewer acknowledged that the promise is that the team will be able to take advantage of all these techniques in a coherent way to improve its cells, as opposed to having a lot of diagnostic data standing on its own.

Reviewer 6:

The reviewer indicated that the PI proposes to design an air-free vessel with an in-situ cell test platform for in situ multimodal characterization of the solid-state battery cell. The reviewer added that such an approach addresses the challenges of high air sensitivity and multi-dimensional properties of the solid-state electrolyte, providing an effective method for understanding the interphase which is critical to solid state battery performance but very challenging to characterize accurately.

Reviewer 7:

The reviewer noted that this project focuses on the development of a diagnostic capability for solid-state-lithium-batteries. The reviewer added that the tool set developed by the project targets addressing the barriers of characterization and understanding of interfacial properties of materials and electrode, which is critical to the development of all solid-state-batteries.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted a very impressive number of accomplishments on developing a thin solid-state battery and the tools to evaluate.

Reviewer 2:

The reviewer highlighted the focus on key issues, such as where and when voids form, how interlayers protect cell components, and how these factors depend on voltage and cycling. The reviewer applauded the micro cell and nano cell fabrication with good performance.

Reviewer 3:

The reviewer indicated that the PI succeeded in fabricating the proposed air-free vessel and micro-/nano-cells that faithfully follow the electrochemistry of conventional bulk cells. The reviewer added that the in-situ cell design and multimodal characterization have already yielded lots of scientific insights and a series of publications including several in high profile journals.

Reviewer 4:

The reviewer reported that the project team developed an air-free transfer chamber, and demonstrated that it can tape cast 50-micron free standing films of Li_6PS_5Cl electrolyte and can produce NMC/electrolyte/Li cells that cycle between 2 and 3.7 V. The reviewer noted that the chamber contains a micro cell mount that can be heated and used to apply pressure to the cell. The reviewer stated that the team is able to perform SEM and Raman measurements of the same cell in the same location with these two different instruments. The reviewer commented that plasma FIB allows for tomography of electrode, and that time of flight (TOF)-secondary ion mass spectrometry (SIMS) reveals the chemical information of interfacial reaction products and spatial distribution. The reviewer commented that the nanoindentation reveals mechanical property changes of the PTO and LPSCl domains, which causes the structure inversion.

Reviewer 5:

The reviewer stated that preliminary results appear promising.

Reviewer 6:

The reviewer expressed that the project is well on track, with the project team successfully developing an air-free vessel and multiple cell designs to characterize solid-state batteries, and that some proof-of-principle data were also collected. The reviewer asked why the solution-processed Li_6PS_5Cl solid electrolyte shows a higher ionic conductivity than the bulk solid electrolyte without solution processing. The reviewer remarked that it is usually observed that the solution processing will decrease the ionic conductivity.

Reviewer 7:

The reviewer stated that the designed air-free vessel integrated with in-situ test platform is a necessarily required and powerful tool to understand the interfaces of the electrodes and materials by eliminating the air exposure or other contaminations. The reviewer remarked that the functionalities of the device have been validated experimentally to provide useful chemical, structural and mechanical information. The reviewer added that the nano-cell design is unique and a nice platform for fundamental understanding of the Li/SSE and cathode interfaces. The reviewer said that the electrochemical performance of the thin solid NMC/SE/Li-In and NMC/SE/Li cells looks promising, but that the mass loading and content of the active NMC in the electrodes were not provided.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the collaboration is with national laboratories plus industry–best collaboration this reviewer has seen.

Reviewer 2:

The reviewer stated that the PI is collaborating effectively with a number of organizations.

Reviewer 3:

The reviewer mentioned that the project team's collaborations include three national laboratories (PNNL, SLAC, and NREL), three universities (Rice, Brown, and University of Houston), and three companies (Ampcera, ThermoFischer, and Solid Power).

Reviewer 4:

The reviewer noted that the collaborations are extensive.

Reviewer 5:

The reviewer remarked that the team has a strong collaboration with multiple institutions from national laboratories, universities, and industry.

Reviewer 6:

The reviewer stated that the PI collaborated with national laboratories, universities, as well as U.S. industries, and that areas of collaboration range from theory, experiment, to electrolyte/cell processing.

Reviewer 7:

The reviewer indicated that the PI has close collaborations with universities, national laboratories, and industries covering tool development, materials, processing, and simulation.

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 state project ended.

Reviewer 1:

The reviewer said that the proposed future research is appropriate.

Reviewer 2:

The reviewer noted that Tasks 2, 3, and 4 are well defined.

Reviewer 3:

The reviewer commented that the PI proposes several directions in future research, all of which are relevant to key scientific problems in solid electrolyte, such as mechanical property, chemical degradation mechanism, and interphase evolution.

Reviewer 4:

The reviewer stated that the project has effectively planned future work, as the team will use the developed tools/platform to study the chemical, structural and mechanical properties of the solid cells.

Reviewer 5:

The reviewer commented that the future work is to now use the instrument on a cell and fully characterize the interface between the ceramic and the active material during operation.

Reviewer 6:

The reviewer recommended that the project team carefully look at the design for the nano cell. The reviewer added that because of the significant decrease in the area of the cell, based on the current design, the resistance from only the ionic conduction in the electrolyte layer will be too large to enable any meaningful electrochemical test.

Reviewer 7:

The reviewer remarked that there is great promise, but a real challenge to integrate all of the information that the project team will get into a coherent picture.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that this is exactly the type of work that the DOE should support as it will help further the progress of solid-state batteries regardless of chemistry under evaluation.

Reviewer 2:

The reviewer commented that the DOE believes an investment in solid state is part of its mission and this company is developing important tools to investigate developments.

Reviewer 3:

The reviewer remarked that the air-free vessel can be used for in situ characterization of various materials critical to achieving the DOE objectives.

Reviewer 4:

The reviewer acknowledged that this effort will lead to a better understanding of the degradation and failure mechanisms of solid-state batteries.

Reviewer 5:

The reviewer applauded the great effort to make fundamental measurements on well-characterized cells.

Reviewer 6:

The reviewer stated that this project supports the overall DOE objectives in providing clean energy solutions, specifically, the beyond Li-ion battery option that has higher energy density and better safety characteristics than the conventional liquid electrolyte-based Li-ion batteries.

Reviewer 7:

The reviewer mentioned that this project is well aligned with DOE/VTO's objective of vehicle electrification, particularly when it comes to the development of next generation high energy all-solid-state Li 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 indicated that the project is appropriately funded.

Reviewer 2:

The reviewer mentioned that the team's progress has been excellent.

Reviewer 3:

The reviewer remarked that the team has sufficient resources for the project.

Reviewer 4:

The reviewer acknowledged that the resources are sufficient.

Reviewer 5:

The reviewer noted sufficient resources.

Reviewer 6:

The reviewer noted that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 7:

The reviewer reported that the PI and team have sufficient resources to achieve the stated milestones in a timely fashion.

Presentation Number: bat490
Presentation Title: First-Principals Modeling of Cluster-Based Solid Electrolytes
Principal Investigator: Puru Jena (Virginia Commonwealth University)

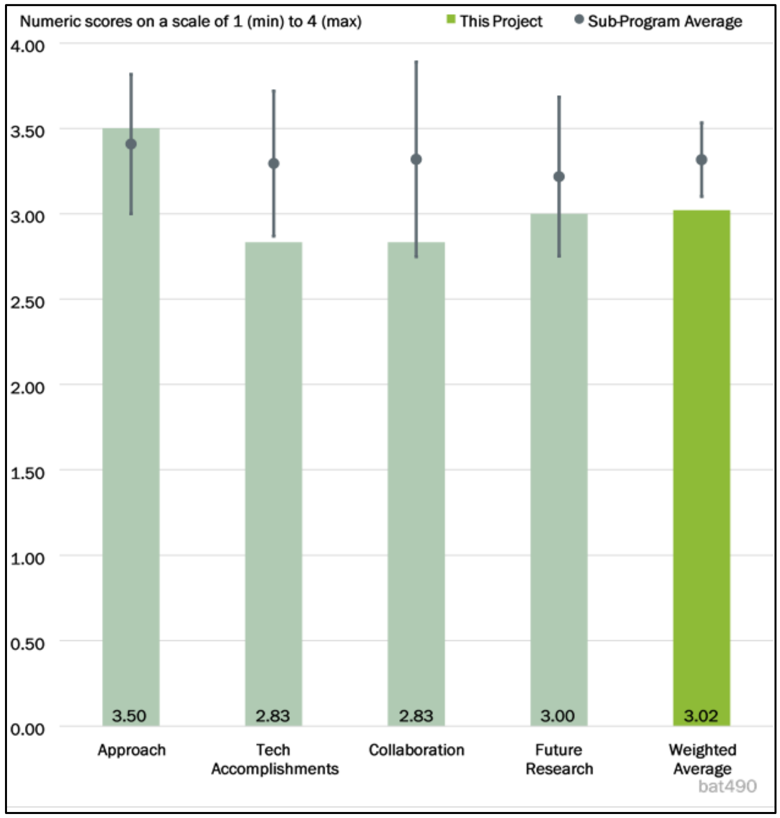


Figure 2-46 - Presentation Number: bat490 Presentation Title: First-Principals Modeling of Cluster-Based Solid Electrolytes Principal Investigator: Puru Jena (Virginia Commonwealth University)

Presenter

Puru Jena, Virginia Commonwealth University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted the novel approach to identify and design cluster-based compounds for solid electrolytes with the first principle calculation.

Reviewer 2:

The reviewer commented on the interesting, bold and novel approach where single atom sites are substituted with a cluster of ions larger in size and more electronegative, but stable as well. The reviewer added that the modeling screening approach is appropriate and efficient, as new compositions have been proposed.

Reviewer 3:

The reviewer indicated that overall, the approach appears good. The reviewer added that the presence of three partners who appear to have experimental roles is a major positive, and that relevant materials appear to be under investigation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project team has established a database of predicted cluster-based structures that are potentially suitable for solid electrolytes. The reviewer added that ion conductivity, bandgap, and activation energy are calculated for all the materials in the database.

Reviewer 2:

The reviewer remarked that low level theory methods were used to initiate the search for new compositions (clusters), followed by DFT calculations and feedback loop for optimization. The reviewer mentioned that the computational cost seems to be mostly due to the calculation of diffusivities, otherwise just simple energy relaxation of bulk compositions. The reviewer noted the efficient approach for fast results.

The reviewer posed a few questions about the presentation.

- Other than energy calculations, how can one assess if the predicted compositions/formulations can be synthesized?
- What are the major criteria for choosing the cluster, other than activation energy (E_a) and ionic size?
- Total energy of the chemically mixed structure is found to be increasing linearly with the increasing concentration of the cluster-ions being substituted by atomic ions. In response to question of how the team calculates the “Probability distribution function,” the presenter answered, “Molecular dynamics,” to which this reviewer asked if this was not expected.
- How does the point-charge electrostatic model compare with the DFT optimization? How confident is the project team about the screening process based on point charges being complete?
- Can the project team elaborate on the following statement, “Established model based on the local topology of the anion-mediated Li-transport”?
- How is the activation barrier for Li transport estimated? From AIMD?
- Why Particle swarm optimization? Other, more reliable programs exist.

Reviewer 3:

The reviewer stated that the milestones are not quantitative so it is hard to assess the significance of the progress. The reviewer did not see any experimental results in the deck, and noted that it is unclear what challenges the experimental partners are having, and whether the connection with experiments will in fact take place in the project, and if it will be a strong and productive connection.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the team has collaborations with national laboratories and other universities on materials synthesis and characterization.

Reviewer 2:

The reviewer remarked that three different institutions are mentioned as partners for synthesis and characterization. The reviewer added that so far, only computational results are shown, but that it is understood that the computational screening comes first followed by synthesis of the proposed compositions afterwards.

Reviewer 3:

The reviewer stated that it is excellent that there are partners, but it is unclear what the connections are and the significance of the output based on the slides presented.

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 state project ended.

Reviewer 1:

The reviewer noted that in order to further down select the best candidates for the solid electrolytes, the team needs to characterize the interface stability. The reviewer added that it is very important to provide guides on how to synthesize the predicted materials.

Reviewer 2:

The reviewer stated that the proposed computational work is in-line with the project goals. The reviewer indicated that the experimental confirmation via synthesis of the best proposed compositions is mentioned in the remaining challenges section, but not in the future work.

Reviewer 3:

The reviewer commented that relevant future work is listed, but that without quantitative milestones or more specific descriptions around the connection with experiments, it is hard to know whether the deficiencies mentioned above will be addressed in future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project is working on solid electrolyte materials, which fits into DOE objectives.

Reviewer 2:

The reviewer mentioned that the study provides a fundamental understanding of the cluster-based structures and their suitability for high-performance solid electrolytes. The reviewer indicated that this may spawn inventions of novel solid electrolytes for ASSBs.

Reviewer 3:

The reviewer stated that screening for new and novel solid-state electrolytes using computational techniques 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:

The reviewer noted that the team has sufficient resources for the targeted works.

Reviewer 2:

The reviewer stated that the amount of work and effort needed to better explore the available space for new electrolytes using computational approaches (manpower), and the experimental validation of the proposed compositions might require more funding.

Reviewer 3:

The reviewer remarked that Slide 2 mentions a $33,000 budget for FY 2020, and asked if it is a typo. The reviewer added that if it is not, then it looks like the team is struggling to spend the funding.

Presentation Number: bat491
Presentation Title: Predictive Engineering of Interfaces and Cathodes for High-Performance All Solid-State Lithium-Sulfur Batteries
Principal Investigator: Badri Narayanan (University of Louisville)

Presenter

Badri Narayanan, University of Louisville

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

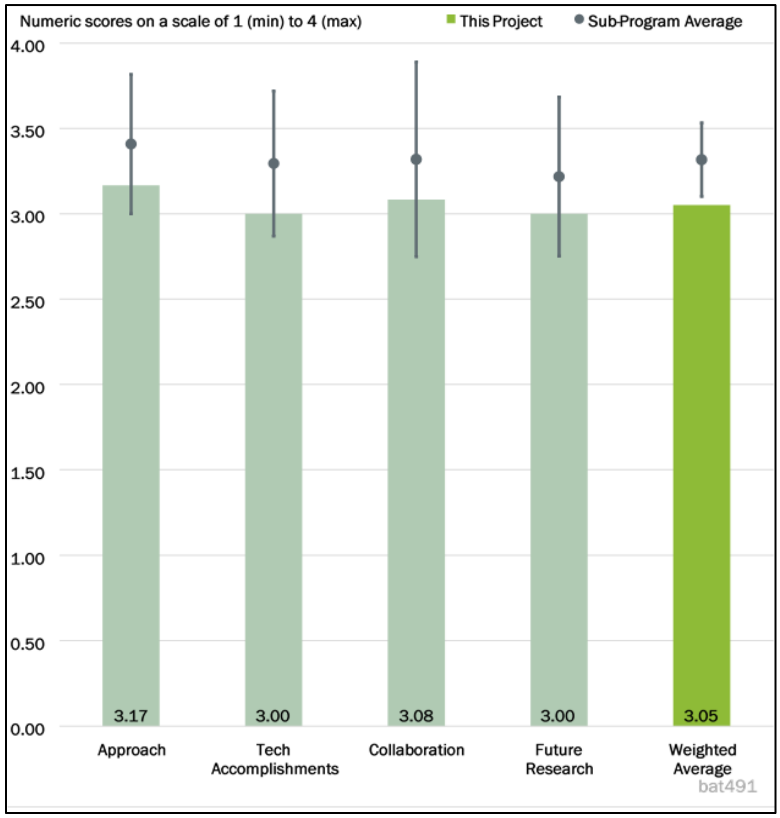


Figure 2-47 - Presentation Number: bat491 Presentation Title: Predictive Engineering of Interfaces and Cathodes for High-Performance All Solid-State Lithium-Sulfur Batteries Principal Investigator: Badri Narayanan (University of Louisville)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that there is a nice combination of modeling and experimental work. The reviewer added that most of the technical barriers have been addressed, and that the project is feasible though challenging.

Reviewer 2:

The reviewer noted that a number of computational approaches including first principles, kinetic Monte Carlo, and atomistic modeling are proposed to achieve atomic-scale understanding of transport, reactions, and materials evolution in solid-state lithium-sulfur batteries. The reviewer indicated that experimental efforts were also proposed to validate the computational results. The reviewer remarked that these fundamental studies will lead to a better understanding of key challenges in solid state batteries. The reviewer explained that Lithium argyrodite was used as the solid electrolyte system and mesoporous sulfur was used as the cathode. The reviewer said that the project team proposed to use ionic liquid based catholyte in the cathode composite. The reviewer mentioned that previous efforts have shown many important attributes of solid-state batteries can be compromised by incorporating liquid electrolytes. The reviewer concluded by saying that all solid-state lithium sulfur batteries without any liquid electrolyte have also been demonstrated by many research groups.

Reviewer 3:

The reviewer indicated that Li-S batteries have numerous problems to overcome, including requirement for large amounts of dioxolane (DOL). The reviewer was not sure how the authors plan to deal with this. The reviewer was not convinced that MD calculations on such short time and space scales are sufficient to determine reactivity.

Reviewer 4:

The reviewer stated that the PI focuses on solid state Li-S battery and uses theoretical modeling to guide the composition optimization of argyrodite ($Li_{6+y}P_2S_{8-y}X_y$, where X can be Cl or F) solid electrolyte and to gain fundamental understanding about the interphase. The reviewer added that the PI also uses ionic liquid to address the interfacial contact issue between solid electrolyte and sulfur cathode. The reviewer indicated that these are addressing key issues facing solid state lithium-sulfur batteries.

Reviewer 5:

The reviewer remarked that the proposed approaches are comprehensive and cover materials synthesis, cell test, and theoretical simulation. The reviewer stated that this project targets at the interfaces and cathodes of all solid-state Li-S battery, but the proposed approach is actually an integration of ionic liquid electrolyte, additional solvents and Argyrodite solid electrolytes. The reviewer concluded that would make the system more complicated due to the chemical compatibility issues of solid electrolyte with ionic liquid and especially the ether solvents.

Reviewer 6:

The reviewer remarked that getting Li/S to work is a major challenge. The reviewer reported that the approach here is to use AIMD to determine the best anion substitution in a LiPSX sulfide electrolyte for improved conductivity and stability, after which the project team synthesized the electrolyte and built a cell.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the modification of the solid electrolyte led to greatly improved performance. The reviewer indicated that this was a good demonstration of combined modeling and experimental work. The reviewer added that the system will be rather challenging to achieve high energy density because of the poor electronic conductivity of S which makes high loading problematic.

Reviewer 2:

The reviewer commented that the project team was very successful in identifying an electrolyte with higher conductivity and better stability. The reviewer acknowledged that the team has a pretty good handle on the mechanism of conduction and reaction with lithium. The reviewer reported that the team successfully synthesized the electrolyte, and built a cell with the chosen electrolyte, with the cathode being 35% sulfur by weight. The reviewer was not sure of the porosity of the cathode, as the team added an ionic liquid to the cathode for ionic conduction. The reviewer noted that the cell starts at 300 mAh/g and ends at 200 mAh/g after 100 cycles. The reviewer stated that the team added DOL to the cathode and improved the capacity to 800 mAh/g at beginning of cycling and finished at 500 mAh/g at cycle 100. The reviewer added that the cell had an overall capacity of 0.5 mAh/cm^2, and that the initial work was interesting but the final cell build was not very impressive.

Reviewer 3:

The reviewer remarked that the project team identified F-doping as an effective approach to improve the ionic conductivity of Li argyrodite solid electrolytes. The reviewer noted that it is surprising to see long-range motion of F ions in the Li_6PS_5F electrolyte as the ionic conductivity of F anion in solids is typically very low. The reviewer mentioned that more detailed characterizations are needed to confirm successful substitution of F in the solid electrolytes. The reviewer added that the interfacial stability between solid electrolyte was also studied in Li-Li symmetrical cells, but the current densities are still limited to 0.15 mA/cm^2. The reviewer indicated that Li-S full cell with ionic liquid in the cathode was also tested, and the performance of the full cell are still limited. The reviewer reported that some voltage noise can be observed during charging processes.

Reviewer 4:

The reviewer noted that the project team can make any mixture of halogens in the LPS using a low-cost scalable technique, leading to improved conductivity. The reviewer added that combined with the theoretical understanding, this is a very valuable result. The reviewer wondered if this sort of thinking can be extended to other SEs.

Reviewer 5:

The reviewer stated that the PI shows that modeling guided solid electrolyte optimization, especially in maximizing ionic conductivity, succeeded in synthesizing solid electrolyte with designed composition. The reviewer remarked that the PI also made great progress in developing models for studying the interphases between electrolyte and cathode/anode. The reviewer indicated that full cells consisting of sulfur-carbon cathode, ionic liquid (improving the contact), solid electrolyte, and lithium metal anode are tested and show promising performance. The reviewer noted that the PI also showed good publication record.

The reviewer reported that the cathode loading which is around 1mg/cm^2 needs to be improved. The reviewer observed that the shaky electrochemical curve during the charging stage needs to be addressed. The reviewer added that the PI addresses the interfacial contact issue between solid electrolyte and cathode using ionic liquid. The reviewer asked about the contact between electrolyte and lithium metal anode, and mentioned that this may also need to be addressed.

Reviewer 6:

The reviewer remarked that the F co-doped Argyrodite solid electrolytes developed under this project has much lower ionic conductivity and Li critical current density if compared with other reported Cl- or Br- based Argyrodite electrolytes. The reviewer added that the compatibility of the solid electrolyte with ionic liquid and solvents is an important factor to the cell cycling stability, but that it was not studied in this project. The reviewer noted that sulfur loading in the electrode is too low to evaluate the effectiveness of the approach, and that sulfur utilization rate is very low, even when excess amount of liquid electrolytes were used in the cell.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the team worked well together to combine modeling and experimental research.

Reviewer 2:

The reviewer stated that this was a multi-PI project with all PIs at the University of Louisville that collaborated with top modelers at Argonne.

Reviewer 3:

The reviewer noted that all work was done at the University of Louisville, but that new collaborations with ANL and ORNL will improve collaboration.

Reviewer 4:

The reviewer reported that the PI collaborated with both national laboratories and universities.

Reviewer 5:

The reviewer expressed that the PI has good collaboration across the universities and national laboratories. The reviewer added that the PI indicated collaborations with Oak Ridge National Laboratory on neutron diffraction analysis, but no such results were included in the report.

Reviewer 6:

The reviewer remarked that it was all done at the same institution, and encouraged collaborations with other 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed work is on target, and that particularly focusing on higher loading is important for testing the viability.

Reviewer 2:

The reviewer remarked that the PI proposed several important directions for future research, including increasing sulfur loading and decreasing the amount of ionic liquid.

Reviewer 3:

The reviewer acknowledged that the project has a clear plan for future work. The reviewer indicated that chemical compatibility between the solid electrolyte and liquid parts should be considered in future research, and that design and optimization of the high loading sulfur electrode architecture should be a focus.

Reviewer 4:

The reviewer mentioned that future work lists a number of modeling tasks to better understand the conductivity, which will unlikely lead to improved cell capacity or capacity retention.

Reviewer 5:

The reviewer noted that almost all of the future work involves theory, and that this does not seem balanced.

Reviewer 6:

The reviewer indicated that the project team needs to study in detail the failure mechanisms of Li-S full cells. The reviewer added that the voltage noises or spikes during charging are unlikely caused by kinetics as is proposed by the team. The reviewer reported that Polysulfide shuttle or lithium dendrite shorting can also lead to similar voltage spikes. The reviewer suggested that more characterizations including both electrochemical and materials characterizations should be done to understand the underlying cause. The reviewer encouraged the team to also study the cathode electrolyte interface in an all-solid-state setup, as the addition of ionic liquid electrolytes in the cathode composite does not seem to help much on the kinetics.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that a functioning high energy Li-S clearly would meet many of the DOE objectives owing to the great abundance of S and low cost.

Reviewer 2:

The reviewer remarked that this project will enable the development of solid-state Li sulfur batteries.

Reviewer 3:

The reviewer indicated that this project supports the overall DOE objectives in providing clean energy solutions, specifically, the beyond Li-ion battery option that has higher energy density and better safety characteristics than the conventional liquid electrolyte-based Li-ion batteries.

Reviewer 4:

The reviewer said that this project focuses on solid-state Li-S battery, which is a promising energy storage technology and aligns well with DOE/VTO's objective of vehicle electrification.

Reviewer 5:

The reviewer noted that DOE still considers Li/S a viable technology for improving battery energy density. The reviewer added that this work was mainly helpful in developing techniques for establishing better electrolytes, and that the overall system has a long way to go.

Reviewer 6:

The reviewer expressed that Li-S cells with solid electrolytes are not in the mainstream, and that the use of ionic liquids is problematic at lower temperatures. The reviewer added that while using SEs avoids the Li sulfide shuttle—perhaps the biggest problem with cells that use liquid electrolytes—it's not clear that using SEs makes the situation any better in terms of 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 noted that the project is appropriately funded.

Reviewer 2:

The reviewer stated that the resources are sufficient.

Reviewer 3:

The reviewer commented that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 4:

The reviewer observed that the PI's team has sufficient resources and capabilities to perform the proposed research.

Reviewer 5:

The reviewer expressed that it is impressive that this group of professors were able to come up with 20% cost share to be matched with $1,000,000 from DOE, and added that the project will need a lot more money to advance this system.

Reviewer 6:

The reviewer remarked described project resources as barely adequate, and that the addition of ANL and ORNL will be important.

Presentation Number: bat492
Presentation Title: Machine Learning for Accelerated Life Prediction and Cell Design
Principal Investigator: Eric Dufek (Idaho National Laboratory)

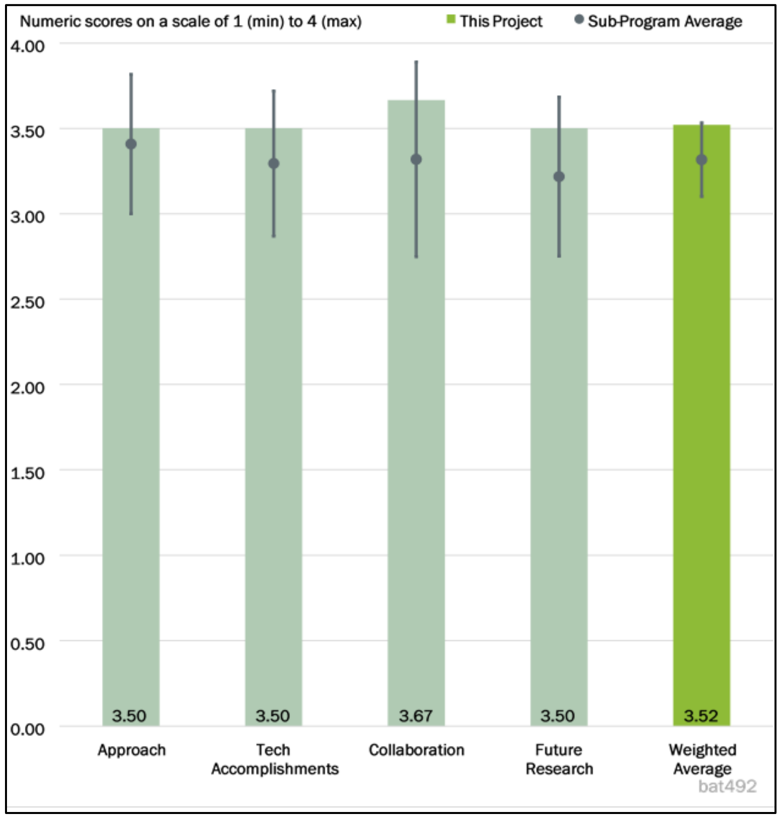


Figure 2-48 - Presentation Number: bat492 Presentation Title: Machine Learning for Accelerated Life Prediction and Cell Design Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the program is very well defined and the approach is robust.

Reviewer 2:

The reviewer noted that the approach involves machine learning to accelerate the cycle life prediction of batteries including capturing degradation mechanisms through logistic regressions. The reviewer commented that the milestone lists “initiate Deep Learning related to electrochemical signatures”, while current models are mostly shallow learning models. The reviewer indicated that there may not be a need to do deep learning, but that it would be good to check and show that shallow learning models work well enough.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the work done so far shows very clearly the potential for ML-based methods to perform early life prediction and fast charging. The reviewer mentioned that the current work has used synthetic data and used ML models to identify the signatures. The reviewer noted that the team has used other data to provide initial results, which provides confidence that these approaches are likely to work well.

Reviewer 2:

The reviewer commented that the progress so far has been impressive, and suggested emphasizing on graphite/NMC chemistry rather than spending more resources on LTO/LMO chemistry. The reviewer asked the project team to try to use data from USABC projects for various chemistries including silicon-based anode. The reviewer explained that there is lot of cycle life, calendar life, and lately fast charging cycling data that will be helpful to develop models and validate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the team is well-balanced and brings excellent complementary expertise. The reviewer observed that the team has also been extending their collaboration network outside very effectively.

Reviewer 2:

The reviewer suggested establishing a collaboration with Stanford University possibly in the area of manufacturing processes and new materials development, as some work has been published by that group. The reviewer added that it will be very useful to involve cell developers at the earliest possible so that methods could be verified and validated with a larger set of data and latest chemistry.

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 state project ended.

Reviewer 1:

The reviewer acknowledged that the proposed project plan is sound. The reviewer remarked that the process for collaboration of data will be a key development activity that will be broadly useful, and that setting the right practices in place would be crucial.

Reviewer 2:

The reviewer suggested to include, define, and start working on manufacturing processes related work. The reviewer observed that it is mentioned on "Relevance Objective" Slide 3, but that there is no defined work for this objective.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer mentioned that reducing overall battery cost via reduction in cell validation cost, materials development, cell design and manufacturing are very important objectives to go after, and will help the battery industry significantly.

Reviewer 2:

The reviewer expressed that the program clearly helps in accelerating the prediction of performance, reducing time to predict, and understanding failure modes.

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 team is staffed at the right level to deliver the milestones.

Reviewer 2:

The reviewer commented that it may be worthwhile to assess resources after mid-way through to add more resources rather than after two full years of the project at the next AMR review.

Presentation Number: bat493
Presentation Title: WPI USABC LCFC Project
Principal Investigator: Yan Wang (WPI)

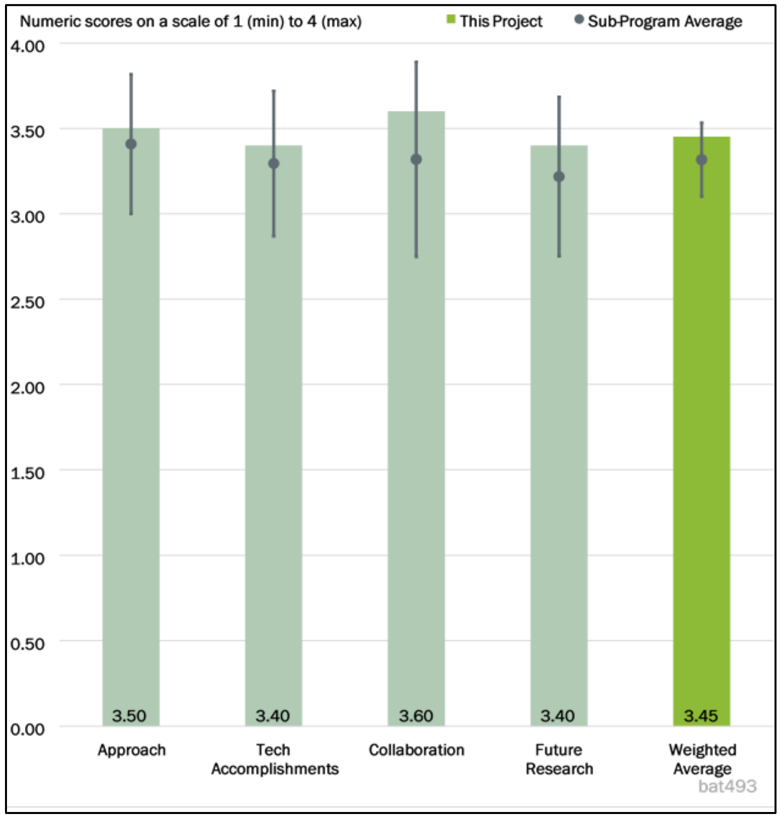


Figure 2-49 - Presentation Number: bat493 Presentation Title: WPI USABC LCFC Project Principal Investigator: Yan Wang (WPI)

Presenter

Yan Wang, WPI

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the efforts addressed the high energy battery fast charging need through an interesting approach on solvent-free manufacturing method for hetero-structured cathodes and anodes.

Reviewer 2:

The reviewer remarked that low-cost Li-ion cells can and should be achieved not only through low-cost material development but also through low-cost manufacturing. The reviewer added that in these regards, this project took a very relevant approach.

Reviewer 3:

The reviewer expressed that the tasks are well-designed to meet the objectives, and that a comprehensive cost analysis of the new approach to fabricate the electrode will be helpful.

Reviewer 4:

The reviewer observed that ion conduction and resistance are intrinsic properties of the electrode, and added that tailoring them can provide a viable pathway to a fast-charging electrode. The reviewer indicated that the two-layer approach can help to solve the transport problems and still provide a decent mass loading combined with fast-charge properties.

Reviewer 5:

The reviewer mentioned that the approach is to use a novel dry casting method to fabricate electrodes. The reviewer added that active material/binder/carbon is spray cast without a solvent onto a current collector and then calendared with a heated roller to ensure appropriate binding. The reviewer observed that the electrodes are prepared and characterized at various C-rates, then compared to electrodes made using a more traditional slurry casting technique. The reviewer reported that modeling is also performed to understand appropriate electrode porosity, and that the project appears well-designed and feasible. The reviewer expressed concern that the modeling appears to have focused on the elucidation of a “dual” porosity electrode architecture, and it is not clear how these results would inform dry-spray electrode fabrication. The reviewer asked if there are plans to develop “graded/layered” electrodes?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer liked all the aspects of this work, and remarked that it was well balanced among process, modeling, experiment. The reviewer affirmed that the work was well planned and organized, and that cell performance of solvent-free electrodes is impressive. The reviewer recommended more rigorous evaluation such as power characteristics, high temperature storage, and calendar life.

Reviewer 2:

The reviewer observed that the dry spray method looks promising, and said that it will be more convincing if the yield is reported (the percentage of the sprayed powders that stay on the electrode).

Reviewer 3:

The reviewer indicated that the progress so far is good, and that it will be interesting to see the extended lifecycle tests of the cells. The reviewer added that it would be great to provide an estimation of the technology in Wh/L and Wh/kg on the cell level, combined with a sensitivity analysis (how much specific energy density loss provides how much percent improvement in fast charging). The reviewer suggested that the calendric aging and DCIR rise are two other points to consider in the progress of the project.

Reviewer 4:

The reviewer stated that the modeling is very interesting and clearly shows the benefit of a layered porosity electrode architecture. The reviewer added that dry sprayed electrodes have been prepared and have similar, or perhaps a bit better, performance than conventional slurry-cast electrodes, which is a great result that could lower fabrication costs rather significantly if fully developed. The reviewer concluded that this project appears to be making great progress.

Reviewer 5:

The reviewer stated that progress in modeling and solvent-free manufacturing were as scheduled. The reviewer added that it was demonstrated that the cell with electrodes made with solvent-free manufacturing technique has relatively better fast charging capability compared to that with the cell electrode made with wet processing. The reviewer noted that it is not fully clear how many cells were produced to generate the testing results, and that the limited number of cells may not be sufficient to demonstrate the properties of the cell produced with the developed solvent-free technique.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that collaborations among team members are excellent.

Reviewer 2:

The reviewer observed that collaboration partners are well selected and coordinated, and that the contribution of each partner is very clear.

Reviewer 3:

The reviewer noted that ANL and Microvast test batteries using the solvent-free electrode made by the team.

Reviewer 4:

The reviewer noted that having an established company building and providing the cells for the tests clearly helps the pace of the project, and that it might be beneficial to include some partners with a deep analytical understanding of the SEI and electrolyte compositions.

Reviewer 5:

The reviewer indicated that the collaboration between WPI, Rice University, Microvast, and Texas A&M University (TAMU) is working really well with all collaborators appearing to have clearly defined roles and making good progress as a 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that future research is nicely planned.

Reviewer 2:

The reviewer remarked that the project will benefit from the extended lifecycle tests, and highlighted other points to consider such as multilayer pouch cells; DCIR system investigation; and electrolyte variation. The reviewer added that a cost estimation of process should be carried out in order to proof its applicability.

Reviewer 3:

The reviewer reported that future work focuses on pouch cell fabrication and evaluation. The reviewer expressed interest in seeing whether the team can make the “dual porosity” electrodes that the modeling has clearly shown to be effective at improving fast charge capability.

Reviewer 4:

The reviewer agreed with all the proposed future research, yet encouraged the team to expand this effort to double side coating and multi-layer pouch cells. The reviewer recommended more rigorous cell characterization.

Reviewer 5:

The reviewer stated that future work is properly illustrated, and that it will be interesting to know if the solvent-free technique is applicable to multi-layer pouch cell manufacturing. The reviewer added that the technology transition plan of the developed technique is not very clear, and suggested that the contractor reaches out to potential partners for battery manufacturing at the end of this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the objective of this project to develop low-cost batteries capable of fast charging for EV applications supports DOE goals.

Reviewer 2:

The reviewer affirmed that this project is very relevant to the DOE goal to develop low-cost Li-ion cells.

Reviewer 3:

The reviewer observed that this project supports the overall DOE objectives by avoiding solvents in the manufacturing of lithium-ion battery electrodes.

Reviewer 4:

The reviewer indicated that this project fully supports the DOE objectives.

Reviewer 5:

The reviewer commented that dry spray casting could dramatically reduce the environmental impacts of battery manufacturing, which makes this project directly applicable to 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 stated that resources appear sufficient for this project.

Reviewer 2:

The reviewer noted that the funding level is appropriate for the project.

Reviewer 3:

The reviewer suggested giving more resources to the team so it can develop larger scale equipment and multi-layer pouch cell via double side coating.

Reviewer 4:

The reviewer remarked that the project would benefit from collaboration with equipment manufacturers.

Reviewer 5:

The reviewer said that the resources seem to be sufficient, even a bit on the low side for the proposed work.

Presentation Number: bat494
Presentation Title: Microvast USABC LCFC Project
Principal Investigator: Wenjuan Mattis (Microvast)

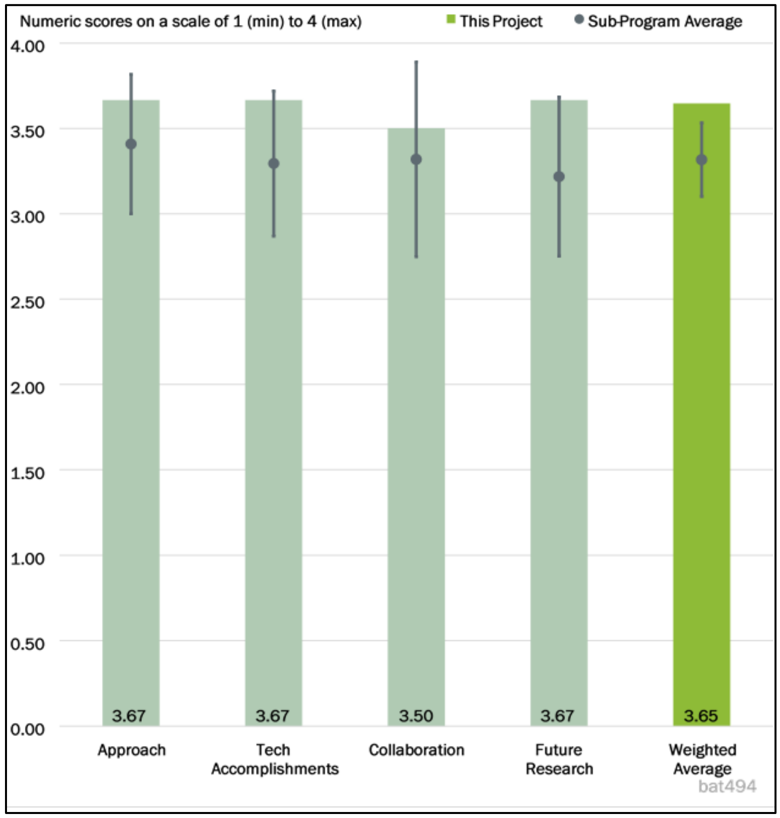


Figure 2-50 - Presentation Number: bat494 Presentation Title: Microvast USABC LCFC Project Principal Investigator: Wenjuan Mattis (Microvast)

Presenter

Wenjuan Mattis, Microvast

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that novel full concentration gradient low-Co cathode materials and additives for Lithium-ion battery fast charging have been addressed in this project. The reviewer noted that several interesting approaches were proposed and/or developed appropriately, including the employment of a graphite/Si based alloy.

Reviewer 2:

The reviewer mentioned that the tasks are well-designed to meet the objectives, and that the combination of the Aramid separator, FCG cathode, and electrolyte additive is innovative.

Reviewer 3:

The reviewer said that the approach to this program is to develop low-Cobalt (less than 2.5 wt%) gradient materials to reduce cathode material price, and combine them with an additive that improves the rate capability of cells that employ the gradient material. The reviewer added that electrochemical characterization and cycle lifetime assessment are primarily used for characterization. The reviewer stated that the project has very well-defined goals and that given the year one progress, those goals appear very achievable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that performance targets have been met so far.

Reviewer 2:

The reviewer remarked that great progress has been made, with the materials development completed for both the gradient active material and lab-scale quantities of the additive prepared. The reviewer added that the gradient material has high cycle life in a 260 Wh/kg pouch cell, although targeted cost still needs to come down a bit. The reviewer mentioned that the additive also appears to allow very good repeated fast charging, with 60% capacity retention after 700 2.5C charging cycles.

Reviewer 3:

The reviewer expressed that progress for year one is impressive, and that the proposed milestones were met. Another effort funded by DOE for the calendar life testing was also suggested: https://www.nrel.gov/transportation/assets/pdfs/silicon-calendar-life-report-04012021.pdf.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the contractor has a good collaboration with the INL testing team, and that research progress has been properly reported to the USABC program manager.

Reviewer 2:

The reviewer observed that Idaho National Laboratory helps on the testing protocols.

Reviewer 3:

The reviewer noted the collaboration with INL, which has helped with cell analysis, and USABC.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed future study is reasonable.

Reviewer 2:

The reviewer indicated that future research is nicely planned, especially on improving the energy density.

Reviewer 3:

The reviewer observed that future work will focus on integrating Si into the anode to boost energy density, and that the additive will also be studied to understand its influence on the SI anode. The reviewer concluded that these are reasonable directions that should result in improved energy density.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project supports DOE goals by working to improve Li ion battery sustainability by potentially eliminating the use of cobalt in the cathode electrode, lower costs, address energy security questions regarding cobalt, improve the accessibility of electric vehicle ownership, facilitate fast charge to address range concerns, and lower costs to make them more affordable.

Reviewer 2:

The reviewer noted that this project supports the overall DOE objectives by reducing the cost and improving the performance of lithium-ion batteries.

Reviewer 3:

The reviewer said that yes, the development of low cobalt and fast charging materials are both directly related 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 stated that the funding level is reasonable for the scheduled work.

Reviewer 2:

The reviewer indicated that resources appear sufficient for the project.

Reviewer 3:

The reviewer observed that the diagnosis part of the project would benefit from working with a university partner.

Presentation Number: bat495
Presentation Title: AMO/VTO FOA Award Applied Materials
Principal Investigator: Ajey M. Joshi (Applied Materials)

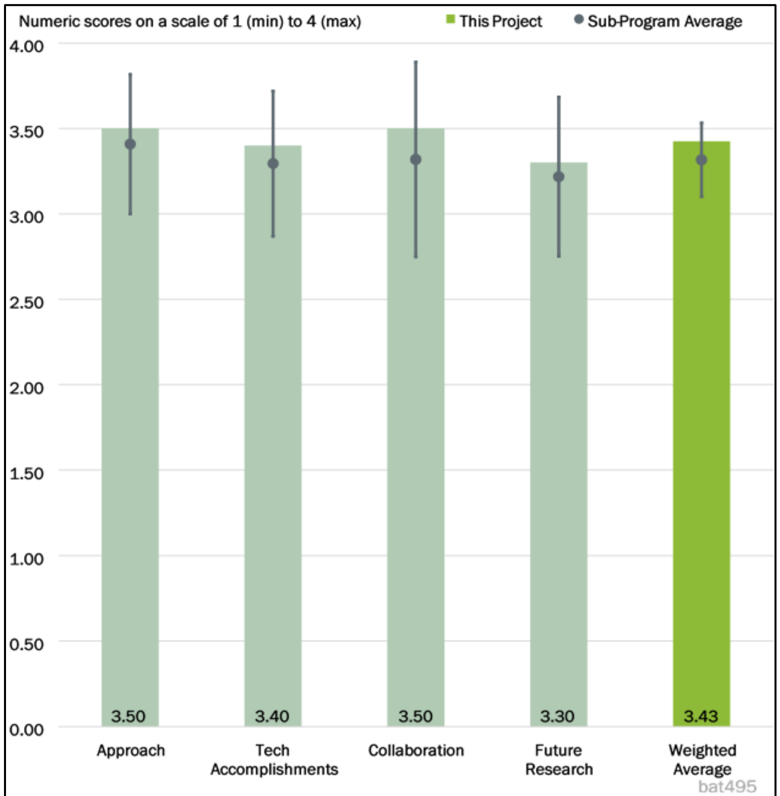


Figure 2-51 - Presentation Number: bat495 Presentation Title: AMO/VTO FOA Award Applied Materials Principal Investigator: Ajey M. Joshi (Applied Materials)

Presenter

Ajey M. Joshi, Applied Materials

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer expressed that to enable low cost, low efficiency Si or SiO_x anode materials for high energy density Li-ion battery development, prelithiation is an effective route. The reviewer agreed that the proposed work addressed technical barriers well, and liked the approach of this work in terms of scaled manufacturing. The reviewer noted that for even higher energy density cell using Li metal anode, this approach is also very effective.

Reviewer 2:

The reviewer mentioned that the project leverages the unique expertise of Applied Materials and the partners to develop a Li metal evaporation process for battery applications. The reviewer observed that the tasks are well-designed to meet the objectives.

Reviewer 3:

The reviewer remarked that the approach is to develop and implement a Li metal deposition tool to prepare Li metal anode and pre-lithiated SiO_x anodes. The reviewer added that the tool has been developed, electrodes have been made and distributed to manufacturers, and the tool has been used to pre-lithiate a SiO_x-C anode, which has also been integrated into a pouch cell by a collaborator. The reviewer stated that in other words, Applied Materials (AMAT) is leveraging this unique tool to potentially advance high energy anodes.

Reviewer 4:

The reviewer expressed that the technical barriers for lithium batteries with r2r were addressed, which may pave the way for large scale battery production. The reviewer added that it is unclear if the technology to be developed is applicable to the current lithium-ion batteries with energy cells (relatively less energy density) or power cells for hybrid vehicle applications to establish domestic battery production lines.

Reviewer 5:

The reviewer stated that the program addresses some of the key barriers of high-volume manufacturing for high energy anode systems. The reviewer indicated that the technical approach is very clear, and said that it would be interesting to see a cost estimation and/or prognosis for the processes, and the costs it adds to a final cell design. The reviewer commented on the necessary overhead in the production facility, e.g., requirements for the dry room or inert atmosphere and associated costs. The reviewer suggested that approaching the suggested TRLs, these operational necessities should be clearly lined out, addressed, and minimized.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that year one performance targets are met.

Reviewer 2:

The reviewer observed that progress has been made and major go/no-go milestones have been met. The reviewer remarked that for the figure to show Roll-to-Roll Li Deposition Demonstration, testing condition “Cycling: 0.33C discharge to -1.0 V, 30min rest after discharge,” it seems questionable for the cell to discharge to -1.0V.

Reviewer 3:

The reviewer reported that the developed prelithiation showed energy density increase and cycle life improvement and asked if there is any limitation of Li deposition in terms of mAh/cm^2. This reviewer also inquired about the target Li deposition speed for practical application as well as the estimated cost, e.g., in $/kWh.

Reviewer 4:

The reviewer observed that some progress has been made on the way to high-energy lithium-ion cells, however the reviewer noted that the overall integration into an existing production line should be emphasized and investigated more. The reviewer mentioned that the make-or-break point of this technology will be the integration into existing equipment for lithium-ion cell production.

Reviewer 5:

The reviewer stated that all milestones are on track, and go/no-go decision points have all been “Go’s.” The reviewer added that the Li deposition tool has been used to make Li metal electrodes, although the cycling data shows significant fade in NMC622/Li cells. The reviewer indicated that this could of course be entirely related to the electrolyte of choice rather than the quality of Li deposited, but that it would be useful to complete an analysis on the deposited metal purity. The reviewer observed that the Li-Li symmetric cells performed much better, and that the SiO_x-C composite electrodes were also prelithiated and cycled with reasonable capacity retention.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer mentioned that the strong research team seems to have a very good collaboration among team members.

Reviewer 2:

The reviewer remarked that the collaboration is well coordinated to compliment limitations of AMAT.

Reviewer 3:

The reviewer noted that a strength of the project is the five partners from both downstream battery manufacturers and national laboratories, each contributing their strength, and highlighted that it is an organically integrated collaboration.

Reviewer 4:

The reviewer indicated that the team includes many collaborators, including Zenlabs and PNNL, who have tested SiO_x-NMC and Li metal-NMC cells, respectively, for this project. The reviewer added that LBNL, ANL, and Saft are also collaborators, which is clearly a strength of this project.

Reviewer 5:

The reviewer stated that the team is well set up, but that interactions between partners are not 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the barriers for future work have been identified, and that future work for next budget period was illustrated, but not in detail. The reviewer asked if there is any possibility for this project to demonstrate the manufacturing technique on large battery cells (e.g., greater than 10Ah) such as those that can be used for electric vehicles.

Reviewer 2:

The reviewer noted that the future research direction is well proposed in terms of cost, scaling, and validation.

Reviewer 3:

The reviewer remarked that the future research is nicely planned, especially on the scale up of roll-to-roll manufacturing.

Reviewer 4:

The reviewer mentioned that future work focuses on using the Li deposition tool to scale up to larger cells, and to improve the tool to increase output and allow roll-to-roll manufacturing. The reviewer added that these directions seem reasonable if this technology can improve the state-of-the-art performance anode materials. The reviewer noted that Li metal will still have its challenges regardless of the outcome of this project, and initial data for SiO_x-C cycling capability looks comparable to materials that are not prelithiated.

Reviewer 5:

The reviewer expressed that the proposed future research is okay, and that a strong emphasis on the cost estimation and process parameters, e.g., atmosphere in which pre-lithiation foil can be handled, added costs for the production, etc. should be considered. The reviewer stated that a calculation of how the pre-lithiation dose influences the lithium inventory in the cell and how this affects the amount of cathode material needed for cell would also be highly appreciated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the objectives of this project—to advance batteries with prelithiated SiO_x-C anodes with energy density greater than 337Wh/kg from TRL 5 to TRL 7, to advance batteries with Li-metal anode with energy density greater than 375Wh/kg from TRL 4 to TRL 6, and to develop a Li deposition system to meet high volume manufacturing (HVM) requirements from TRL 4 to TRL 8—support DOE's goals.

Reviewer 2:

The reviewer observed that this project is very relevant to DOE's goal to achieve high energy density Li-ion cells for long-range, long cycle life EV application.

Reviewer 3:

The reviewer noted that this project supports the overall DOE objectives by developing a key manufacturing capability for high-energy lithium-ion batteries.

Reviewer 4:

The reviewer agreed that the project supports the overall DOE objectives.

Reviewer 5:

The reviewer said that yes, Li metal and SiO_x-based anodes are potential high energy alternatives to graphite and, if challenges associated with their reversibility are solved, would result in high energy density batteries, in accord 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 noted that the funding level is appropriate for the planned work.

Reviewer 2:

The reviewer remarked that the resources are sufficient to achieve the milestones.

Reviewer 3:

The reviewer expressed that the diagnosis part of the project would be strengthened by including a university partner.

Reviewer 4:

The reviewer indicated that for the current progress the funding seems to be excessive, however the reviewer assumed that a lot of the costs are in the later stage of the project associated with machine costs.

Reviewer 5:

The reviewer noted that the resources seem sufficient, although perhaps a bit on the high side ($12 million from DOE over 3 years), for this project.

Presentation Number: bat496
Presentation Title: Silicon Consortium Project: Advanced Characterization of Silicon Electrodes
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

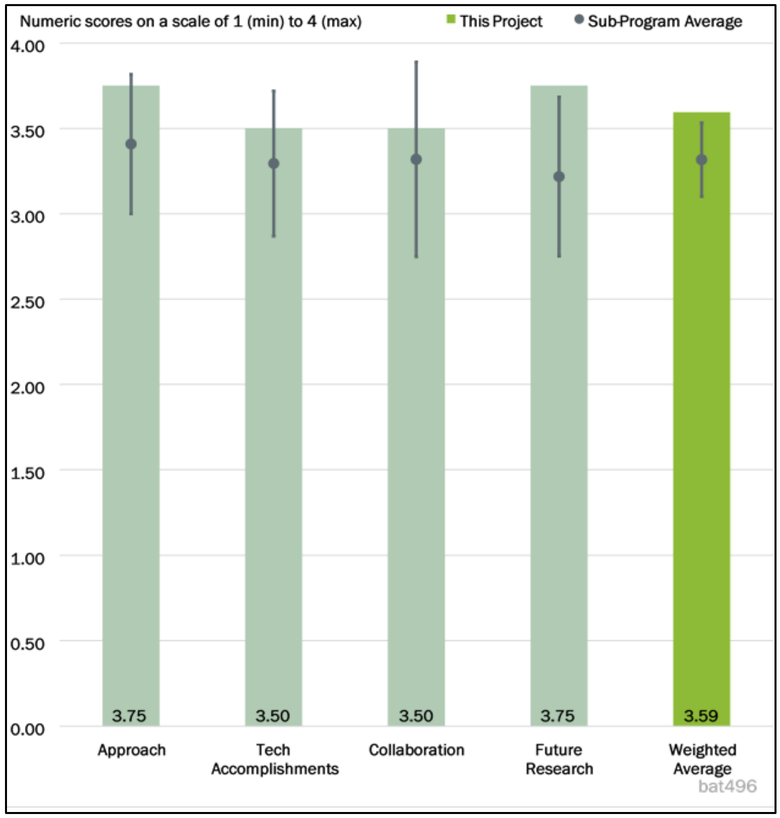


Figure 2-52 - Presentation Number: bat496 Presentation Title: Silicon Consortium Project: Advanced Characterization of Silicon Electrodes Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter

Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the approach to understand SEI on Si surface is outstanding. The reviewer acknowledged that the techniques and the approach to separate and study the material is relevant to meet the objectives of the project.

Reviewer 2:

The reviewer stated that this is highly focused work utilizing advanced diagnostic tools to characterize the Si interface.

Reviewer 3:

The reviewer mentioned that SEI is the most critical part for silicon-based anode to have acceptable cycling and calendar life.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported excellent achievements on SEI analysis with advanced characterization techniques.

Reviewer 2:

The reviewer stated that the results presented are very rich and illuminating, and that the project team did a nice job. The reviewer added that the EDS+STEM data beautifully depict how the Si particles break down in course of cycling, which is also nicely supported by the microcalorimetry data. The reviewer also applauded the results from synchrotron xrd and neutron spectroscopy data, along with the SEI composition and structure data. The reviewer was not sure the Zintl phase data are significant enough to be pursued further.

Reviewer 3:

The reviewer mentioned that there are some outstanding results that provide greater understanding of the problem facing Si anode, but that there is still more work needed in identifying the mitigation plans to overcome these challenges.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer reported outstanding collaboration and coordination across all the project teams.

Reviewer 2:

The reviewer noted that extensive collaboration with the other teams is reflected in the data/activities.

Reviewer 3:

The reviewer remarked that the project team is very strong, but that it is mainly composed of national laboratories. The reviewer recommended that since Si is also a hot topic for industry, it could be better to have some battery manufacturers on 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the diagnostic tools at LBNL are always very information-rich and insightful, and it is expected that the work proposed will help gain further insights in the Si/SEI properties. The reviewer is looking forward to the key results in relation to guidance based on the data for Si electrode or electrolyte design that will considerably prolong the durability of this Si anode.

Reviewer 2:

The reviewer indicated that the proposed future plan is appropriate and sufficient.

Reviewer 3:

The reviewer observed that there is lot more work needed to complete the project, but that the approach used to meet the goals is relevant and achievable.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that a full characterization of the Si SEI is essential to develop a robust Si electrode for the next generation Li ion battery.

Reviewer 2:

The reviewer noted that silicon-based anode is a very important candidate to improve lithium-ion battery energy density, which is aligned with DOE objectives. The reviewer added that to develop a good silicon anode, the most challenging task is to find a way to stabilize SEI on Si surface. The reviewer remarked that effective and advanced SEI characterizations will provide scientific guides for electrolyte screening and silicon electrode surface modification.

Reviewer 3:

The reviewer highlighted the importance to further understand how to stabilize the Si surface to make it a useful anode material to gain energy density and DCFC.

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 is being sufficiently funded.

Reviewer 2:

The reviewer observed that it is sufficient and milestones have been achieved.

Reviewer 3:

The reviewer expressed that the resources are sufficient to meet the program objectives.

Presentation Number: bat497
Presentation Title: Silicon Consortium Project: Electrochemistry of Silicon Electrodes
Principal Investigator: Christopher Johnson (Argonne National Laboratory)

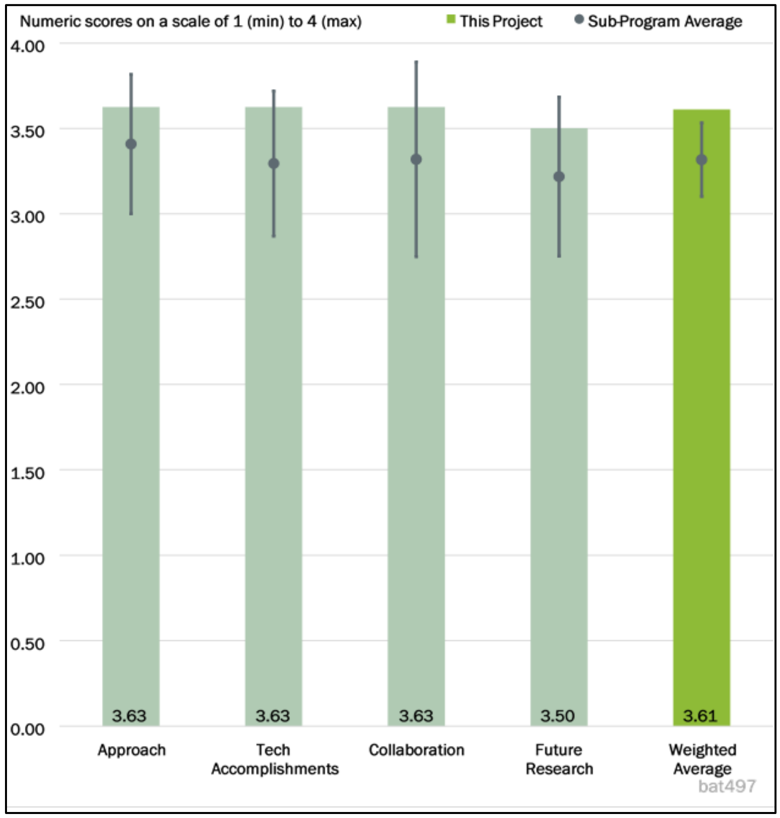


Figure 2-53 - Presentation Number: bat497 Presentation Title: Silicon Consortium Project: Electrochemistry of Silicon Electrodes Principal Investigator: Christopher Johnson (ANL)

Presenter

Christopher Johnson, ANL

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the project is carefully thought-out and well-planned, involving a good mix of experimental and modeling work.

Reviewer 2:

The reviewer expressed that a stable SEI is very critical to enable high-capacity Si containing anode in LIBs. The reviewer said that however, the understanding of SEI on Si is very limited, and that this approach is in the right direction to have better understanding of Si SEI.

Reviewer 3:

The reviewer remarked that an accelerated method to study calendar aging is very important, specifically for Si anodes. The reviewer added that the approach is relevant to the objectives of the project and is well designed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that calendar life work using the Vhold technique is a nice protocol developed. The reviewer added that while the principle is well-known, the additional thoughts that went into it to base the work on stable values is appreciated. The reviewer mentioned that the work is world-class and the results are quite insightful. The reviewer asked why one cannot use Jeff Dahn's equipment for the same purpose.

Reviewer 2:

The reviewer observed that the techniques used to evaluate SEI reactivity and calendar life are sound. The reviewer commented that the anode composition, however, is far off from a real anode in LIBs, as it includes too much carbon black and binders, which may limit the value of the work to practical applications.

Reviewer 3:

The reviewer noted that DOE used to study calendar aging, and its correlation to the model is an excellent accomplishment. The reviewer expressed that however, there still is a lot more work that needs to be done to validate the relationship to make the model more useful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there is outstanding collaboration and coordination across all project teams.

Reviewer 2:

The reviewer noted that there is complementary collaborative work as reflected by the modeling data where the modeling expertise came from one lab and the data from this lab.

Reviewer 3:

The reviewer observed that the team is excellent and diversified, and suggested working with industrial partners for practical application.

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 state project ended.

Reviewer 1:

The reviewer stated that a number of important studies have been proposed that will aid in better understanding and advancing the Si anode technology such as modeling of calendar life, and electrode parameters determination to enable modeling work.

Reviewer 2:

The reviewer observed that the plan is sound.

Reviewer 3:

The reviewer indicated that the planned future work will be enough to meet the program objectives, but that there is still more that needs to be done to make the results more useful and relevant.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that since Si anode does have the potential to significantly improve the next generation Li ion batteries, this project is very relevant to support DOE objectives.

Reviewer 2:

The reviewer agreed that Si anode is a great candidate for high energy (HE) LIBs, and that SEI study is very critical to enable Si-based anode for HE LIBs.

Reviewer 3:

The reviewer stated that understanding how calendar life affects Si anodes is the most critical problem to solve to make these anodes more useful.

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 is a handsomely funded project.

Reviewer 2:

The reviewer indicated that the resources are sufficient to meet program objectives.

Reviewer 3:

The reviewer noted that the team has sufficient personnel and tooling to execute the plan, and that an industrial partner will be a plus.

Presentation Number: bat498
Presentation Title: Silicon Consortium Project: Next-Gen Materials for Silicon Anodes
Principal Investigator: Nathan Neale (National Renewable Energy Laboratory)

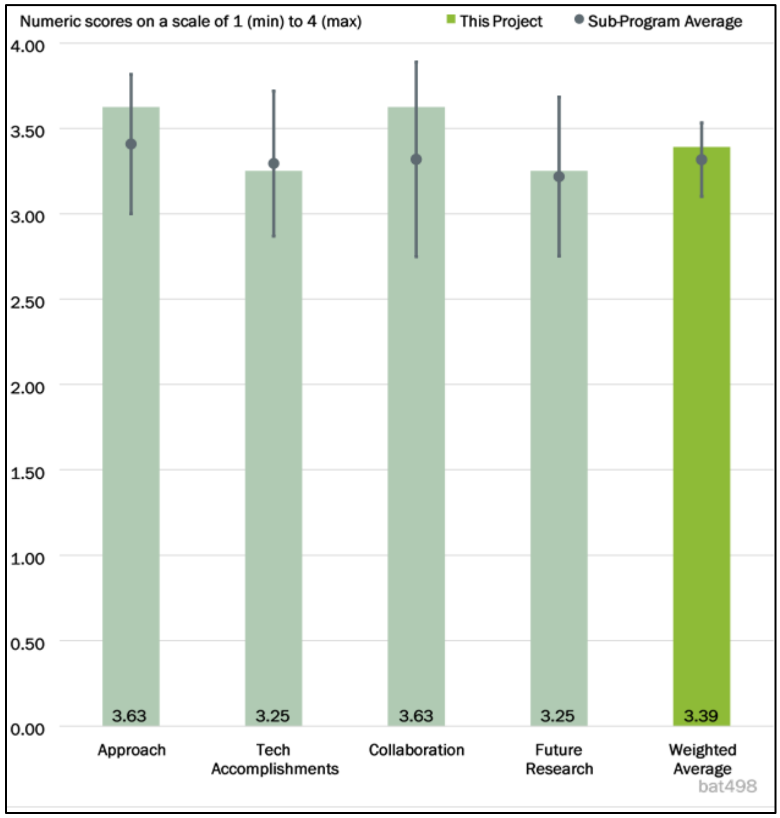


Figure 2-54 - Presentation Number: bat498 Presentation Title: Silicon Consortium Project: Next-Gen Materials for Silicon Anodes Principal Investigator: Nathan Neale (National Renewable Energy Laboratory)

Presenter

Nathan Neale, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that surface modification is a reasonable approach to help build a stable SEI on Si anode surface.

Reviewer 2:

The reviewer observed that while the stated approaches of material and electrolyte composition changes have been practiced quite considerably in these projects, one needs to pursue them further due to the lack of any other out-of-the-box option as of yet.

Reviewer 3:

The reviewer expressed that the approach to study materials that can be used to mitigate issues related to SEI formed on Si is very relevant in making this material useful for battery application. The reviewer added that Si anode stability is an issue that needs more research to understand, but that in parallel, approaches like these are needed to find an alternate solution to the Si stability problem.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that there is a good number of different approaches being made to improve the stability of Si during cycling. The reviewer commented that understanding why these material composites enable Si stability will be a remarkable accomplishment.

Reviewer 2:

The reviewer stated that the approaches have been regularly used in the past and the results shown here do not indicate as of yet that the team is bringing about a significant impact vis a vis previous results. The reviewer hoped to see considerable improvements to the current results since the project is in its very early stages. The reviewer indicated that the Zintl phase data are not that extraordinary but the Si-titanium (Ti) alloy cyclic voltammetry (CV) data seem interesting. The reviewer also questioned if production using a laser-quenching is a practical process. The reviewer added that some results are difficult to compare. The reviewer explained that the Osaka data, which appear promising at 88% after 700 cycles, were collected at C/10 but those with PECVD B:Si were collected at C/3 and still delivered 500 cycles to 90% capacity retention. The reviewer noted that only these two sets of data seem to stand out.

Reviewer 3:

The reviewer mentioned that the performance looks promising, but that there is too much carbon black and binder in the anode, which is far off from practical applications, which normally have 2-4% binder and less than 2% carbon blacks. The reviewer added that it seems the silicon anode is prelithiated in half cells first and then assembled with a cathode to form full cells. The reviewer highlighted that it is well-known that prelithiation will help compensate initial lithium loss, and that it will be better to use a practical prelithiation method which has potential to be adopted by industry. The reviewer inquired about the first cycle efficiency without prelithiation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that this is a consortium with outstanding team members with strong interactions among them.

Reviewer 2:

The reviewer remarked that this is an excellent and diversified team.

Reviewer 3:

The reviewer stated that there is outstanding collaboration and coordination across all project 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that the plan is sound, but that a formulation close to practical application will be preferred.

Reviewer 2:

The reviewer observed that there is lot more that needs to be done to understand how the material interactions affect cycle and calendar life. The reviewer suggested that more research is needed to meet the program objectives, and that cost to benefit analysis is needed to check if these improvements are relevant.

Reviewer 3:

The reviewer commented that aside from the SiTi anode, the rest are well-practiced approaches and it is hard to visualize whether there will be nothing more than low-level incremental improvements to the results that will be attractive from practical application point of view. The reviewer expressed that there is hope that the team will be creative with its selection and make an impact on the program.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project is highly relevant in order to develop next generation high energy/low-cost Li ion batteries.

Reviewer 2:

The reviewer commented that silicon materials with surface modification which can facilitate stable SEI formation is critical to support the development of HE LIBs.

Reviewer 3:

The reviewer highlighted the importance of studying alternative methods to mitigate the problems associated with Si stability.

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 funding level seems appropriate to support this project.

Reviewer 2:

The reviewer commented that the resources are sufficient to execute the plan.

Reviewer 3:

The reviewer remarked that the resources are sufficient to meet the program objectives.

Presentation Number: bat499
Presentation Title: Silicon Consortium Project: Mechanical Properties of Silicon Anodes
Principal Investigator: Katherine Harrison (Sandia National Laboratories)

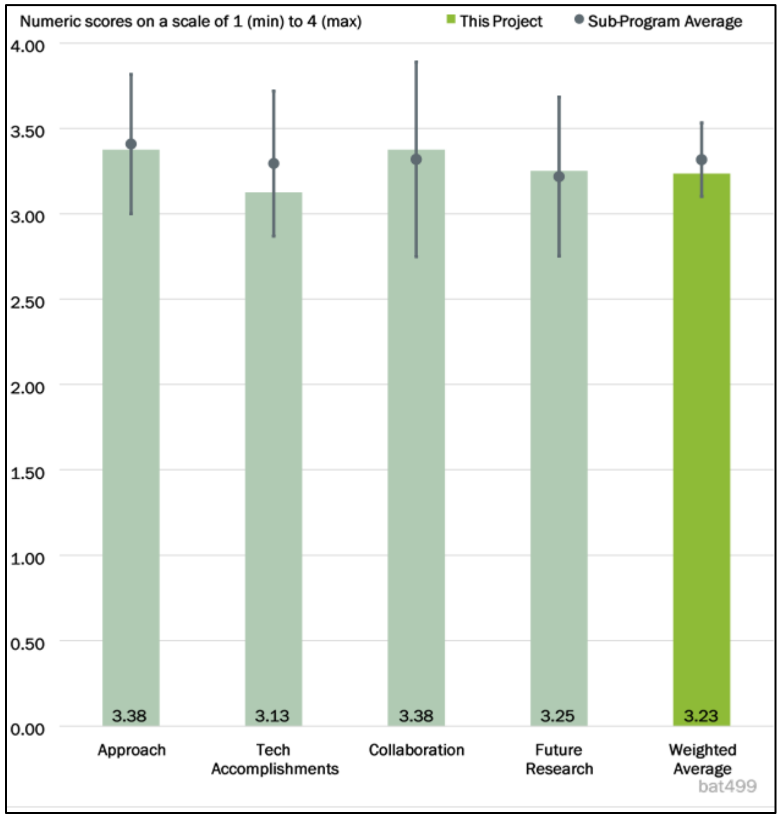


Figure 2-55 - Presentation Number: bat499 Presentation Title: Silicon Consortium Project: Mechanical Properties of Silicon Anodes Principal Investigator: Katherine Harrison (Sandia National Laboratories)

Presenter

Katherine Harrison, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the proposed approaches cover a variety of techniques as listed.

Reviewer 2:

The reviewer mentioned that a stable SEI is critical for the application of silicon-based anode in HE LIBs. The reviewer said that this approach is very helpful to understand how SEI fails on Si anode and thus very beneficial to high-capacity anode development. The reviewer added that the experiment design is executable and sound.

Reviewer 3:

The reviewer observed that the approach to study Si anode mechanical stability is outstanding. The reviewer explained that it is very difficult to differentiate the actual change in thickness from noise from the instrument in this scale, but that the approach using multiple methods to measure the same thing and correlating the results is well designed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project has just started and first data from Moire interferometry show it to be unsuitable due to inaccuracy, but that hopefully scanning microscopy will yield better results.

Reviewer 2:

The reviewer expressed that it has been an excellent effort in understanding which techniques work and which are too noisy to get any good information. The reviewer added that there is still lot of effort needed to understand the relationship between the results from different techniques, and that the go/no-go points need to be well established.

Reviewer 3:

The reviewer indicated that there are very limited results and it is hard to judge.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that it is a very strong consortium, and that the team will leverage other's expertise effectively.

Reviewer 2:

The reviewer applauded the excellent and diversified team.

Reviewer 3:

The reviewer noted that there is outstanding collaboration and coordination across all project 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that the plan is sound, and that the work will help understand how mechanical properties and mechanical manipulation impact life of silicon anodes. The reviewer added that it may provide good guidance for further Si materials surface modification for better stability.

Reviewer 2:

The reviewer noted that there needs to be well defined go/no-go points in the future work to better steer the project to meet its original objectives.

Reviewer 3:

The reviewer expressed that, as mentioned above, several mechanical and electrochemical approaches have been proposed to carry out the mechanical characterization of the SEI, and it remains to be seen how effective they will be. The reviewer suggested that it might be useful to talk to the Xerox PARC team who investigated mechanical strain properties using fiber optics/Bragg.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that better understanding of the mechanical behavior of the Si SEI layer is useful to design the next generation Li ion batteries.

Reviewer 2:

The reviewer said that yes, the project supports the development of high-capacity anode for HE LIBs.

Reviewer 3:

The reviewer remarked that understanding the mechanism of mechanical failure in Si anodes will help make the material more applicable to automotive applications that require long calendar 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 indicated that the funding level seems sufficient to provide good support for the project.

Reviewer 2:

The reviewer mentioned that the resources are sufficient to achieve the planned tasks.

Reviewer 3:

The reviewer expressed that the team has sufficient resources to complete the project.

Presentation Number: bat500
Presentation Title: Silicon Consortium Project: Science of Manufacturing for Silicon Anodes
Principal Investigator: Gabe Veith (Oak Ridge National Laboratory)

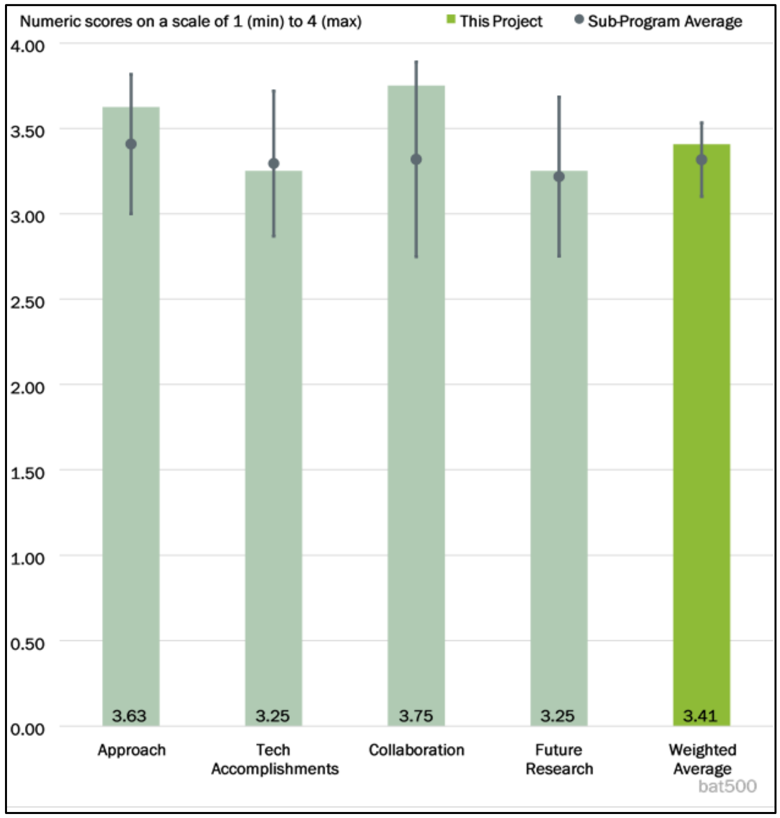


Figure 2-56 - Presentation Number: bat500 Presentation Title: Silicon Consortium Project: Science of Manufacturing for Silicon Anodes Principal Investigator: Gabe Veith (Oak Ridge National Laboratory)

Presenter

Gabe Veith, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that there are several attractive approaches such as coating and pre-lithiation that have been investigated to stabilize the Si anode materials.

Reviewer 2:

The reviewer expressed that in general, carbon coated Si materials as well as prelithiation would extend cycling life of LIBs with silicon anode, which can increase energy density of EV batteries for longer driving range.

Reviewer 3:

The reviewer noted that fabricating carbon coated Si and Si prelithiation are two of the best approaches to mitigate Si anode instability during cycling. The reviewer highlighted the importance of understanding how manufacturing techniques can affect the performance of these techniques.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that while electrochemical pre-lithiation is a well-established process now, the thermal evaporation method seems interesting based on the initial results. The reviewer noted that it is not clear how efficient this process is for scaling up, for uniformity, and from a cost and mass-production point of view.

Reviewer 2:

The reviewer remarked that the project made good progress on carbon coated Si preparation. The reviewer expressed that there is no data, however, to support the claim of "Achieved 1000 cycles with greater than 80% capacity retention with new cell chemistries". The reviewer added that the specific capacity for silicon anode on Slide 4 is too low, below 150mAh/g, less than half that of normal graphite anode. The reviewer said that the prelithiation protocol might be good for a concept proof in the lab, but that it is not practical.

Reviewer 3:

The reviewer noted that there is good progress in demonstrating which manufacturing conditions improve performance, but that there is still more work needed in understanding the failure mode for thick Si anode coatings. The reviewer stated that the mitigation will have to involve understanding how the properties of all the material interact when thick electrodes are made, and that is going to take a lot of effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer expressed that the collaboration with other teams was reflected in the work to understand material and processing issues for Si anodes, neutron scattering and coating method development.

Reviewer 2:

The reviewer noted an excellent and very diversified team.

Reviewer 3:

The reviewer applauded the outstanding collaboration and coordination across all the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the future plan sounds reasonable, and that the key to make silicon anode stable is SEI formation and gassing reduction during cycling and storage. The reviewer recommended incorporating these two into the future plan.

Reviewer 2:

The reviewer observed that future work to further explore the thermal evaporation method seems interesting. The reviewer added that the other work proposed, such as studies with reduced binder or other carbon coatings (not specified though), seems a little generic with unclear impact.

Reviewer 3:

The reviewer said that there is a lot more future work needed to understand the mechanism involved in making thick Si anode work as expected. The reviewer noted that the project needs to refocus efforts on identifying and optimizing specific conditions that give the most benefit towards achieving the program objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that manufacturing high quality Si anodes is very important to develop next generation Li ion batteries.

Reviewer 2:

The reviewer observed that silicon-based anode materials are a critical candidate for high energy EV battery development.

Reviewer 3:

The reviewer said that it is extremely relevant to understand how manufacturing conditions and material interactions affect Si anode performance. The reviewer added that optimizing these is the clear path to meeting the objective of making a viable Si anode that is useful for 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 commented that the funding for this part of the work seems appropriate.

Reviewer 2:

The reviewer noted that the resources are sufficient to achieve milestones, and that it may be a plus to have an industrial partner to have better understanding and a point of view for practical applications.

Reviewer 3:

The reviewer remarked that the program has sufficient resources to meet the objective set at the start.

Presentation Number: bat501
Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode
Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

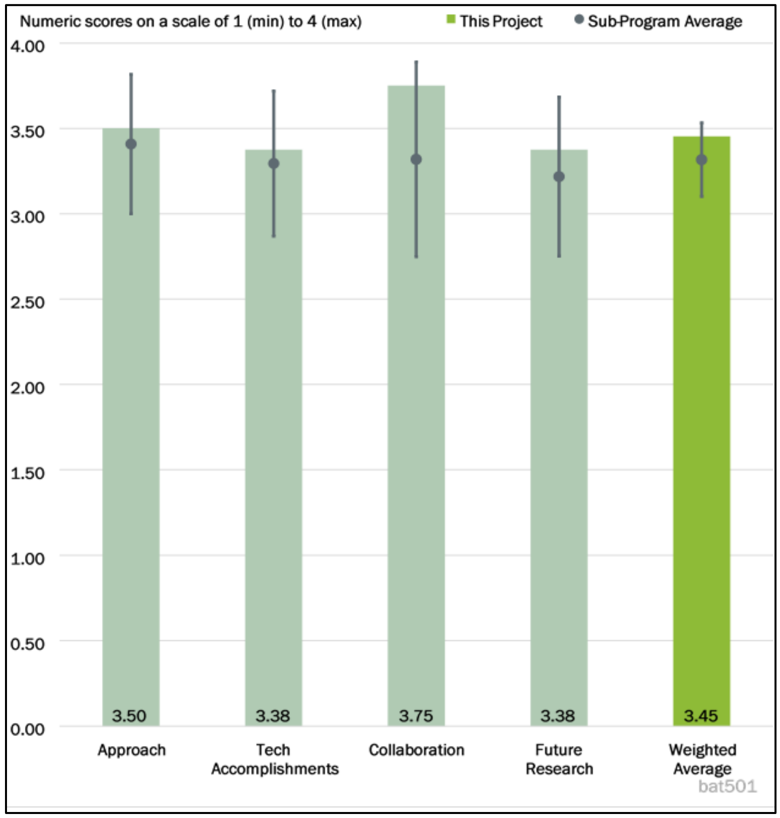


Figure 2-57 - Presentation Number: bat501 Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicon Anode Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

Presenter

Kristin Persson, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the approach in this study was highly organized, involving leading-edge computational studies leveraging the most sophisticated modeling tools out there.

Reviewer 2:

The reviewer expressed that it is great to find a possible reaction path for the formation of known components in SEI. The reviewer stated that it will be excellent to utilize the findings to predict products from new electrolyte designs.

Reviewer 3:

The reviewer remarked that SEI on Si anode is one of the most complex systems in the battery industry to understand. The reviewer reported that there are just too many variables to properly understand the optimized conditions that enable the best performance from Si anode. The reviewer commented that the approach to model SEI so these variables can be narrowed down is well designed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the results are remarkable. The reviewer explained that it can be exemplified by the results that lead to the formation of LEDC, involving 6,000 species and 4,500,000 reactions. The reviewer asked how one defines “expected” and “novel,” and of the novel, how one distinguishes whether this is indeed a plausible route. The reviewer asked if the model imposes both thermodynamic and kinetic pass/fail criteria before moving on to the next steps.

Reviewer 2:

The reviewer observed that progress has been made to find the possible reaction path for SEI some components.

Reviewer 3:

The reviewer indicated that there has been good progress made in developing the model to train it to select relevant variables, but that there is still a lot more that needs to be done to further improve probability and correlate it with physical confirmation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer reported that multiple studies within the project involved close collaboration among the consortium members.

Reviewer 2:

The reviewer noted an excellent and very diversified team.

Reviewer 3:

The reviewer stated that there is outstanding collaboration and coordination across all project 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the work proposed is a ground-breaking from a battery researcher’s point of view, and helps to really understand the evolution of these mechanisms via the modeling work. The reviewer asked how one can know how reliable these modeling results are. The reviewer asked if there is any surrogate, hopefully less complex system, that can be modeled to validate such work.

Reviewer 2:

The reviewer said that the project is to use modeling support silicon and development, and that it may be more beneficial to find how SEI forms differently on Si compared with graphite.

Reviewer 3:

The reviewer indicated that there is lot more that needs to be done to make the model work with high confidence. The reviewer commented that the effort needed to overcome the challenges seem to be too great, and that there needs to be a refocus on work plan to meet the final program objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer expressed that fundamental understanding of the SEI characteristics derived via modeling is of utmost significance to develop Si-based next generation Li ion batteries.

Reviewer 2:

The reviewer said that yes, SEI is critical for the development of high energy LIBs with Si anode, which has high potential for EV batteries for longer driving range.

Reviewer 3:

The reviewer mentioned that the model activity is very important to find answers related to Si anode stability. The reviewer explained that the model should be used to guide the experiments to understand how the various materials interact to improve Si anode stability.

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 is a well-funded project.

Reviewer 2:

The reviewer noted that the resources are sufficient to achieve the milestones.

Reviewer 3:

The reviewer remarked that the time and effort needed to achieve the objective are not sufficient. The reviewer explained that this effort will need additional resources to run the various conditions needed, and that the program objective needs a refocus to achievable results.

Presentation Number: bat502
Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Si Anode (Si-HPC)
Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

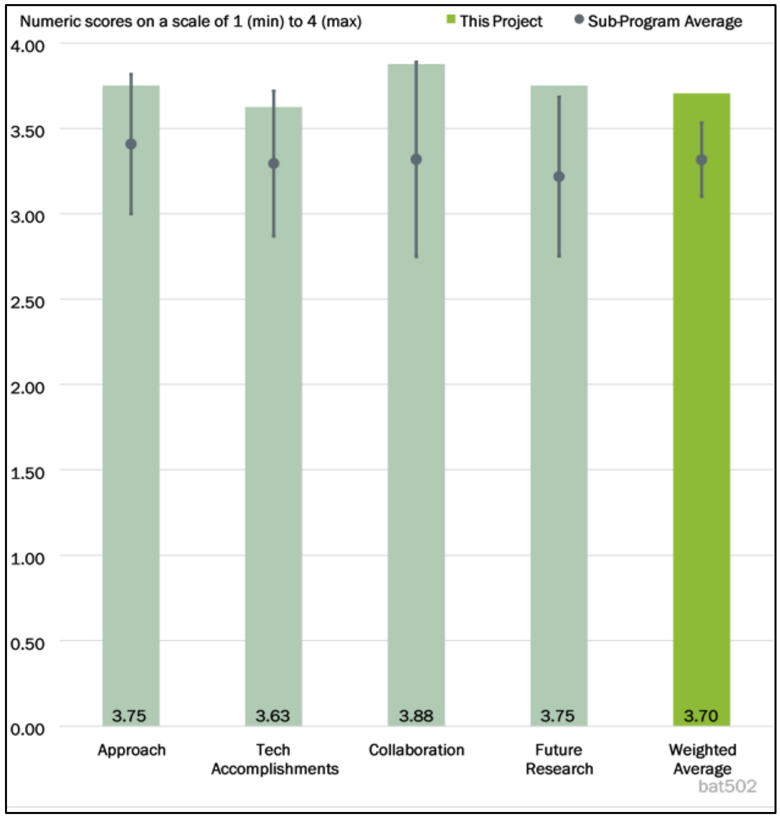


Figure 2-58 - Presentation Number: bat502 Presentation Title: (PI to provide a new title) Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Si Anode (Si-HPC) Principal Investigator: Andrew Colclasure (National Renewable Energy Laboratory)

Presenter

Andrew Colclasure, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the approach to understanding Si anode stability in an electrolyte is outstanding. The models will help narrow down the variables by removing highly improbable conditions.

Reviewer 2:

The work was very well-organized making use of the atomistic models developed at LBNL and ORNL.

Reviewer 3:

The reviewer remarked that it is great to find a possible reaction path for the formation of known components in SEI. It will be excellent to utilize the findings to predict products from new electrolyte designs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said this is a very comprehensive study aimed at understanding the SEI characteristics at the Si surface leveraging atomistic modeling carried out at LBNL and ORNL. Results of this complex modeling seems to confirm what we experimentally know, i.e., the expected effects of such parameters as voltage, resistance, or expansion/contraction.

At the end of the day though, one would love to use these results to design, develop, or predict the behavior of the corresponding system. While the data obtained thus far are insightful, the reviewer asked whether that goal can be reached with these studies.

Reviewer 2:

The reviewer commented that good progress has been made to predict the thickness growth of SEI film and the dependence on voltage. Have efforts been made to validate these findings with experimental data?

Reviewer 3:

The objectives set at the start of the year has been achieved, but the reviewer indicated that there is still lot more to be done to meet overall project objectives.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said there is outstanding collaboration and coordination across all the project members.

Reviewer 2:

An excellent and very diversified team was observed by this reviewer.

Reviewer 3:

The reviewer remarked that this work had active collaboration with the other modeling teams of LBNL and ORNL as evidenced by the data shown.

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 state project ended.

Reviewer 1:

The reviewer asserted that the plan is sound, especially inclusion of "Implement Si particle chemo mechanical influences on SEI performance."

Reviewer 2:

The reviewer noted a list of important activities that will advance the understanding of Si SEI layer has been proposed including incorporation of additional species, experimental validation of the developed mechanism (especially the current and species concentration), and mechanical considerations of the SEI layer. Despite the very comprehensive nature of these studies, they are based on a whole slew of assumptions. The reviewer remarked that it would be good to show some analysis that reflects the fidelity of these results as a function of those assumptions.

Reviewer 3:

This reviewer indicated that there is a lot more to be done to achieve project objectives and suggested that future work may need to be refocused to achieve the final objective in the provided time.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, and noted that SEI is critical for the development of high-energy LIBs with a Si anode, which is a highly potential candidate for EV batteries for longer driving range.

Reviewer 2:

The reviewer remarked that the basic understanding and modeling of the Si interface is important for developing next-generation LIBs.

Reviewer 3:

The reviewer said that it is very relevant to reduce the variables in understanding the stability of a Si anode in the electrolyte.

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 level is appropriate.

Reviewer 2:

The reviewer said that resources are sufficient to achieve milestones.

Reviewer 3:

The reviewer commented that the project would need more time and more funds to complete the stated objective, or there needs to be a refocus of the objectives to complete on time.

Presentation Number: bat503
Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicone Anode
Principal Investigator: Jean-Luc Fattebert (Oak Ridge National Laboratory)

Presenter

Jean-Luc Fattebert, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

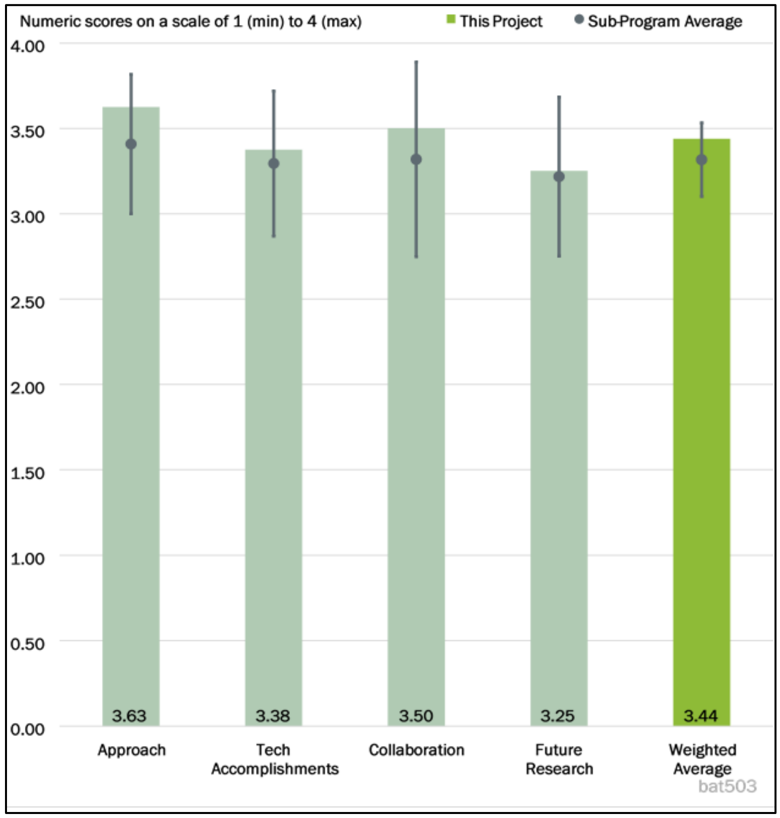


Figure 2-59 - Presentation Number: bat503 Presentation Title: Integrated Modeling and Machine Learning of Solid-Electrolyte Interface Reactions of the Silicone Anode Principal Investigator: Jean-Luc Fattebert (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

For this reviewer, it is great to find possible reaction path for the formation of known components in SEI. It will be excellent to utilize the findings to predict products from new electrolyte designs.

Reviewer 2:

The reviewer remarked that this is very advanced work to simulate the generation of species at the SEI using molecular dynamics techniques.

Reviewer 3:

The reviewer remarked it is an outstanding effort to model SEI on a Si anode. There are just too many variables to effectively understand how the interaction between the Si anode and an electrolyte happens.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that while it is understood that a number of assumptions were made (which may or may not be fully correct) for this modeling work, it is highly gratifying and instructive to see that these studies led to a good agreement with what people macroscopically had found out.

Reviewer 2:

Progress has been made to show formation of inorganic and organic products in SEI, according to this reviewer.

Reviewer 3:

The reviewer noted that there is some good development in the model that shows how the initial interaction of the electrolyte occurs with a Si anode, but there is still much more that needs to be done to understand Si stability in relevant real-world conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted an excellent and very diversified team.

Reviewer 2:

The reviewer commented that there is outstanding collaboration and coordination across all project team members.

Reviewer 3:

The reviewer remarked that it can be easily expected that the PI had a lot of collaboration with the LBNL and NREL teams, leading centers for such modeling work.

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 state project ended.

Reviewer 1:

The reviewer pointed out that given the fact a framework has been developed, it will be interesting to see, as the author proposes, how other parameters–additives, anode surface, binder, temperature, or even types ([Li] metal), etc.—affect the SEI characteristics. It would, however, be important to carry out sensitivity analysis on the various assumptions made during the modeling. This would give researchers some level of confidence in the data.

Reviewer 2:

The reviewer commented that the project is to use modeling to support Si development. It may be more beneficial to find how SEI forms differently on Si compared with graphite. It may be more meaningful to focus on a larger time scale since the unit for the life of the LIB is a year, not a second.

Reviewer 3:

The reviewer remarked there is lot more work to be done to meet final project objectives. Future work needs to be refocused to meet project objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented fundamental understanding of the SEI growth mechanism on the Si electrode is of utmost importance to an improved anode and consequently an improved, next-generation LIB.

Reviewer 2:

The reviewer affirmed that, yes, and explained that SEI is critical for the development of high-energy LIBs with a Si anode, which is a highly potential candidate for EV batteries for longer driving range.

Reviewer 3:

The reviewer pointed out that it is very relevant to understand the interactions between Si anode and electrolyte.

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 seemed appropriate to this reviewer.

Reviewer 2:

The reviewer remarked that resources are sufficient to achieve milestones.

Reviewer 3:

The reviewer commented that there is lot more that needs to be done to meet project objectives. The team needs more resources to meet them in a timely fashion.

Presentation Number: bat504
Presentation Title: 3D Printed, Low Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries
Principal Investigator: Eric Wachsman (University of Maryland)

Presenter

Eric Wachsman, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

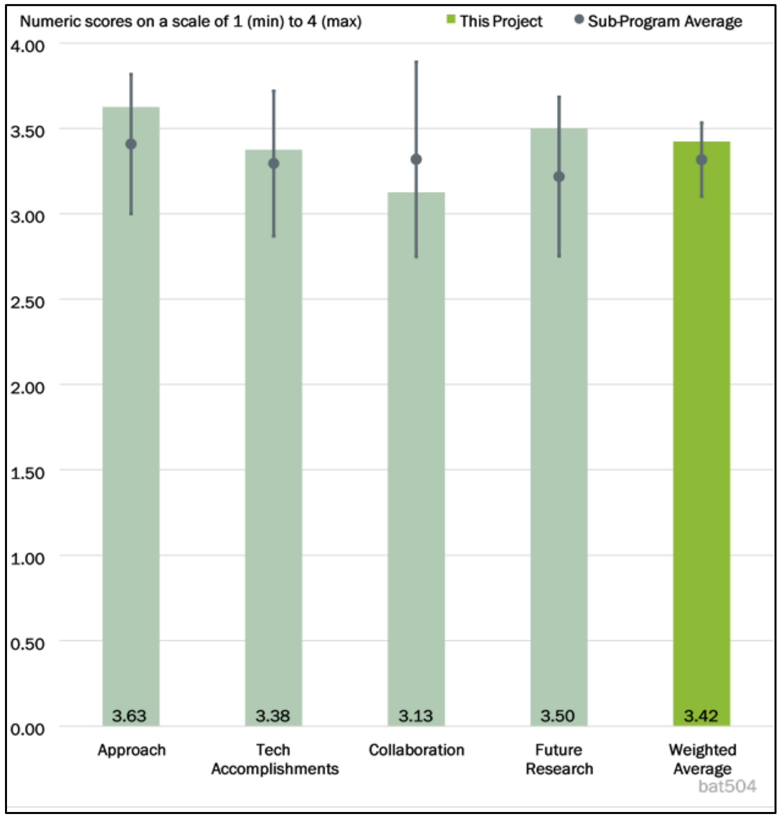


Figure 2-60 - Presentation Number: bat504 Presentation Title: 3D Printed, Low Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries Principal Investigator: Eric Wachsman (University of Maryland)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the low tortuosity, high porosity electrode fabrication approach is compelling.

Reviewer 2:

The reviewer detailed how the approach of this project, as performed by Wachsman, Hu, and co-workers, aims to form 3-D printed, low tortuosity frameworks of Li garnets for batteries with gravimetric energy densities beyond 500 Wh/kg. The main technical barriers addressed are (1) improvement of the electrode/electrolyte interfaces by precisely tuning the interfacial surface area through 3-D printing ceramics and (2) structure-property relationships of how different ceramic architectures affect the total energy density, depth of discharge, and the C-rate. These barriers are indeed important, and the approach is quite novel among ceramic processing, especially with multi-cation ceramics like Li garnets. The reviewer observed that although this project was delayed by COVID-19, the team did an adequate job performing the experiments, as outlined in their approach. Overall, the team has implemented an effective approach to overcome these barriers.

Reviewer 3:

The reviewer commented that the team developed 3-D printing techniques to build architected solid-state electrolytes (SSE) to enhance the contact with electrode materials. The approach has the potential to decrease interfacial resistance and enhance mechanical robustness and therefore increase the energy density and possibly rate performance. The integration of modeling work helps guide the experimental designs of the printed architecture. The reviewer said the project is well designed.

Reviewer 4:

The reviewer pointed out that the 3-D printed SSE will enable thicker electrodes with more interfacial surface areas for higher energy density.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the project "3D Printed, Low Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries" reports a number of important accomplishments. This project led to models of cathode structures and their relation to electrochemical properties; enabled novel ceramic processing techniques such as 3-D printing to achieve ceramic architectures that were predicted by the models; optimized 3-D structures; improved cathode-electrolyte interfaces with garnets and sulfur (S)/nickel manganese cobalt oxide (NMC); and led to cells that approach 500 Wh/kg. Overall, the technical accomplishments are effective and contribute to overcoming the barriers for Li garnet SSEs.

Reviewer 2:

The reviewer noted that the project is 80% complete due to pandemic delay. The cell-level optimization and performances are limited (e.g., 300 Wh/kg and 500 Wh/kg for Li-S or Li-NMC). However, the experiments show very promising preliminary results with this 3-D printing approach. The different 3-D structures for Li-NMC and Li-S are well designed.

Reviewer 3:

The reviewer said this year the team conducted simulation work to optimize the 3-D architecture and compared it with experimentally derived structures. The conclusion is finer features with lower tortuosity is preferred, which is intuitively expected. Due to the pandemic, the PI mentioned the progress of the experimental part has been unfortunately delayed, while good progress has been made in the cell performance testing.

Reviewer 4:

The reviewer remarked that, generally, the early data look promising, and it is nice that this SSE can be used with both high-voltage NMC and high-capacity S cathode materials. But clearly interfacial and other impedances are still major issues to be overcome here. The NMC electrochemical data (Slide 11) is with a loading of 1.5 mg/cm^2 and at a rate of 0.05C. Note that the loading is equivalent to about 0.25 mAh/cm^2—a factor of 10 too thin compared to commercial systems.

The reviewer said that the S results on Slide 9 are much different, with a report of 3.2 mAh/cm^2 and current of 20 mA/g which is 7C, which seems to possibly be a misprint. The reviewer noted it is very rare to cycle a solid-state battery (SSB) or a S cell at such a high rate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked the team appears to have close, appropriate collaborations as well as coordination with other institutions.

Reviewer 2:

Although minimal collaboration was shown, this reviewer indicated that it is not critical because this is a university R&D project.

Reviewer 3:

The reviewer said the team listed one collaborator.

Reviewer 4:

The reviewer noted that the team has one university collaborator.

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 state project ended.

Reviewer 1:

The reviewer commented the proposed research seems to be similar to last year's due to the pandemic delay. As of the project end date, the project is not 100% finished. It is important to finish the rest of the work because it is very interesting and promising.

Reviewer 2:

The reviewer said that there are very aggressive future plans to make cells that deliver 500 Wh/kg and cycle 200 times—it seems highly unlikely, given the current loadings and rates shown here. The reviewer noted that the reported 800 mAh/g of the team's S cathode is impressive, but well below the theoretical capacity.

Reviewer 3:

The reviewer commented the team plans to continue the effort in the remainder of fiscal year FY) 2021. Although the team has shown preliminary cell performance testing results, there is still a big room for improvement. For example, the mass loading of NMC or S is still far from a practical application and the set goal of 300 Wh/kg. How to avoid the use of liquid electrolyte in cell performance testing is still a challenge to be solved.

Reviewer 4:

The reviewer pointed out the project "3D Printed, Low Tortuosity Garnet Framework for Beyond 500 Wh/kg Batteries" has ended (March 31, 2021).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that the project is highly relevant.

Reviewer 2:

The reviewer said the 3-D printing of the low tortuosity garnet framework is a good SSE candidate for both Li-ion and Li-S batteries. In addition, the 3-D printing is a repeatable and scalable process.

Reviewer 3:

The reviewer detailed that this project is relevant to a number of DOE objectives, namely, the objective to develop affordable batteries with increased energy densities (or specific energies) for applications in the EV market. Although this project has overcome some of the technical objectives, there is still more work to do, as cathode/SEI still present numerous issues in different battery systems. While this project achieved greater than 300 Wh/kg batteries, it was noted that more funding will be necessary to try other types of architectures and further scale the production of these architectures. This project addresses many of the DOE goals and also achieves some of the technical objectives of the Battery500 program.

Reviewer 4:

The reviewer said the project is supportive of DOE's objective in clean energy storage and electrification of vehicles, given that SSBs are a much safer and higher-energy-density choice. The project aims to tackle the manufacturing of SSBs that are far from mature. Proper integration techniques that can maximize the benefits from high-capacity metallic Li, high conductivity and safe SSE, and high-capacity cathodes, are urgently needed.

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 due to COVID-19, this project was delayed and the team stated that it took a no-cost extension. This reviewer found that cathode-SEIs are incredibly important and deserve special attention from the DOE. This team has the proper equipment and resources to carry out this kind of research, and this team also has a number of active collaborations both internally and externally. These collaborations can help expedite this work if it continues to receive funding from future calls.

Reviewer 2:

The reviewer saw no issues with resources.

Reviewer 3:

The reviewer remarked the team has great resources to finish the project.

Reviewer 4:

The reviewer said the team has the resources to complete the required work. It seems that an extended period might be needed to tackle the technical challenges.

Presentation Number: bat505
Presentation Title: Advanced Electrolyte Supporting 500 Wh/Kg Li-C/NMC Batteries
Principal Investigator: Chunsheng Wang (University of Maryland)

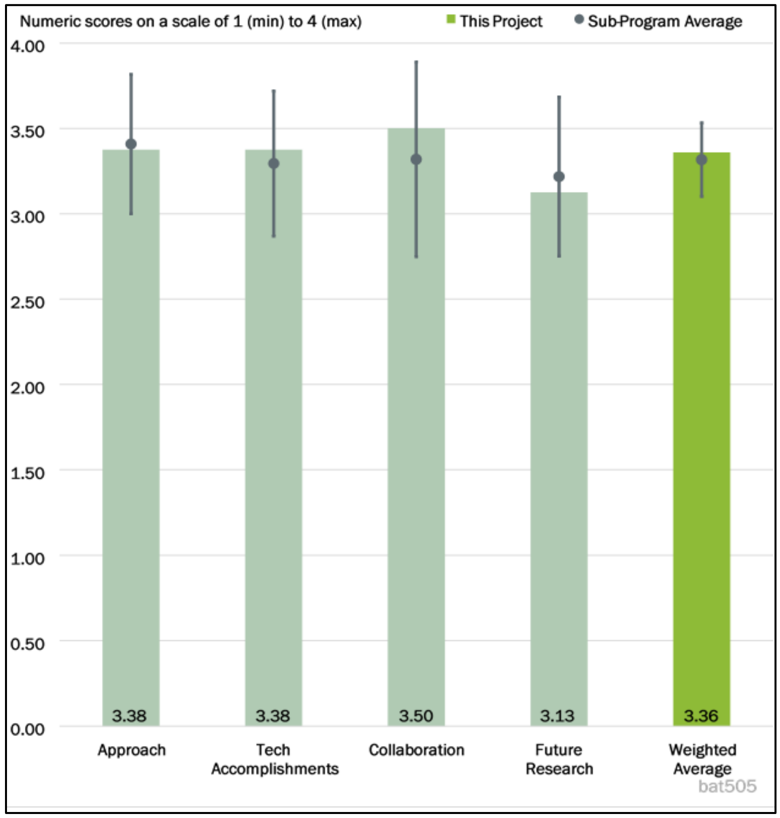


Figure 2-61 - Presentation Number: bat505 Presentation Title: Advanced Electrolyte Supporting 500 Wh/Kg Li-C/NMC Batteries Principal Investigator: Chunsheng Wang (University of Maryland)

Presenter

Chunsheng Wang, University of Maryland

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the team wants to use Li-metal in a cell and plans to do this by creating a an SEI that is mostly lithium fluoride (LiF). The team plans to do this through several approaches including a nitrate reinforced carbonate electrolyte, a solvent-free eutectic electrolyte, and a new ionic liquid electrolyte.

Reviewer 2:

The reviewer noted that this project focuses on addressing Li dendrite and interfacial issues in Li batteries, which are important and relevant to DOE's objectives. The proposed approaches of nitrated reinforced carbonate electrolyte, eutectic electrolyte, and ionic liquid electrolyte are scientifically sound and were proved effective to form a LiF-rich SEI Li anode.

The reviewer cited how concerns of using $LiNO_3$ in Li/NMC811 are chemical instability and safety concerns of $LiNO_3$ in high-voltage/energy Li batteries. For eutectic and ionic liquid electrolytes, Li-ion transport properties in the electrolyte and wetting of thick electrodes would be problematic in practically high-energy Li batteries.

Reviewer 3:

The reviewer commented the “Strategy/Approach” is based on two unproven speculations: the “LiF-Li_3N SEI” bonds weakly with Li, allowing it to expand or shrink with Li; and LiF SEI promotes Li diffusion along the LiF-Li interface. The reviewer remarked there is no evidence for either.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the new electrolytes, e.g., nitrate reinforced carbonate electrolytes, solvent-free eutectic electrolyte, and ionic liquid electrolyte, appear to be highly promising.

Reviewer 2:

The reviewer said the PI and team successfully deployed the proposed approaches in the project. LiF-rich SEI was proved effective in improving Li cycling efficiency and extending cell cycle life. Long cycling at lean electrolyte conditions is still a challenge. This project focuses on the fundamental problems of high-energy Li-NMC cell; however, it seems that the PI put too much effort on the low--voltage materials of sulfurized polyacrylonitrile (S@PAN) and sulfurized porous carbon (S@PC). The reviewer noted that no results were reported on the Li-C anode, which is an important part of this project.

Reviewer 3:

The reviewer remarked that the team made cells with nickel cobalt aluminum oxide (NCA) and NMC 811 as the cathode with Li and a nitrate-based electrolyte and showed good cyclability for 150 cycles and compact Li plating. The team used the same electrolyte in a Li-S cell where PAN was used as the binder in the cathode. The cell cyclability capacity was less than 700 mAh/g for about 90 cycles. The reviewer noted how the team used the solvent-free eutectic electrolyte in a S cell and operated at 80°C, 30°C above the eutectic temperature. Again., the team gets about 700 mAh/g cyclability capacity and measured a CE of the Li of 99.2%. For this ionic liquid, the team again expects an LiF SEI that will suppress dendrite growth; using NCM again, the team gets good cyclability to 120 cycles with regard to CE and shows 85% capacity retention after 120 cycles. In pouch cells, the reviewer indicated that the team achieved 300 cycles, but the cells are just 2 mAh/cm^2. None of the results so far are off the charts although the CE still looks good. The ionic liquid is used in a Li-S cell and the team still just gets 600 mAh/cm^2.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted collaborations with experts at U.S. Army Research Laboratory (ARL), Saft America, and BNL seem to be highly effectively.

Reviewer 2:

The reviewer said the team brought in real experts from industry and national laboratories to get critical work and guidance.

Reviewer 3:

The reviewer remarked the PI has close collaborations with ARL, a national laboratory, and the battery 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked this project has a clear plan for future work. Efforts on Li-NMC811 should be enhanced to extend the cycle life at both high areal loading and lean electrolyte conditions. Efforts on S@PAN and S@PC may be diluted.

Reviewer 2:

The reviewer recommended that future research should include experimental investigation of the two basic assumptions that (1) the "LiF-Li_3N SEI" bonds weakly with Li allowing it to expand or shrink with Li and (2) LiF SEI promotes Li diffusion along the LiF-Li interface.

Reviewer 3:

The reviewer said that future plans are very specific other than to try to make everything better.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented the project is highly relevant to the DOE objectives.

Reviewer 2:

The reviewer said the Li-NMC battery technology has a high potential to realize high energy and long lifespan as a promising next-generation battery technology. This project aligns well with DOE's objectives of vehicle electrification.

Reviewer 3:

The reviewer pointed out that DOE wants to get to 500 Wh/kg, and this can be done with a Li anode. This work provides three ways to get there. There need to be more cycling data to see when or if the dendrites appear.

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 PI has close collaborations externally and has sufficient resources to perform the proposed research.

Reviewer 2:

The reviewer remarked resources seem sufficient. The researchers need more effort on the S electrode and more cycling data on their NCM and NCA cells to see how well their electrolyte is suppressing dendrites.

Reviewer 3:

The reviewer commented the team has excellent resources.

Presentation Number: bat506
Presentation Title: Composite Cathode Architectures Made by Freeze-Casting for All Solid State Lithium Batteries
Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

Presenter

Marca Doeff, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

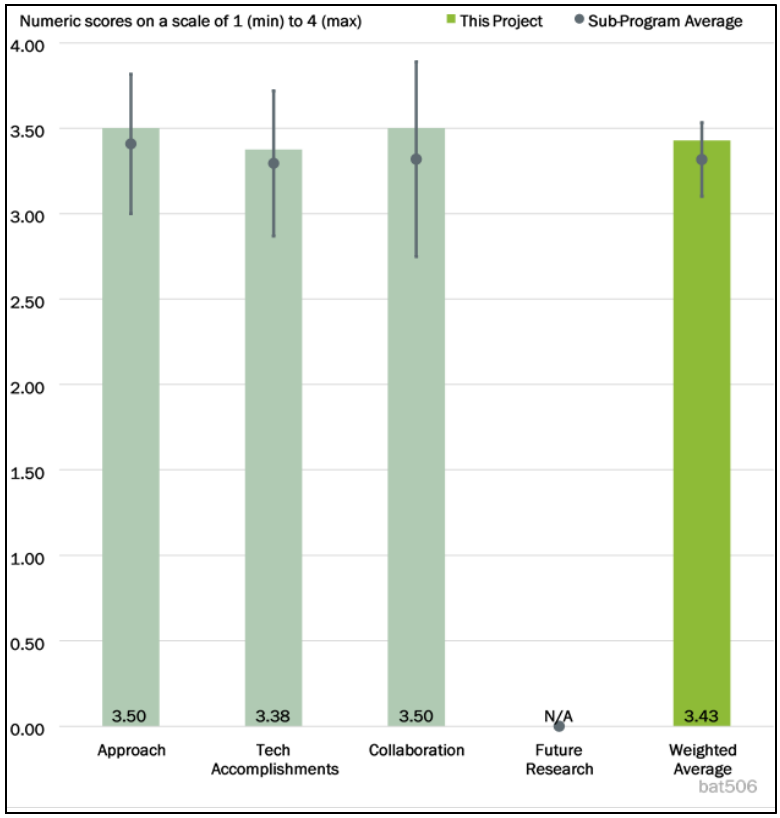


Figure 2-62 - Presentation Number: bat506 Presentation Title: Composite Cathode Architectures Made by Freeze-Casting for All Solid State Lithium Batteries Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that freeze-tape casting lithium lanthanum zirconium oxide ($Li_7La_3Zr_2O_{12}$, LLZO) then infiltrating with NMC is a nice idea, and could help with reducing interfacial impedance. There are nice diagnostics to discover that LLZO reacts with many carrier solvents versus reactivity between LLZO and succinonitrile (SN).

Reviewer 2:

The reviewer noted that the approach of this project, as performed by Doeff and co-workers, aims to form composite cathode architectures via freeze-tape casting for next-generation all-solid-state batteries. The main technical barriers addressed are (1) energy density and (2) cost of production. While the energy density of the batteries can be calculated by the lab-scale demonstrations of the calls, the cost is somewhat difficult to calculate. Both of these barriers are indeed important, and the reviewer noted that the approach is quite novel among ceramic processing (e.g., freeze-tape casting of dense/porous bi-layers and tri-layers). Although this project was delayed by COVID-19, the team did an adequate job performing the experiments, as outlined in their approach. The team also completed optimization steps to tune the porosity of the LLZO, which allowed better infiltration of the cathodes. Also, the team has addressed the origins of the cathode/LLZO interfacial impedance, which is a major contributor to compromised battery performance. Overall, according to the reviewer, the team has explored a novel approach to forming dense/porous Li garnet architectures, but still require future work to further improve energy density of all-solid-state cells.

Reviewer 3:

The reviewer commented freeze-tape casting can make porous structures with high directionality and thin thickness for use in SSBs. The challenge is that the aligned pores will tilt during the processing, as shown in Slide 7. There is a tradeoff between making the structure thin and making the pores highly aligned.

Reviewer 4:

The reviewer said the project focuses on infilling of cathode materials into a freeze-casted porous/dense bi-layer LLZO film to increase the contact between electrode and electrolyte. If successful, the approach can be scalable and the cell performance can be improved, which addresses the energy density and cost barriers. The project includes fabrication and cell testing only for the 2-year term. It was well designed for the scope and budget. Improving the infilling efficiency seems to be very challenging using the freeze-casted template due to the less controlled porous channels. To make this approach more practical, the reviewer suggested that more efforts might be needed to increase the cathode loading.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented the team showed reasonable charging-discharge performance based on the all-solid-state design at room temperature. SN was added to increase the ionic conductivity and enhance the contact and showed beneficial effects in cell performance.

Reviewer 2:

The reviewer said the project "Composite Cathode Architectures Made by Freeze-Casting for All Solid-State Lithium Batteries" reports a number of important accomplishments. This project led to the development of a novel method to make porous/dense bi- and tri-layer Li garnet scaffolds and gained an understanding of the origins of the high impedance at the cathode/SEI. The team optimized freeze tape-cast structures, developed methods to better infiltrate cathodes into porous Li garnets, and came up with methods to better wet the Li-Li garnet interface (e.g., zinc oxide [ZnO]). While these technical accomplishments are all excellent, the energy density of as-assembled cells was quite low with the NMC 811 cathodes. The reviewer posited that further assessment of the NMC/Li garnet interface may provide evidence as to the origin of the interfacial impedance. As noted in the presentation, infiltration is still a major hurdle for this project. While the approach is novel, more attention could be given to this issue. As noted, solvents can possibly degrade LLZO (e.g., rapid H^+/Li^+ transfer between the ceramic and the solvent).

Reviewer 3:

The reviewer said the progress is good, and the filtration of active materials is still the big challenge for the project.

Reviewer 4:

The reviewer said that the project is complete

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented collaboration is clearly explained in the slides, and the team has very good coordination with partners.

Reviewer 2:

The reviewer said the team appears to have close, appropriate collaborations as well as coordination with other institutions (e.g., Montana State University and Mercedes-Benz).

Reviewer 3:

The reviewer remarked there are collaborations across national laboratories, a university, and industry.

Reviewer 4:

The reviewer said that the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project "Composite Cathode Architectures Made by Freeze-Casting for All Solid State Lithium Batteries" has ended (March 31, 2021). This reviewer found that cathode-SEIs are incredibly important and deserve special attention from the DOE.

Reviewer 2:

The reviewer asked if there was any effort to investigate enabling chemical bonding between NMC and LLZO. NMC does expand and contract 10% or so during lithiation-delithiation, thus a chemical bond might be helpful.

Reviewer 3:

The reviewer said the project has ended.

Reviewer 4:

The reviewer remarked the project ended on March 31, 2021.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked this project is relevant to a number of DOE objectives, namely, the objective to develop affordable batteries with increased energy densities (or specific energies) for applications in the EV market. Although this project aims to address this objective, there is still more work to do, as cathode/SEI still present numerous issues in different battery systems. While this project achieved greater than 100 Wh/kg batteries, the project did not move past the go/no-go stage because the energy density was presumably too low using the approaches outlined in the presentation. This reviewer noted that more funding will be necessary to try other types of architectures and further scale the production of these architectures. In total, this project addresses many of the DOE goals. This reviewer found that cathode-SEIs are incredibly important and deserve special attention from the DOE.

Reviewer 2:

The reviewer said aligned porous structure for an SSE is highly relevant to the DOE objectives in developing next-generation energy storage devices such as SSBs.

Reviewer 3:

The reviewer said the project is highly relevant.

Reviewer 4:

The reviewer commented that although LLZO has very good electrode stability and high ionic conductivity, the material integration and cell level assembly are very challenging. This project aimed to solve this issue for the practical application of SSBs. It supports the overall DOE objective in clean energy storage and the wide adoption of 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 the team was able to meet most of the milestones despite COVID-19. This team has the proper equipment and resources to carry out this research, and this team also has a number of active collaborations both internally and externally. These collaborations can help expedite this work if the team continues to receive funding from future calls. This reviewer found that cathode-SEIs are incredibly important and deserve special attention from the DOE.

Reviewer 2:

The reviewer remarked that there are good resources for this effort.

Reviewer 3:

The reviewer stated that LBNL has great resources for the team and the project.

Reviewer 4:

The reviewer commented that the team has lab resources to complete the milestones set in the proposed work including sintering, infilling, cell assembly, and battery testing. For troubleshooting, more characterizations and conductivity measurements might be helpful.

Presentation Number: bat507
Presentation Title: Controlled Interfacial Phenomena for Extended Battery Life
Principal Investigator: Perla Balbuena (Texas A&M)

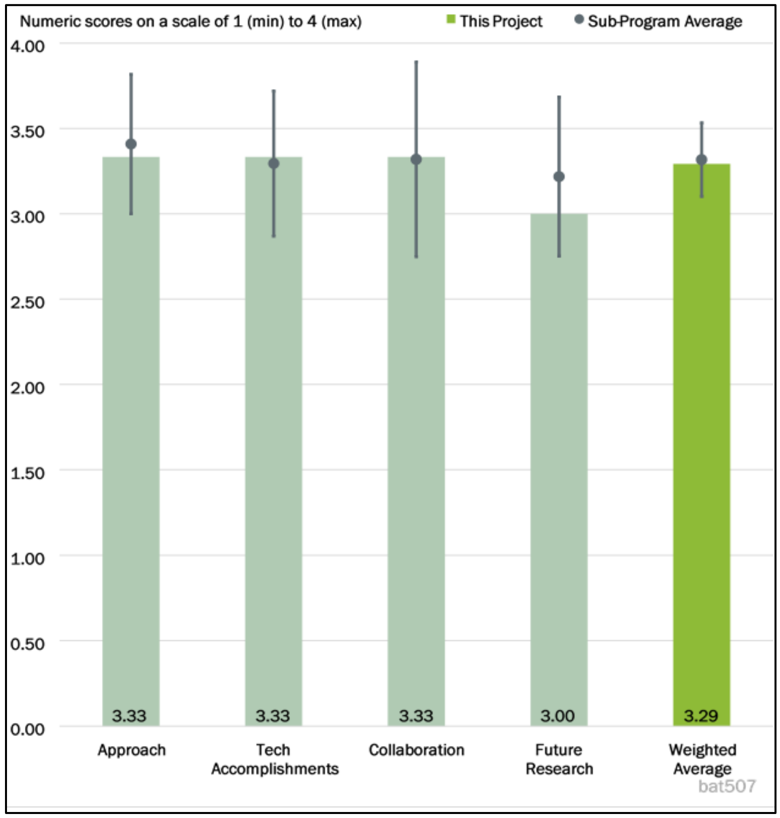


Figure 2-63 - Presentation Number: bat507 Presentation Title: Controlled Interfacial Phenomena for Extended Battery Life Principal Investigator: Perla Balbuena (Texas A&M)

Presenter

Perla Balbuena, Texas A&M

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked the team uses extensive ab-initio molecular dynamics and molecular dynamics simulations to investigate the effect of salt concentration on Li-ion transport in batteries in the presence of an electric field. The team is using the information to provide possible mechanisms for Li transport and guidance for optimum electrolyte compositions. The reviewer asserted that this was great work.

Reviewer 2:

The reviewer found that overall, the approach seems strong. There is detailed work on electrolyte structure and ion-transport mechanisms, and the results appear to be well documented in journal publications. Collaboration with other research groups is important. This reviewer did not see a list of milestones in the presentation, which made it hard to tell if the approach is clearly aimed at addressing the milestones.

Reviewer 3:

The reviewer noted how the team uses ab initio molecular dynamics (AIMD) to study the ionic conductivity in electrolytes. While improved fundamental understanding helps in technical developments, the research should be aimed at predicting new materials for high ionic conductivity electrolytes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the team has developed some new understanding of ion-transport mechanisms in electrolytes. It is expected that the team will be able to provide theoretical guidance to control the interface phenomena to extend battery life.

Reviewer 2:

The reviewer noted a large number of insightful results from state-of-the-art computational work and in-depth analysis work. The reviewer posed a few questions about the presentation: First, how long are the molecular dynamic (MD) simulations for ionic conductivity? Enough statistics? Second, what is the dependence of the results on initial configurations? Are the results independent of initial configurations? Third, how can Li Fermi level change with SEI? Li being a conductor?

Reviewer 3:

The reviewer remarked the presentation is somewhat hard to follow, as the slides are quite busy and this is not the reviewer's exact research area. That said, the results are addressing important electrolyte systems and concepts and there are numerous publications in which the work is presented.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commended the project team for collaboration with PNNL teams. It is the right direction to work with experimental teams to explain experimental results and to explore new materials or approaches to synthesis of new materials.

Reviewer 2:

The reviewer said collaborations provided possible SEI and cathode-electrolyte interphase (CEI) compositions for high concentration electrolytes, which is a very challenging task.

Reviewer 3:

The reviewer said there is collaboration with PNNL, but the slides give the impression the collaboration is primarily occasional discussions rather than joint planning of work, which would probably be more impactful.

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 state project ended.

Reviewer 1:

The reviewer remarked proposed future work is very challenging given the complexity of the SEI and CEI compositions and structures. The results might depend on the specific compositions and structures used to model the SEI and CEI.

Reviewer 2:

The reviewer said the team has provided a detailed plan for further evaluations of ion transportation of various liquid electrolytes. Since solid electrolytes are currently the research trend, the team should also consider applying the simulations in solid electrolytes.

Reviewer 3:

According to the reviewer, the proposed future work is rather generic, and it would be helpful if there were also more specific future work specified to help evaluate how it ties into the milestones and project objectives. As written, the future work is more open ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the work presented in this project supports the efforts of scientists in the battery community by providing useful insights and fundamental understanding that will lead to better formulations and battery performance. This project supports the overall DOE objectives.

Reviewer 2:

The reviewer commented this is one of the few battery research teams doing theoretical work. Good theoretical work will provide guidance to technical developments.

Reviewer 3:

The reviewer said that, yes, it is addressing ion transport.

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 amount of effort and time required to conduct this task is quite substantial. The complexity and the attention to details needed in this project might profit from extra funding.

Reviewer 2:

The reviewer said resources appear sufficient.

Reviewer 3:

The reviewer commented the team has sufficient resources.

Presentation Number: bat508
Presentation Title: Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries
Principal Investigator: Mei Cai (General Motors, LLC)

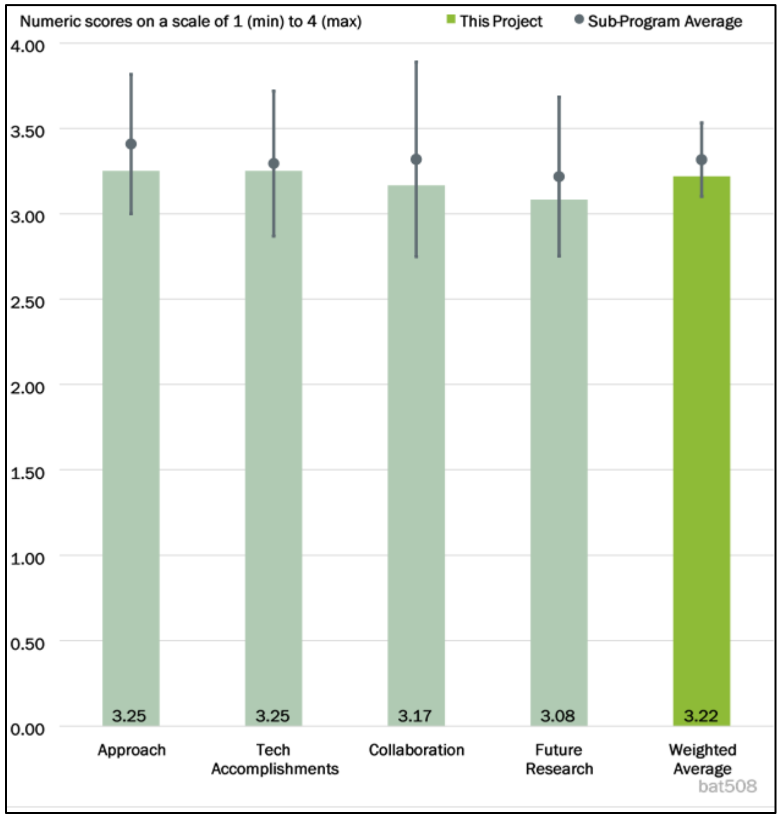


Figure 2-64 - Presentation Number: bat508 Presentation Title: Design, Processing, and Integration of Pouch-Format Cell for High-Energy Lithium-Sulfur Batteries Principal Investigator: Mei Cai (General Motors, LLC)

Presenter

Mei Cai, General Motors, LLC

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked this project focuses on key barriers of developing high-energy Li-S batteries. The proposed approaches of cathode binder, electrode processing, separator coating, and dual-phase electrolyte are important and relevant to the performance improvement of Li-S cell.

Reviewer 2:

The reviewer said the approach to the work is sound. The high S loading objective, reduced porosity electrode, and polysulfide shuttle technical barriers were addressed. The energy density was promising though far below what is hoped for a Li-S system so room remains for further work to optimize.

Reviewer 3:

The reviewer remarked it appears that General Motors (GM) is interested in understanding the Li-S system and that it has in-house capabilities for making electrodes and cells. The approach has been to make S electrodes on dual-side coating equipment and then make a cell that addresses well-known problems of Li/S, like polysulfide migration to the anode. Subsequently, the team investigated a separator that helps mitigate sulfide migration. It is also investigating systems with an electrolyte for the cathode and a separate one for the anode.

Reviewer 4:

The reviewer said that this project aims to development a number of solutions to address the key challenges of Li-S batteries, including S cathode optimization, electrolyte or separator optimization, and pouch cell fabrication and testing. The cathode optimization seems to focus on improving the contact within the cathode and with the current collector. Additives that may be used to physically or chemically absorb dissolved polysulfides may be considered in the cathode optimization. The reviewer noted that the electrolyte design focuses on developing dual-phase electrolytes (polymer and liquid electrolytes), but this process will likely complicate the cell fabrication process.

Reviewer 5:

The reviewer commented that because the polysulfide-trapping interlayer may take S away from contributing to energy storage, an approach based on blocking polysulfides may be more effective.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that progress forward toward the overall project was good and meets the technical objectives laid out for this project.

Reviewer 2:

The reviewer noted that this group was successful in coating a S carbon electrode with high S content (70%) and found that separator being used provided good cyclability——the cell starts above 1,100 mAh/g and gradually declines to just under a 1,000 mAh/g after 60 cycles. It seems that the CE is declining at the same rate as the capacity, which for this reviewer is a little worrisome. The team has initiated some investigations into dual electrolytes that show better performance than a typical liquid electrolyte system. However, it looks like these systems die at around 100 cycles. The team has a new dual-electrolyte system that shows stable cycling to 350 cycles but at only 600 mAh/g. Overall, remarked the reviewer, it looks like the company is getting on its feet in Li-S and is trying some new ideas out but no great results yet to speak of.

Reviewer 3:

The reviewer said that materials scale-up has been achieved at the kilogram per batch level. Equipment for continuous electrode processing and surface coating have been set up and was used for large-areal electrode fabrication. Separator coating shows positive effect on capacity retention and mass transport, but mass contribution of the coating layer should be considered and minimized. The reviewer said that the durability of the dual-phase electrode needs more detailed study, particularly the phase stability for long time testing and how to maintain the two separated phases inside a real coin or pouch cells.

Reviewer 4:

The reviewer was unclear what the “complete solution” is in the sentence, “Small businesses or institutes could benefit from this complete solution, thus reducing the effort required for their own development work on the system.” The amount (mass and volume) of the dual-phase electrolytes used to achieve the performance reported in the poster presentation was also unclear to the reviewer.

Reviewer 5:

The reviewer noted that in the past year, the team has been developing scale-up synthesis of carbon-S composite and R2R fabrication of S cathodes. The team also developed a metal oxide/carbon coated separator to suppress polysulfide shuttle. The team implemented a dual-layer electrolyte in the cell to protect Li. No pouch cell data were included in the report. Based on the existing data (6 mg/cm^2 S, approximately 1,200 mAh/g capacity, dual-layer electrolyte, 100 micron [µm] Li), it is also questionable that the team can approach or even come close to the proposed target.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the project has close collaborations with universities, a national laboratory, and industry.

Reviewer 2:

The reviewer noted that the team has collaborated with a number of partners from national laboratories, universities, and industry.

Reviewer 3:

The reviewer said the collaboration appears to be okay across the project team. It was not specifically addressed in the poster other than naming the collaborators.

Reviewer 4:

The reviewer commented this is a large company that is trying to protect IP and just getting started so the team is not ready to bring in additional help yet.

Reviewer 5:

The contributions from II-VI Incorporated and Miltec UV International are not evident from the poster presentation.

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 state project ended.

Reviewer 1:

The reviewer remarked that considering the challenging system, an appropriate approach is laid out. It might be difficult to implement and expensive considering its complexity.

Reviewer 2:

The reviewer noted that the future research will focus on a new dual-electrolyte system and will try to improve its performance—capacity and cycle life. This cell will be at 6 mAh/cm^2.

Reviewer 3:

The reviewer said the amount (mass and volume) of electrolyte should enter the calculation of capacity and energy density of the full cells.

Reviewer 4:

The reviewer said this project has clearly planned future work. The chemical and phase stability of the dual-phase electrolyte and issues associated with use of such electrolyte in practical cells should be carefully considered and addressed. Functionality of a dual-phase electrolyte should be validated in a S/C electrode since both SPAN and short chain S cathodes have much less polysulfide dissolution compared to S/C. The reviewer suggested that the S/C cathode should be the focus of the future work to achieve high cell-level energy.

Reviewer 5:

Because it is close to the end of the project, instead of further exploring another cathode such as sulfurized polyacrylonitrile (SPAN), or other dual-electrolyte designs, the reviewer recommended that the team integrate the best results into a pouch cell and see how it looks, i.e., integrating the best S-C cathode, best electrolyte design, and best separator into a pouch cell with an EV-relevant capacity (e.g., 2 Ah). The team will also need to study the effect of the test protocol on the pouch cell performance, as the team proposed. The reviewer noted that results will help VTO and the battery community to understand the current status of liquid electrolyte Li-S battery development.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked this project supports the development of next-generation Li battery and thus aligns well with DOE's objectives of vehicle electrification.

Reviewer 2:

The reviewer pointed out that enabling a Li-S system has the potential to reach dollar per kilowatt-hour metrics owing to the low cost of S and the high potential energy density of such a system if enabled with high loadings of S and long cycle life.

Reviewer 3:

The reviewer commented that the project supports the Battery500 program.

Reviewer 4:

The reviewer said this project will help development of high energy density Li-S batteries for EV applications.

Reviewer 5:

The reviewer noted that DOE is spending a significant amount of resources on Li-S in Battery500, so this is certainly a chemistry of interest. GM is looking to improve this 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 remarked the resources were sufficient for this project.

Reviewer 2:

The reviewer commented this is a difficult chemistry with no promise of success. GM is using its Li-ion equipment and some new ideas to try to get it to work. This must be a comfortable level of resources.

Reviewer 3:

The reviewer said the team has sufficient resources to complete the work.

Reviewer 4:

According to the reviewer, the team itself and collaborators have sufficient resources to execute the proposed research.

Reviewer 5:

The reviewer stated the team has ample resources.

Presentation Number: bat510
Presentation Title: Electrochemically Stable High Energy Density Lithium-Sulfur Batteries
Principal Investigator: Prashant Kumta (University of Pittsburgh)

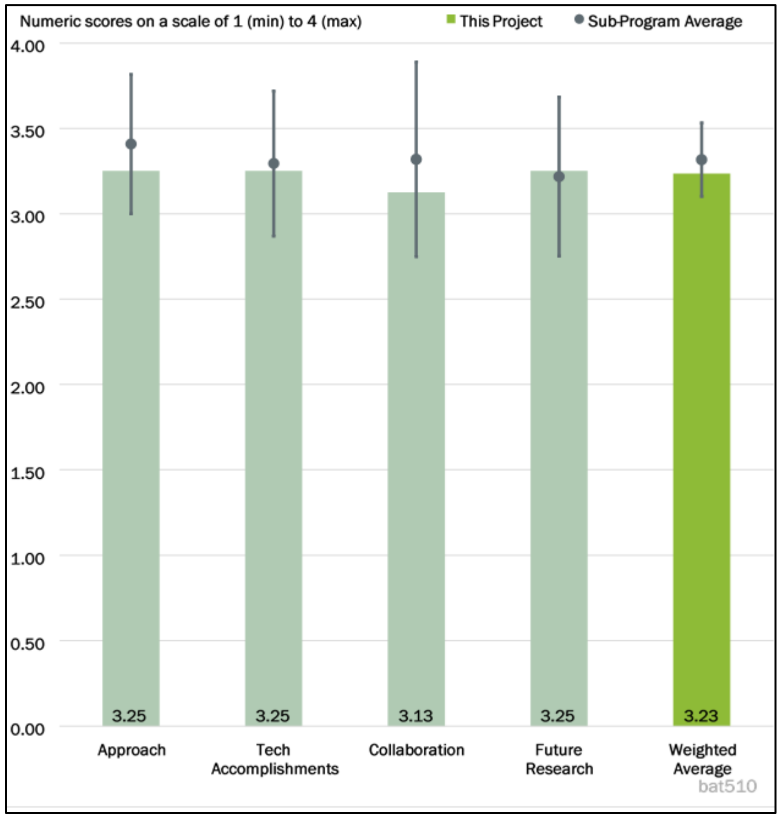


Figure 2-65 - Presentation Number: bat510 Presentation Title: Electrochemically Stable High Energy Density Lithium-Sulfur Batteries Principal Investigator: Prashant Kumta (University of Pittsburgh)

Presenter

Prashant Kumta, University of Pittsburgh

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 25% of reviewers felt that the resources were sufficient, 75% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said overall, this appears to a challenging project with a good approach. A variety of technical approaches are made to improve the operation of the Li/S battery, and commercially relevant designs and evaluation criteria are used to assess the approaches.

Reviewer 2:

The reviewer said the approach used to develop and synthesize cathode materials that can meet the targets for this project is interesting as it is trying to make use of functionality, catalysis, and dispersion. For this end the approach uses a Li-ion conductor and functional electro-catalysts dispersed complex framework materials (with composition 90 weight percent [wt.%] S) to improve the reaction kinetics of high order polysulfides (PS) conversion to low order PS. The approach will rely on multiple parameters to optimize the composition and structure of the cathode.

Reviewer 3:

The reviewer remarked the combination of the lithium-ion conductor (LIC) coated complex framework materials (CFM) and the dendrite-free lithium-structurally isomorphous alloys (Li-SIA) seems to be working well in making high-energy density Li-S batteries. The CFM used by the team is supplied by others. The team should try to develop the CFM with equivalent or better properties on its own or secure a domestic supply chain for the precursors.

Reviewer 4:

The reviewer noted a well-designed, systematic work to design and fabricate high loading (equal to or greater than 6 mg/cm^2) S-rich CFM electrodes (equal to or greater than 63 wt% S in the electrode) exhibiting high areal capacity (approximately greater than 5 mAh/cm^2) and excellent cyclability (over 100 cycles) and to combine the electrodes with a dendrite-free, Li alloy anode in both coin cell and pouch cell configurations. The reviewer said there was not enough information on plans for how to overcome limited cycle life, capacity fade, and low CE by forming stable SEI and CEI layers in surface-engineered and scaled-up electrodes to reach energy density equal to or greater than 500 Wh/kg and a cycle life of approximately 1,000.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the project shows good results. The milestones listed are very aggressive for a project of this size, and the reviewer did not think the presentation includes data showing some of the milestones being reached. For example, the reviewer did not see data for the December 2020 go/no-go although it is marked as completed. The results shown have areal capacities of around 3.5–4.5 mAh/cm^2, not the 6 mAh/cm^2 that is stated. However, the fact that both single-layer and multi-layer cell results are shown is quite impressive. The reviewer said it would have been helpful if the project team had provided the gaps remaining as the team comes to the end of the project and thoughts on whether or how those gaps may be addressed. Also, the reviewer did not see a definition of Li-SIA; the reviewer asked what the composition of the anodes is. It appears to be some type of alloy.

Reviewer 2:

The reviewer said the team has tested the 100-mAh single layer and 250-mAh four-layer pouch cells up to 60 cycles. The electrochemical stability for higher cycle numbers is still to be tested or improved. The cell capacity of the cell is not proportional to the number of layers, even though their energy densities are comparable.

Reviewer 3:

The reviewer remarked several accomplishments and demonstrations of the concept were already shown, and the project is in good progress. The reviewer posed questions and had comments about the presentation. Regarding the sentence on Slide 22, “Improve reaction kinetics and sulfur utilization by microstructure engineering,” (Slide 22), the reviewer asked if it is possible to estimate how much microstructure engineering and improvement of reaction kinetics will improve the performance. The reviewer noted that using computational modeling to improve the reaction kinetics is a great place to start. Do you expect further complexity for the synthesis and optimization of the functional catalysts?

Reviewer 4:

The reviewer said the team has demonstrated several technical accomplishments and progress in the overall project. The project is in a great shape in terms of milestones and publications. The team has developed a high throughput, high yield, commercially inexpensive process for the synthesis of electrochemically stable S infiltrated CFM-S that enable high S loading (greater than 63 wt.%). LIC dispersed on nanocrystalline porous architecture of CFM shows excellent ability of trapping PS and maintaining ionic conductivity of the electrode with the high areal capacity of approximately 5 mAh/cm^2 and excellent cyclability (over 100 cycles). The reviewer asked if the team can describe the in situ optimization process for the bifunctional catalyst cathode material applied to achieve microstructure control of FEC within S grain or at the S grain boundary? The reviewer offered as a general comment that better characterization and imaging of carbon nanofiber (CNF) cathode material development to demonstrate S infiltration and microstructure control is needed. The reviewer noted that the Li-S single-layer pouch cell shows significant capacity fade: 0.28% per cycle at 0.1C and limited cycle life. A challenge still remaining for the team is to fabricate single-layer/multi-layer (approximately 20 cm^2) pouch cells with energy density greater than or equal to 500 Wh/kg and a cycle life of 1,000 cycles. The reviewer asked how this work with liquid electrolyte compares with the state-of-the-art solid electrolytes in achieving these goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said several collaborations are listed with specific tasks according to their expertise.

Reviewer 2:

The reviewer said that coordination appears to be good. It was hard to tell the exact contributions from the slides, although a good team appears to be assembled.

Reviewer 3:

The reviewer encouraged the team to collaborate with national laboratories to utilize modern structural and morphological characterization techniques (synchrotron and neutron).

Reviewer 4:

The reviewer said that the collaboration with the Nanomaterials for Energy Conversion Storage Technology (NECST) Laboratory–Energy Innovation Center in Pittsburgh on developing modified coin cell testing and carbon nanoarchitectures and developing pouch cell testing seems effective. The reviewer said the team should look into establishing more collaboration on materials characterization and imaging.

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 state project ended.

Reviewer 1:

The reviewer noted that the future works includes an attempt to achieve cells greater than 500 Wh/kg. This has been the goal of the Battery500 program, but it seems a really challenging goal for an approximately $1 million project at a university. In the slides the project team shows less than half of that target and has 6 months left in the project. It may be more appropriate to focus on smaller cells and knowledge generation.

Reviewer 2:

The reviewer said there is a long way to go to reach the 500-mAh target. The team is aware of the challenges, but the future plan does not have enough details.

Reviewer 3:

The reviewer noted ambitious future plans on multi-layer pouch cells meeting the targeted capacity of greater than 6 mAh/cm^2 and exhibiting stable cycle life of 1,000 cycles followed by design and testing of 500 mAh (0.5 Ah) multi-layer pouch cells with initial targeted energy density of more than 500 Wh/kg. Safety field testing will be performed on approximately 100 mAh single-layer pouch cells (greater than or equal to 500 Wh/kg) in collaboration with PNNL and an industry partner, and 12 test cells meeting the performance and safety standard will be delivered to DOE.

Reviewer 4:

The reviewer commented that proposed future work should lead the project to completion. Major challenges are still present as mentioned in the "Challenges" section. Demonstration of successful generation of multi-layer pouch cells matching single-layer performance is a good start.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that Li-S batteries can be used for high-capacity energy storage. The efforts to make better Li-S battery support the DOE objectives.

Reviewer 2:

The reviewer said this work is in line with DOE-Battery500 goals to fabricate, evaluate performance, and optimize 20 cm^2 pouch cells of cell capacity more than 100 mAh and target energy density (greater than or equal to 500 Wh/kg).

Reviewer 3:

The reviewer affirmed that the project goals align with DOE objectives.

Reviewer 4:

The reviewer remarked the team is working to develop high-energy Li-S 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 said great progress was made and the approach seem reasonable and worth pursuing.

Reviewer 2:

The reviewer remarked resources and expertise seem sufficient to achieve proposed milestones.

Reviewer 3:

The reviewer commented that given the really ambitious milestones, it is hard to see how a project of this size has a real shot at hitting them within the project period. The team should consider scoping the work differently.

Reviewer 4:

The reviewer found that at the 90% completion of the project, the team has not reached the planned objectives.

Presentation Number: bat511
Presentation Title: High-Energy Solid-State Lithium Batteries with Organic Cathode Materials
Principal Investigator: Yan Yao (University of Houston)

Presenter

Yan Yao, University of Houston

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 83% of reviewers felt that the resources were sufficient, 17% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

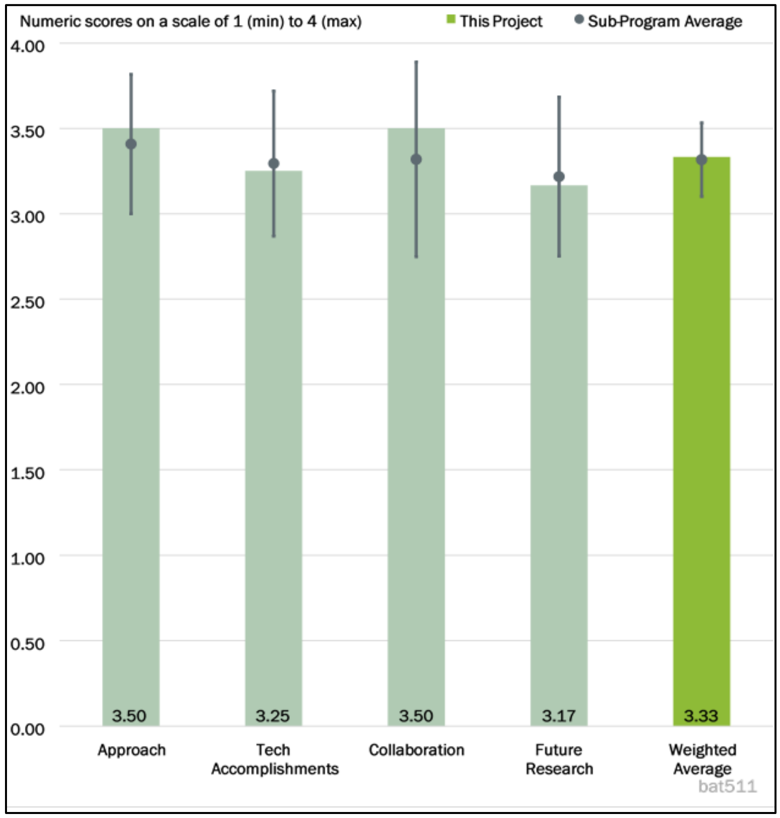


Figure 2-66 - Presentation Number: bat511 Presentation Title: High-Energy Solid-State Lithium Batteries with Organic Cathode Materials Principal Investigator: Yan Yao (University of Houston)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Developing high-voltage, high-capacity organic cathodes is important to improve the energy density of batteries (not limited to SSBs) and lower the cost of electrodes by removing Co and nickel Ni. The project is well designed, and the proposed approaches are feasible.

Reviewer 2:

The reviewer noted that high-capacity organic-based cathode material is among the most important options for Co-free cathodes for next-generation energy storage technologies. An SSB is beneficial to addressing potential dissolution issues of organic-based cathodes. Focusing on electrode architecture and materials utilization is a correct direction. The reviewer said that intrinsic sluggish kinetics of this material would be a focus with possible approaches in hand.

Reviewer 3:

The reviewer noted that the approach uses a non-Co, non-Ni containing organic electrolyte, which has the potential to achieve the 500 Wh/kg project goal. It is unlikely to succeed commercially, but this is normal for early-stage exploratory research.

Reviewer 4:

From what this reviewer can tell, the researchers are making organic insertion materials that are softer than the electrolyte. When a composite electrode of the materials is compressed, it ends up with cathode material surrounding the electrolyte, which prevents a continuous path for ionic transport in the cathode. The reviewer noted that the team developed a solution-based process for encapsulating the active material in the electrolyte, and when this is compressed to form a compact electrode, the electrolyte forms a continuous path.

Reviewer 5:

The reviewer said that it is unclear what approaches the team is taking to address the commonly known problem of low electronic conductivity of organic electrode materials or organic insertion materials (OIMs), which may be rate limiting in fast charging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the understanding of the microstructure enabled some improvements in performance. Reasonable progress toward the objectives was demonstrated.

Reviewer 2:

The reviewer said the team has demonstrated impressive specific capacity (milliamp-hours per gram [mAh/g] OIM) and specific energy (Watt-hours per kilogram [Wh/Kg]). What are the capacity (i.e., mAh/L) and energy density (Wh/L)?

Reviewer 3:

The reviewer remarked the team is on track to meet the proposed milestones. The utilization of the cathode active material was improved by the solution processing process. While the improved interfacial contact can lead to higher utilization of cathode active material, the utilization of the solution process also largely decreases the kinetics of the electrodes due to decreased ionic conductivity in the cathode composite. Even after annealing, the ionic conductivity of solution-processed solid electrolyte still has a much lower ionic conductivity. The reviewer said the team may consider alternative approaches to improve the contact while maintaining the ionic conductivity of solid electrolytes. The team also needs to consider the way to report the voltage of the electrode, i.e., majority of the discharge capacity of UH04 is observed below 2.7 V.

Reviewer 4:

The reviewer said that development of new OIM materials with improved capacity and working voltage is an important accomplishment. The team identified issues of component distribution inside the electrode and effective measures to address. Highly conductive SSE with small particle size is needed for this project.

Concerning the HU04 and HU08 materials test, this reviewer inquired about the mass loading, electrode composition, and current density. A cell test would be at more realistic conditions. In the estimation of cell energy toward 500 Wh/kg, density of solid electrolyte is 1.56 g/cc. The reviewer inquired about the kind of materials or separator porosity.

Reviewer 5:

The reviewer was a little concerned that the team is only achieving about 40% loading of the cathode while still having a rate issue. Unfortunately, the electrode with higher loading shows very poor rate capability. The team's overall loadings are below 1 mAh/cm^2, which is very low for a Li-ion cell, especially because the specific capacity is around 400 mAh/g. These results are after improvements. The reviewer said the team has identified higher energy materials with higher theoretical specific capacities and higher average voltages. The rate capability seems to be a bigger issue than the specific capacity. The reviewer was not sure if this is an electrolyte problem or what the team plans to do about it.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said coordination across the team appears to be working.

Reviewer 2:

The reviewer commented that the team has a reasonable number of collaborations and the ones it has are important to improving the cells.

Reviewer 3:

The reviewer said the team has a strong collaboration with national laboratories, universities, and industry.

Reviewer 4:

The reviewer remarked the PI has close collaborations across universities, national laboratories, and industry.

Reviewer 5:

The reviewer remarked the contributions from collaborators from Solid Power and Ampcera are 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project is near its end. The proposed future work is appropriate for that stage.

Reviewer 2:

The reviewer remarked the team may address the low electronic conductivity issue common to organic electrode materials.

Reviewer 3:

This project has clearly planned future work. The reviewer noted that more efforts would be focused on the new high-capacity, high-voltage cathode materials and cell test at practical conditions.

Reviewer 4:

The reviewer remarked the team's future work includes pursuing higher energy materials and incorporating them into cells. It seems like a hope that the rate capability will be better for the new materials as this reviewer saw no planned work to improve rate and the team plans to go to higher loadings, which will work against them.

Reviewer 5:

The team has made great progress in increasing capacity, voltage, and utilization of the organic cathode. However, the existing performance would not enable a 500-wh/kg cell which, based on the cell design, would need 65% active fraction, 501 mAh/g specific capacity, 12.2 mg/cm^2, and 2.9V. As a matter of fact, it is challenging to reach any of the four metrics, let alone all of them. Given the remaining project time, the reviewer recommended the team do a detailed analysis on the pathways to higher energy cells. Specifically, details—which parameter of the four more effectively can improve the cell energy and which of the four relatively can be improved—will be important for the community to understand the promise of organic electrodes for high energy cells.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that the project is targeted toward a high energy battery, which does not use Co or Ni and thus addresses several project objectives.

Reviewer 2:

The reviewer said the project supports the Battery500 program.

Reviewer 3:

The reviewer commented that SSBs are a real challenge that DOE has elected to pursue due to the promise of improved safety and increased energy density. This work falls in line with this pursuit.

Reviewer 4:

The reviewer remarked the project will lead to low-cost, environmentally friendly cathode materials for next-generation batteries.

Reviewer 5:

The reviewer affirmed this project is closely related to the development of a high-energy Li battery, aligning well with DOE/VTO's objectives of vehicle 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 said resources are sufficient for this project.

Reviewer 2:

According to the reviewer, the team has sufficient resources to complete the work.

Reviewer 3:

The reviewer commented the PI and team have sufficient resources for the proposed research.

Reviewer 4:

The reviewer stated that the team has excellent resources.

Reviewer 5:

The reviewer remarked the team has an interesting technology. However, this is a university-funded project and even though the team only put up 20% cost share, this is a difficult problem that will take more resources.

Presentation Number: bat512
Presentation Title: Highly Loaded Sulfur Cathode, Coated Separator and Gel Electrolyte for High Rate Li-Sulfur
Principal Investigator: Yong Joo (Cornell University)

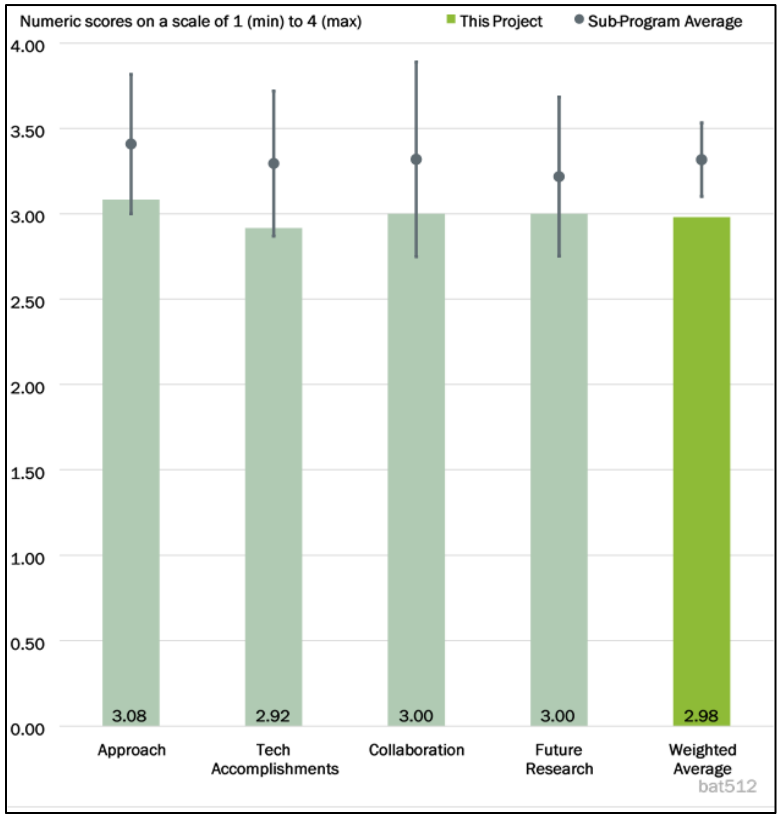


Figure 2-67 - Presentation Number: bat512 Presentation Title: Highly Loaded Sulfur Cathode, Coated Separator and Gel Electrolyte for High Rate Li-Sulfur Principal Investigator: Yong Joo (Cornell University)

Presenter

Yong Joo, Cornell University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked the approach is likely to be difficult to commercialize owing to its complexity. However, it does address the project objectives.

Reviewer 2:

The reviewer remarked that the proposed approaches for a high-loading S electrode, functional separator coating, and gel electrolytes are important and relevant to addressing key technical barriers of high-energy Li-S batteries. The techniques developed for S electrode fabrication and separator coating are unique and applicable to achieve the proposed technical targets. The reviewer noted that the two things that the project team may need to address are high porosity of the S cathode and parasitic weights of the separator coating, both influencing cell-level specific energy and energy density.

Reviewer 3:

The reviewer said the team proposed to optimize high S loading, separator, electrolyte, and pouch cell fabrication and testing to address the key challenges in Li-S batteries. The project is properly designed. Modifying electronic conductivity in the S cathode can improve utilization and trap PS, and developing a ceramic polymer separator can suppress the PS shuttle. Most of the approaches are reasonable, but the reviewer cannot understand the rationale for adding $LiFePO_4$ and $LiMn_2O_4$ in the S cathode to improve S utilization, as these two cathodes are typically considered not good electronic conductors.

Reviewer 4:

The reviewer commented that there are a number of challenges to getting full utilization and cyclability of a Li-S cell. From what this reviewer can tell, the approach is to (1) spray S onto either graphene sheets or carbon sheets and stack them together to make a cathode of high loading, (2) make a polymer-ceramic composite separator coated with graphene to prevent dendrites from growing across the cell (the polymer-ceramic) and prevent PSs from migrating into the separator (the graphene coating), and (3) infuse the separator with a gelable electrolyte to reduce the flammability of the cell. It is at least an attempt to deal with some of the major issues. It was not clear to this reviewer that the team will be effective.

Reviewer 5:

The reviewer remarked the approaches appear to be largely trial-and-error without clearly defined targets. For example, the poster showed an increase in the tensile strength of the polybenzimidazole (PBI) nanofiber (NF) separators from 12.3 MPa to 21 MPa by changing the infusion rate. However, is 21 MPa sufficient?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that with their cathode construction the team gets about 1,000 mAh/g of S at C/5. The team does not indicate the mass ratio of C to S of cyclable S, which is pretty good. The team produced an electrospun separator. With this separator and a gel electrolyte in the separator and an additive, the team demonstrated 1,000 mAh/g cyclability and believed that this is a safer cell than without the gelled electrolyte. The reviewer said the team only shows 20–30 cycles, with no indication of cell loading in milliamp-hours per square centimeter. It is not clear that the team has stopped the migration of polysulfides.

Reviewer 2:

The reviewer recommended that mechanisms responsible for the apparent effect of metal oxides on the S utilization should be explored. How does the team distinguish Li reversibly stored in LFP or LMO from Li stored in S? The team should use non-Li active oxides to help understand the effect of oxides on S utilization.

Reviewer 3:

The team has achieved good results to improve the utilization of the S cathode with a S content of 60%. Increasing the S content only will not necessarily lead to a high energy density cathode. The team should also consider and report the thickness or the areal capacity of the cathode. The reviewer expected to see a gradual increase of the areal capacity as the project moves along to the end, so the team should compare its own results in the past year, for example. The team also demonstrated the fabrication of a ceramic polymer separator and did the flammability test. The reviewer was not sure whether the flammability test is necessary because during cell fabrication the separator will still be infiltrated with flammable liquid electrolytes. It was also not clear to the reviewer how the electrospin-based separator synthesis can be scaled up. More characterizations on the separators, e.g., the porosity, or the amount of liquid electrolyte they can accommodate should be done.

Reviewer 4:

The reviewer noted that the PBI-alumina coated separator demonstrated improved electrochemical and mechanical properties compared with the Celgard separator. Introducing LMO and LFP into the cathode enhanced S utilization in high-loading S cathodes. Gel ceramic electrolyte with additional polyethylene glycol (PEG) had positive effects in suppressing PS crossover and reducing cell polarization. The reviewer said that to validate the developed cathode, coated separator, and gel electrolyte for pouch cells, realistic conditions like a high mass loading electrode and a lean amount electrolyte are suggested for cell test.

When LMO or LFP was used in the cathode, the electrochemical stability window of the liquid and gel electrolytes should be tested and verified, particularly for ether-based solvents like dioxolane (DOL). When exhibiting the cell capacity and cycling data, the reviewer suggested providing S loading, electrolyte/S ratio, and cell testing conditions.

Reviewer 5:

The reviewer commented that it appears that the objectives were not completely achieved. An extension has been granted to try to make further progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the project team has good collaborations with university and industry.

Reviewer 2:

The reviewer said that collaboration appears to be satisfactory across the team.

Reviewer 3:

The reviewer acknowledged that this is a complicated system, but there are a few partners to help with different aspects of the cell design and construction.

Reviewer 4:

The reviewer suggested the team may consider using independent labs to help evaluate and verify cell performance and durability.

Reviewer 5:

The work so far was completed mostly at Cornell only, and the reviewer encouraged more 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the proposed work is appropriate to address the project objectives.

Reviewer 2:

The reviewer suggested that the team investigate the mechanisms responsible for the apparent effect of oxides on S-utilization.

Reviewer 3:

The reviewer said it seems a lot of work needs to be done in the remaining funding period. The reviewer recommended that the team focus on integrating its best cathode, separator, and electrolyte into a pouch cell and see what the performance looks like. The team also proposed to do a number of safety tests, and the reviewer thought that these tests should also be better done in a pouch cell format. Such information will help the VTO and the battery community to understand the status of liquid electrolyte-based Li-S batteries.

Reviewer 4:

The reviewer noted that the project has a detailed plan for the 6-month extension. Based on the progress achieved during the previous project execution, the proposed future research deserves extra time commitment. It would be interesting to integrate the developed cathode, separator, and electrolyte to see the energy limit of a pouch cell and then focus on cell cycling in future projects.

Reviewer 5:

The reviewer said the team proposed to optimize its system (no details provided) and perform rigorous safety testing. Without a cell that cycles 1,000 cycles, this reviewer did not think the team's priority should be safety testing. The reviewer noted that the team will produce large cells of 1–3 Ah and was unsure of readiness to move into scale-up of this technology.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project may help reach Battery500 project goals.

Reviewer 2:

The reviewer affirmed that enabling Li-S supports DOE objectives to reduce dollars per kilowatt.

Reviewer 3:

The reviewer said this project will help develop high-energy Li-S batteries.

Reviewer 4:

The reviewer noted that Li-S is considered a technology that goes beyond Li-ion. Li-S has several issues preventing it from meeting USABC targets. This group is willing to try to address some of them.

Reviewer 5:

The reviewer said this project focuses on the development of a high-rate Li-S battery, which aligns well with DOE/VTO's objectives of vehicle electrification.

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, resources are sufficient.

Reviewer 2:

The reviewer indicated that the team has sufficient resources.

Reviewer 3:

The reviewer said the team has sufficient resources.

Reviewer 4:

The reviewer remarked that the project team has sufficient resources to perform the proposed research, but a 6-month extension would very tight.

Reviewer 5:

The reviewer was unclear that what these researchers have done has resulted in any further progress than previous researchers, and was unconvinced that more in this direction will be fruitful.

Presentation Number: bat513
Presentation Title: Multifunctional Li-ion Conducting Interfacial Materials for Lithium Metal Batteries
Principal Investigator: Donghai Wang (Penn State University)

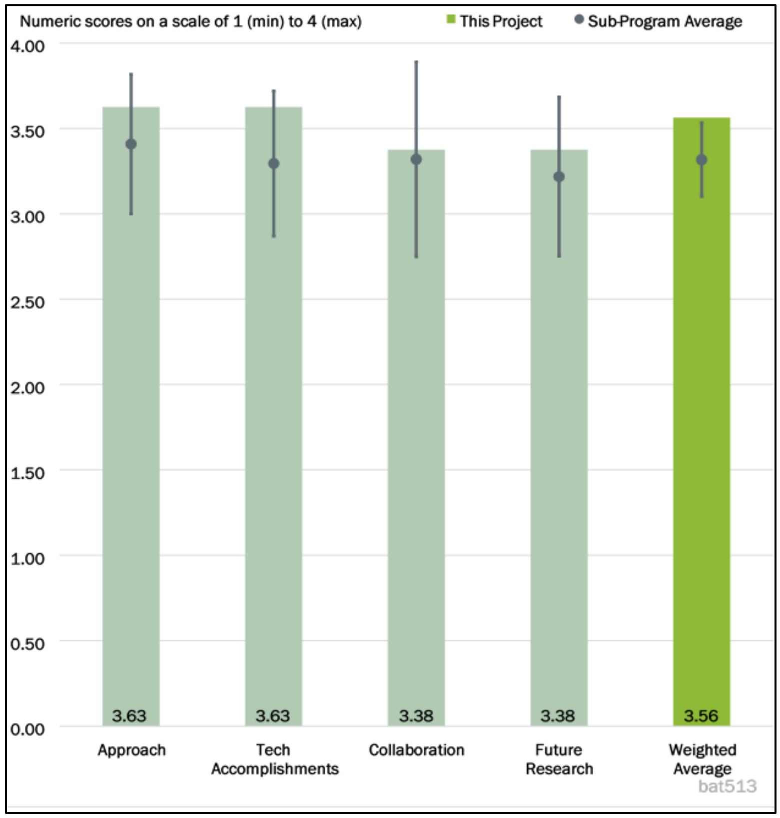


Figure 2-68 - Presentation Number: bat513 Presentation Title: Multifunctional Li-ion Conducting Interfacial Materials for Lithium Metal Batteries Principal Investigator: Donghai Wang (Penn State University)

Presenter

Donghai Wang, Penn State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said this work uses polymer coatings and a new, carbonate-based electrolyte to protect the Li-metal anode. The approach is innovative and practical, and the polymer coating is scalable and compatible with a pouch cell.

Reviewer 2:

The reviewer commented that the team developed a new, ionic-conducting polymer interface to enhance the stability of the metallic Li-metal anode. The approach enables the use of metallic Li as an anode in organic liquid electrolyte-based LIBs. The project is well designed and feasible for real applications.

Reviewer 3:

The reviewer acknowledged a nice approach to try and make Li plating and stripping more uniform and efficient. There is a need to make sure the weight percentage of the non-active materials is relatively low.

Reviewer 4:

The reviewer said the approach of this project, as performed by Wang and co-workers, aims to develop multi-functional Li-ion conducting interfacial materials as a protective layer for Li-metal anodes, enabling Li-metal anodes to cycle with a high efficiency of approximately 99.9% at a high electrode capacity (4 mAh/cm^2) and a high current density (greater than 2 mA/cm^2) for 400 cycles. The main technical barriers addressed are (1) cycle life of Li-metal anodes and (2) voltage stability of the Li-metal anode. The reviewer said that while the project aims to demonstrate Li-metal battery cells with an energy density of approximately 300 Wh/kg and a greater than or equal to 80% capacity retention over 300 cycles using Li-metal anodes with the developed protective layer, the approach demonstrated by Wang and co-workers appears to partly fulfill this goal. The main approach entails two separate methods—novel polymer coatings onto Li metal anodes and electrochemically active mono-layers (EAMs). Overall, said the reviewer, the approach was demonstrated experimentally and appears to be a viable option to enable Li-metal batteries that cycle more than 240 times with 80% capacity retention at high areal capacity and lean electrolyte conditions. Further optimization of these materials can possibly extend the cycle life of Li-metal anodes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the polymer synthesis can be scaled up and next is demonstration of pouch cell performances. Overall, the project is making great process and is on track.

Reviewer 2:

The reviewer noted that significant improvement of cycling stability has been demonstrated after using an ionic conductive polymer protection layer between the anode and electrolyte. It seems that the Li dendrite growth was successfully prevented or delayed. It would be great to know how the system performs at higher charging rates.

Reviewer 3:

The reviewer said that there is a need to confirm that this approach to make current homogeneous is also mitigating dendrite growth. Liquid electrolytes should enable very homogeneous currents but still suffer from catastrophic dendrite shorting.

Reviewer 4:

The reviewer remarked that the project "Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries" reports a number of important accomplishments. This project led to (1) the development of a new hybrid Li-ion conductor that enables Li-metal anodes, (2) structure-property relationships of the new Li-ion conducting layers, and (3) macroscopic performance of the new interlayers under 0.2C and 0.5 C. The reviewer remarked while these technical accomplishments are impressive, more attention should be given to prevention of side reactions between the electrolyte and the Li-metal anode. Additionally, efforts should be directed toward suppressing Li dendrite/filament growth in under practical cycling conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the team appears to have close, appropriate collaborations as well as coordination with other institutions (e.g., Ashland). This project also included collaborations within the lead PI's home institution (Pennsylvania State University [Penn State]). Overall, the work appears to be well coordinated.

Reviewer 2:

The reviewer remarked the collaboration looks good. The team has initiated collaboration with industry for scaling up the Li-ion conducting materials. The project has collaborators for performing modeling work.

Reviewer 3:

The reviewer said the collaborations between the PI and partners are clearly stated. Ashland is helping on scaling up the reactive polymer synthesis.

Reviewer 4:

The reviewer saw no issues with 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project "Multifunctional Lithium-Ion Conducting Interfacial Materials for Lithium-Metal Batteries" will end on September 30, 2021. The proposed future work includes the demonstration of pouch-type cells with Li-metal anodes with a cycle life 300 cycles under high-capacity (4 mAh/cm^2), lean-Li (two-fold excessive Li), and lean-electrolyte (4 µL/mAh) conditions. Provided that this team has cycled cells 243 times with a capacity retention of 80%, this team should be able to meet this milestone in the coming months. The reviewer said adding excess Li and lean electrolyte will be important metrics for the proposed chemistry and design of the batteries, and these studies are strongly encouraged.

Reviewer 2:

The reviewer said the proposed future research focuses on pouch cell as well as practical conditions and is logical and appropriate.

Reviewer 3:

The reviewer commented the team is proposing to assemble and test pouch cells with leaner Li and electrolyte conditions, which is a logical move toward real application. Will the team evaluate the high-rate performance to enable fast charging of the Li-metal batteries?

Reviewer 4:

The reviewer said the team needs to confirm that this approach to make current homogeneous is also mitigating dendrite growth. Liquid electrolytes should enable very homogeneous currents but still suffer from catastrophic dendrite shorting.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project is highly relevant to Li-metal anode development and commercialization.

Reviewer 2:

The reviewer remarked this project has a strong relevance to the DOE. Namely, the objective of this project is to develop affordable batteries with increased energy densities (or specific energies) for applications in the EV market. This project aims to address this objective by fabricating thin, dense, and uniform protective layers on Li-metal anodes. These layers are shown to have stability over a wider voltage range, and the layers were also demonstrated to have a specified level of scalability.

Reviewer 3:

The reviewer remarked that Li metal-batteries will be the next step beyond Li-ion batteries. This research focuses on protecting the Li anode and suppressing Li dendrites using a bottom-up polymer synthesis approach. The project is highly relevant to the overall DOE objectives.

Reviewer 4:

The reviewer noted that successful application of Li metal as an anode will dramatically improve energy density of the cells. Firing hazardous might be reduced if lean electrolyte was used in the cell. The efforts in the project will support DOE objectives for the improvement of 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 noted that the team was able to meet most of the milestones despite COVID-19. This team has the proper equipment and resources to carry out this research, and this team also has a number of active collaborations both internally (through Penn State) and externally (Ashland). Overall, this team completed great work despite setbacks from COVID-19 and met most of the milestones to date.

Reviewer 2:

The reviewer found resources to be reasonable.

Reviewer 3:

The reviewer remarked that the team at Penn State has sufficient resources for the project.

Reviewer 4:

The reviewer said the team seems to have all necessary resources to complete the proposed work.

Presentation Number: bat518
Presentation Title: Solvent-free and Non-sintered 500 Wh/kg All Solid State Battery
Principal Investigator: Mike Wixom (Navitas Advanced Solutions Group)

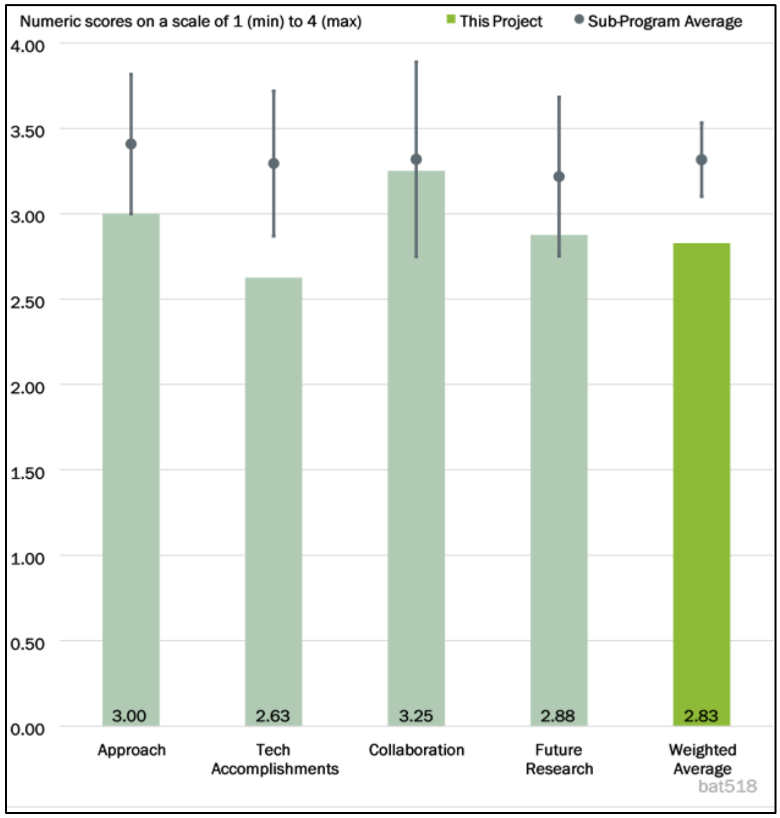


Figure 2-69 - Presentation Number: bat518 Presentation Title: Solvent-free and Non-sintered 500 Wh/kg All Solid State Battery Principal Investigator: Mike Wixom (Navitas Advanced Solutions Group)

Presenter

Mike Wixom, Navitas Advanced Solutions Group

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that overall, the approach is good. Existing materials are explored and modifications imparted to improve air stability. Attempts were made at commercially relevant loadings and other cell attributes. Clearly the team encountered some technical challenges that will prevent reaching the targets, however. The reviewer also noted that this was a clear and easy-to-follow presentation.

Reviewer 2:

According to the reviewer, the team's approach is to develop an advanced dry electrode process that enhances binder dispersion in SSB cathode and SSE films. This project will provide support to the Battery500 program to scale up the production of the materials.

Reviewer 3:

The reviewer said the project was well designed with a focus on addressing first material limitations and then processing challenges, but it was not executed.

Reviewer 4:

The project goal is to demonstrate a fabrication method for all solid-state Li-metal batteries to support the Battery500 program with similar performance to liquid-based systems. The reviewer was not familiar with the real technical challenges related to the fabrication. However, based on milestones and the overall presentation, the reviewer felt like more effort should be made to advance the project. Obviously, the pandemic delayed most of the work as shown in the milestones table. The reviewer did not have a chance to meet the presenter at the AMR (stopped by the poster twice) to get a better feel about the challenges.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project team is clear about what was able to be achieved and what was not. The team will not hit its 500 Wh/kg and 1,000 cycle goal, but of course this is the type of goal that requires more than a project of this size. Some progress in air stability and dry electrode technology was made, which is valuable. The reviewer noted that the team clearly learned more about the challenges in this field.

Reviewer 2:

The reviewer remarked that several milestones in FY 2020 and FY 202121 have been delayed. While this is understandable due to the pandemic, other teams have done better in conducting their projects in the same situation. The team has not found a way to optimize the NMC-SSE interface. The capacity retention of the NMC811 is disappointing. Also, the generation 2 LPS has a better ion conductivity than generation 1 but decays faster in the air than generation 1.

Reviewer 3:

The reviewer said the project was significantly delayed due to COVID-19. The team managed to optimize the dry electrode processes to improve the cycle life with enhanced binder dispersion, reduced binder content, and with the high throughput for industrial application with low cost.

The reviewer noted that surface protection on both cathode and Li anode is still investigated, though there has not been much progress with high loading NMC811 cell performance; the reviewer was doubtful the team will reach 1,000 cycles with 500 Wh/kg at room temperature by the end of the funding.

Reviewer 4:

The reviewer said the project started in 2017, and the reviewer is not confident about the amount of progress made so far. It looks like major challenges remain to be solved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the team appears well composed with clear and important contributions from each team member.

Reviewer 2:

The reviewer remarked the team collaborates with national laboratories and universities.

Reviewer 3:

The reviewer noted that a number of collaborators have been listed; however, the reviewer was not clear about the amount of communication between the partners, as indicated by the remaining challenges listed in the presentation.

Reviewer 4:

The reviewer said that good collaborations are planned but not fully utilized.

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 state project ended.

Reviewer 1:

The reviewer remarked proposed future work looks adequate and in line with the project goals, although very challenging.

Reviewer 2:

The reviewer said the team acknowledged the key tasks that remain in future work. The team also appears realistic that achieving the goals in the milestones will take longer than this project.

Reviewer 3:

The reviewer said the team is aware of the remaining challenges. Future research is proposed but there is a lack of detail to judge.

Reviewer 4:

The reviewer remarked major milestones from FY 2021 still need to be completed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said the project supports DOE objectives to demonstrate a R2R fabrication process incorporating stabilized sulfide SSEs, high-capacity cathodes, and protected Li-metal anodes that can deliver 500 Wh/kg specific energy and achieve life of 1,000 charge-discharge cycles.

Reviewer 2:

The reviewer commented the development of new fabrication methods that can help reduce cost and improve safety and performance will support the overall DOE objectives.

Reviewer 3:

The reviewer noted component and full cell development of 500 Wh/kg cells.

Reviewer 4:

The reviewer said the project provides support to the Battery500 program.

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 team has sufficient resources to conduct the project.

Reviewer 2:

The reviewer said resources and expertise seem sufficient to achieve proposed milestones.

Reviewer 3:

The reviewer commented that with a goal of 2.5 Ah cells, 500 Wh/kg, and 1,000 cycles, there are not enough resources to reach that. The team made progress on several points in its work, but there is a big gap with this target.

Reviewer 4:

The reviewer noted that challenges seem to be in the optimization of the cell components.

Presentation Number: bat519
Presentation Title: Synthesis, Screening, and Characterization of Novel Low Temperature Electrolyte for Lithium-Ion Batteries
Principal Investigator: Xiao-Qing Yang (Lawrence Berkeley National Laboratory)

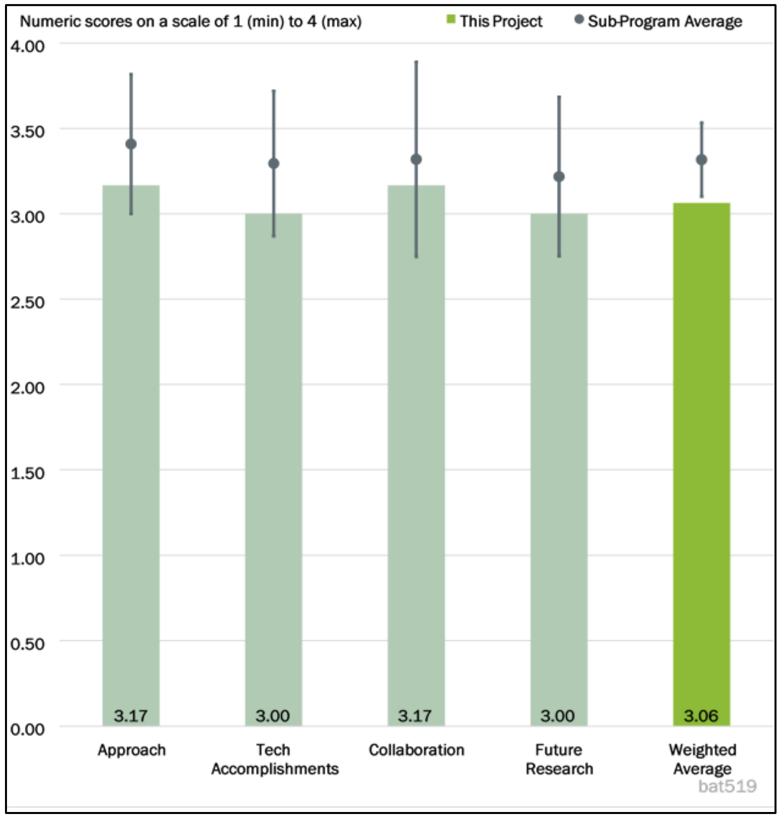


Figure 2-70 - Presentation Number: bat519 Presentation Title: Synthesis, Screening, and Characterization of Novel Low Temperature Electrolyte for Lithium-Ion Batteries Principal Investigator: Xiao-Qing Yang (Lawrence Berkeley National Laboratory)

Presenter

Xiao-Qing Yang, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that electrolytes are needed that do better at low temperature, and this approach is a good one. There is a need to ensure that high-temperature (HT) stability does not suffer, and that is normally what happens with good low-temperature (LT) electrolytes.

Reviewer 2:

The reviewer asserted that the overall approach to performing work is solid, yet there is a minor element of an Edisonian approach in scouting for new electrolyte formulations. There is a good balance between testing and modeling. It is good see half-cell work included in the research.

The reviewer detailed that an Outstanding or Excellent score would have been given if the team had considered the thermodynamics of electrolyte phase behavior at lower temperatures, wherein there can be electrode surface-driven interactions with the electrolyte that promote larger scale aggregation within the electrolyte with possible solid phase formation at electrode surfaces. This is supported by the general observation that, in many cell chemistries, the adverse cell response to decreasing temperature has a higher activation energy than just the activation energy tied to electrolyte conductivity or diffusivity. Also, there was no mention of determining test artifacts such as charge-transfer resistance, a common metric that can help detect anomalous interfacial behavior such as LT phase transitions. Lastly, there is no mention of possible Li plating as a consequence of charging at lower temperatures.

Reviewer 3:

The reviewer said the team needs to provide a rationale for the various approaches. One approach seemed to be a combined exploration of various solvents and additives to enable high conductivity and low SEI impedance at low temperature. The team also proposed a combined approach of localized high-concentration electrolyte (LHCE) and low concentration electrolytes based on 1,1,2,2-tetrafluoroethyl-2,2,3,3-tetrafluoropropyl ether (TTE) solvent.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project team's results showed the LT improvements due to the isoxazole (IZ) electrolyte and reported improvement due to 2 molar (M) lithium bis(fluorosulfonyl)imide (LiFSI)- ethyl methyl carbonate (EMC)/TTE concentrated electrolyte. Some explanations should be provided as to why the proposed LHCE and the low-concentration electrolytes did not improve LT performance. The reviewer highlighted that 2.2 mAh/cm^2 reported loading for the TTE was relatively light and the thinner electrodes might favor LT performance. The reviewer recommended that electrode loading should be reported also for the IZ electrolytes.

Reviewer 2:

The reviewer saw 10% FEC and explained that industry indicates a maximum FEC content of approximately 2%-4% due to gassing issues especially noticeable in larger automotive-sized cells.

Reviewer 3:

The reviewer found that overall, this team has noteworthy credentials. There was good delivery on the video and a good list of candidate electrolyte materials for enhancing LT performance. A minor portion of the poster presentation reflects a bit of random outcomes that do not seem well connected. The reviewer also noted that the use of LiFSI salt carries with it concerns of corrosion at the cathode current collector; so, this has to be well understood to prevent an incorrect diagnosis of cell performance.

This reviewer reported that Slide 7 indicates "An excellent ability of MD simulations using the revised APPLE&P force field to predict the Li+ solvation shell composition, diffusion coefficients of all species and temperature dependence of conductivity." Yet, such solvation shell and conductivity information were not divulged, especially at the desirable condition of -20°C. The reviewer noted that Slide 10 shows assessments at the C/5 rate. Should this actually be at C/3? The connection between Slides 12 and 13 is not clear, as the electrolyte used in Slide 12 is not given. The reviewer found a weak story involving higher T conditions: Slide 12 shows about 33% capacity loss (C/3 basis) at 100 cycles for 50°C. The reviewer noted that Li plating was not evaluated as a possible consequence of charging at lower temperatures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted good collaboration with the University of Maryland, ARL, and University of Rhode Island with clear descriptions of the role of each team member.

Reviewer 2:

The reviewer encouraged some interaction with commercial cell builders to ensure these cells are relevant, and referenced a prior comment about FEC.

Reviewer 3:

The reviewer referenced prior comments, and remarked that the team has good credentials, but apparently missed some key issues relating to operating Li-ion cells at LT: possible surface-initiated solid phase behavior of the electrolyte, possible Li plating, etc. This outcome might have been corrected with better collaboration and coordination within the team and through reaching out to other experts in the field.

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 state project ended.

Reviewer 1:

The reviewer asked if this LT electrolyte did the same or worse than the baseline electrolyte at higher T; normally, it is worse.

Reviewer 2:

The reviewer said this strikes me as being an Edisonian approach that does not mention or emphasize building on the knowledge gained by looking for the origins of poor LT performance. Without identifying such origins there is a lesser foundation for finding meaningful outcomes to mitigate poor performance at lower temperatures. There was no mention made of aging and/or survivability at up to 60°C.

Reviewer 3:

The reviewer said that per the stated objective to develop electrolytes that perform equally well at HT and LT, some future efforts need to be devoted to quantifying HT degradation of their optimized LT electrolytes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said weighing the collective responses expressed in earlier questions, this work supports DOE objectives for advancing the SOA for LT battery electrolytes, which if successful will help expand proliferation of LIB systems to greater geographical areas.

Reviewer 2:

The reviewer commented LT performance will become critical as EVs are more widely commercialized.

Reviewer 3:

The reviewer remarked the project has good objective to mitigate LT performance issues without compromising HT or fast charge rate capabilities.

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 are sufficient given the nature of the team, its objectives, and schedule.

Reviewer 2:

The reviewer said $1 million per year should be sufficient to develop a wide-temperature range electrolyte.

Reviewer 3:

The reviewer had no comments.

Presentation Number: bat520
Presentation Title: Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-Ion Batteries
Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

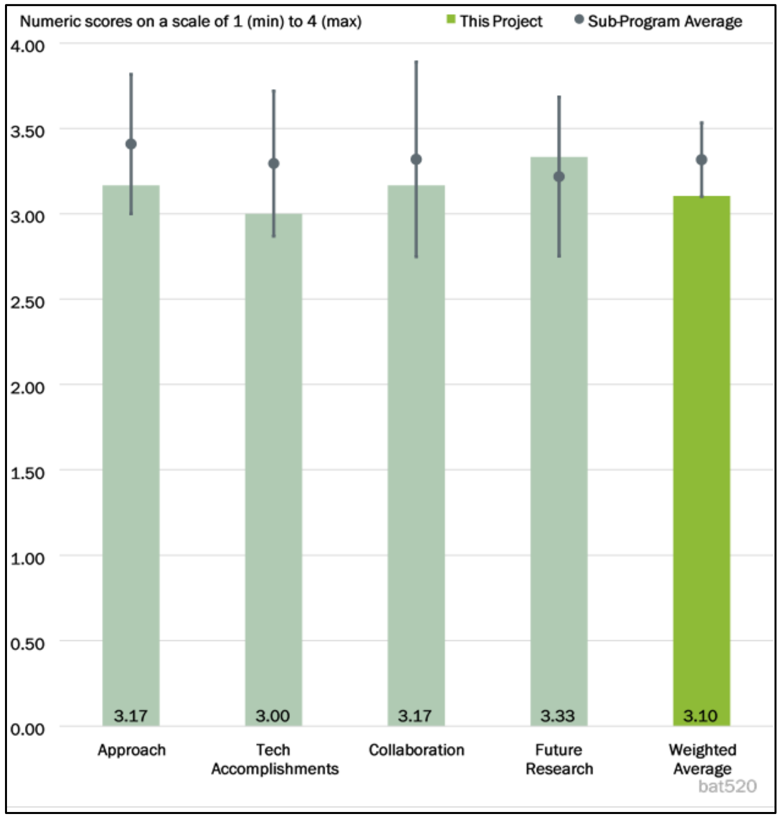


Figure 2-71 - Presentation Number: bat520 Presentation Title: Fluorinated Solvent-Based Electrolytes for Low Temperature Lithium-Ion Batteries Principal Investigator: Zhengcheng Zhang (Argonne National Laboratory)

Presenter

Zhengcheng Zhang, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the proposed combination of additives to reduce SEI resistance and selected solvents to improve LT ionic conductivity is a sound approach.

Reviewer 2:

The reviewer commented the overall approach to performing work is suitable, yet there is an element of an Edisonian approach in scouting for new electrolyte formulations. What seems to be missing at this early stage is an emphasis on determining the origins of poor Li-ion cell performance at lower temperatures, as this is not simply a function of transport properties (diffusivity and conductivity) over the temperature regime.

The reviewer elaborated that an Outstanding or Excellent score would have been given if the team considered the following. Thermodynamics of electrolyte phase behavior at lower temperatures should be considered, wherein there can be electrode surface-driven interactions with the electrolyte that promote larger-scale aggregation within the electrolyte with possible solid phase formation at electrode surfaces. This is supported by the general observation that in many cell chemistries the adverse cell response to decreasing temperature has a higher activation energy than just the activation energy tied to electrolyte conductivity or diffusivity. Slide 3 mentions the topics of charge transfer resistance (RCT) and Li plating, and yet in the presentation that follows there is no mention of RCT (a common metric that can help detect anomalous interfacial behavior such as LT phase transitions), and there is no mention of possible Li plating as a consequence of charging at lower temperatures. The reviewer remarked these topics of RCT and Li plating should be part of the standard approach of core tools for inquiry into LT Li-ion cell performance.

Reviewer 3:

The reviewer remarked investigating esters is a reasonable approach for improving LT performance, but this has been done multiple times so it has to be a very focused investigation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the team provided extensive data demonstrating the benefits of their fluorinated carbonate solvents and esters, in combination with additives such as FEC. The team's modeling provided good insights on how LT impacted ion pairing and solvation sphere that resulted in poor LT conductivity. The reviewer said the team should provide electrode loading to show that the good results were not due to thin light-loading electrodes.

Reviewer 2:

The reviewer said the team is well underway and showing overall good progress at only 33% complete. Although some deficiencies were noted, the reviewer had no doubt they could be remedied in future work.

The team has assembled a good list of candidate electrolyte materials for enhancing LT performance. Regarding electrolytes at 0.6M, the reviewer stated that this could lead to localized, dramatically starved electrolytes when cells undergo concentration polarization, a strong possibility at lower temperatures. This will produce a corresponding low-conductivity region (e.g., near the cathode surface during cell discharge). The reviewer recommended more studies over salt concentration. Regarding the use of butyronitrile (BN), the reviewer asserted that this carries with it an added toxicity burden that should be factored in, as feasible.

The reviewer said it was good to see cation solvation structure mentioned in this work. Regarding Slide 10, the reviewer asked if the detrimental results for LiFSI systems could be tied to the corrosive action of LiFSI. Regarding Slide 14, the reviewer wanted to know what modeling basis was used for electrolyte conductivity? Modeling results vary with experimental values by about 50%, showing a lack of modeling fidelity that will severely diminish using this modeling basis as a screening and/or learning tool. The reviewer referenced the residence times on Slide 14 and noted that these values are informative and their non-linear trends over temperature are much appreciated. The approach to studying electrolyte additives is logical and well performed.

The reviewer noted that in the video there was no audio for about the last 1.5 minutes, and there were no HT results yet. Cell data evaluations involving RCT were not performed but are highly anticipated for future work. Li plating was not evaluated as a possible consequence of charging at lower temperatures.

Reviewer 3:

The reviewer pointed out that 25% FEC is used here, which industry indicates is not possible in large pouch cells due to gassing. Industry limits FEC content to 2%–4% due to gassing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaboration appears to be well managed and intact.

Reviewer 2:

The reviewer cited good collaboration with LBNL, and said that some descriptions should be provided on Navitas' contribution to the team.

Reviewer 3:

The reviewer recommended some collaboration or communication with commercial cell builders to ensure that electrolytes are commercially relevant.

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 state project ended.

Reviewer 1:

The reviewer remarked future work shows a favorable, effective combination of experimental and modeling work that will help build understanding of the origins of poor LT performance of Li-ion cells.

Reviewer 2:

The reviewer noted that all of these esters certainly improve LT conductivity, which has been known for years, and generally make 40°C and higher temperature life much worse; the gassing is often large. The reviewer would encourage this team to do higher T testing to ensure that life there is not compromised.

Reviewer 3:

The reviewer remarked per the team's stated objective to develop electrolytes that perform equally well at HT and LT, some future efforts need to be devoted to quantifying HT degradation of optimized LT electrolytes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said improved LT performance is highly relevant.

Reviewer 2:

The reviewer remarked weighing the collective responses expressed in earlier questions, this work supports DOE objectives for advancing the SOA for LT battery electrolytes, which if successful will help expand proliferation of Li-ion battery systems to greater geographical areas.

Reviewer 3:

The reviewer commented that there is a good objective to mitigate the LT performance issue without compromising HT or fast charge rate capabilities.

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 sufficient resources.

Reviewer 2:

The reviewer said resources are sufficient given the nature of the team, its objectives, and schedule.

Reviewer 3:

The reviewer asserted that $700,000 per year should be sufficient to develop LT electrolytes.

Presentation Number: bat521
Presentation Title: Ethylene Carbonate-Lean Electrolytes for Low-Temperature, Safe, Lithium-Ion Batteries
Principal Investigator: Bryan McCloskey (University of California, Berkeley)

Presenter

Bryan McCloskey, University of California, Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

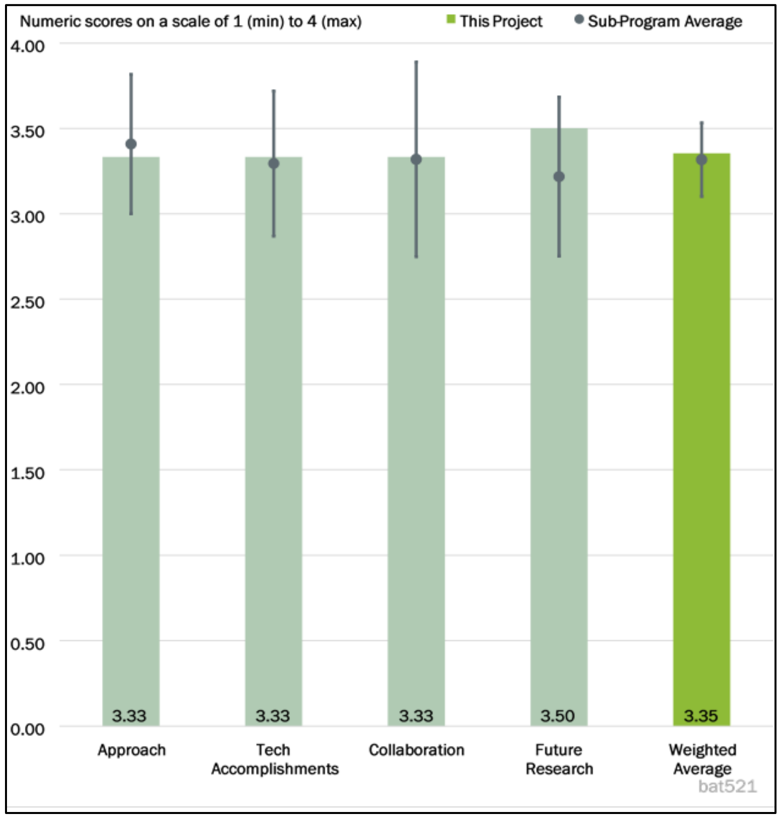


Figure 2-72 - Presentation Number: bat521 Presentation Title: Ethylene Carbonate-Lean Electrolytes for Low-Temperature, Safe, Lithium-Ion Batteries Principal Investigator: Bryan McCloskey (University of California, Berkeley)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this is a very good approach to trying to improve LT performance.

Reviewer 2:

The team utilized the ANL Cell Analysis, Modeling, and Prototyping (CAMP) electrodes with practical loadings (more than 2.5 mAh/cm^2) that avoid skewing the findings for LT as is the case for low loading electrodes. Future electrolyte projects should be based on agreed, standardized electrodes from CAMP in order to compare the performance of various electrolytes. The reviewer said the team's combined approach of using electrochemical testing with ionic transport modeling for different concentrations and additives is a sound approach.

Reviewer 3:

The reviewer remarked the overall approach to performing work is solid, as it appears to capture the fundamentals of elucidating the origins of poor Li-ion cell performance at lower temperatures. There is a good balance between testing and modeling. Use of half-cell work in the research is a key feature to assign weight to cathode versus anode sensitivity to temperature conditions.

The reviewer noted that the emphasis on RCT at both electrodes is valuable in that it can be used to explore related factors such as the exchange current density. Such terms will help detect thermodynamic behavior of electrolyte phase transitions at lower temperatures, wherein there can be electrode surface-driven interactions with the electrolyte that promote larger scale aggregation within the electrolyte with possible solid phase formation at electrode surfaces.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the team's study provided great insights on the poor LT performance issue in Li-ion cells. The three-electrode study showed charge transfer at graphite anode dominating at low temperatures and their molecular dynamics modeling showed decreased conductivity due to increased ion pairing at low temperatures.

Reviewer 2:

The reviewer provided insight regarding the projects' question of finding an SEI additive to use with gamma-butyrolactone (GBL). In the past, many have used small amounts of ethylene carbonate (EC) (5%–10%) to form the SEI. However, GBL is known to introduce HT life and gassing issues, so the reviewer would be careful before pushing it much further.

The reviewer was glad that LBNL has limited FEC to 10% or less as industry has settled on about 2%–4% FEC due to gassing in large format automotive cells RCT dominates LT as both cathode and anode go high but anode dominates. The reviewer thought that this is exactly what Andy Jansen found 15 years ago in the Advanced Technology Development (ATD) program.

Reviewer 3:

The reviewer remarked that given that the work is about 50% complete, the extent of accomplishments and progress is on track and is along a logical progression. A key objective for FY 2021 is to understand the origin of resistances within Li-ion batteries at low temperature. Toward this goal, test methods and analysis techniques have been well demonstrated.

The reviewer found some noted deficiencies that will likely be resolved in future work:

- The team needs to greatly expand the list of candidate electrolyte solvents and salts.
- The team needs to develop more informative structure-function relationships to aid in co-solvent and salt selection.
- The team does not mention possible Li plating as a consequence of charging at lower temperatures and how to detect and mitigate this outcome.
- The team does not mention Li-ion cell survivability and aging at higher temperatures (e.g., 50°C).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed that there is a great partnership with LBNL for analysis and ANL CAMP facility for electrodes.

Reviewer 2:

The reviewer said collaboration was reasonable for a national laboratory R&D project.

Reviewer 3:

The reviewer remarked collaboration and coordination appear to be well managed, judging from the cohesive progression of the research. For future work, this project may benefit by reaching out to other outside collaborators in key areas (additives, temperature consequences over multiple time and spatial scales, and thermodynamics).

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 state project ended.

Reviewer 1:

The reviewer pointed out that the final deliverables are 100 mAh, which is great, but the team will not likely see a gassing issue there. So, the PI might consider some other investigations to uncover gassing issues—often they do not show up until size is 5–10 Ah.

Reviewer 2:

The reviewer remarked the future work stated in this project will allow deeper insights into the origins of diminished Li-ion cell performance at lower temperatures, and provide a path toward mitigating technical obstacles. The reviewer noted a deficiency: not mentioned is the aspect of Li-ion cell survivability and aging at higher temperatures (e.g., 50°C).

Reviewer 3:

The reviewer noted that the GBL additive has been studied extensively in the past for use in Li-ion cells. However, the new diagnostic tools developed recently should enable the team to gain insights on the proposed effort to understand why GBL reduces charge transfer at the cathode. The reviewer said the team should also devote future effort to understand why FEC reduces charge transfer at low temperatures, especially at the anode.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that improved LT performance is highly relevant especially as EVs become closer to wide-scale market adoption.

Reviewer 2:

The reviewer remarked weighing the collective responses expressed in earlier questions, this work supports DOE objectives for advancing the SOA for LT battery electrolytes, which if successful will help expand proliferation of LIB systems to greater geographical areas.

Reviewer 3:

The reviewer asserted that a good understanding of factors affecting LT performance is critical for achieving a wide temperature electrolyte.

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 $2.35 million, 3-year effort should be sufficient to achieve a good understanding of the LT issue and provide mitigations.

Reviewer 2:

The reviewer remarked resources are sufficient given the nature of the team, the objectives, collaborations, and schedule.

Reviewer 3:

The reviewer saw no issues with resources.

Presentation Number: bat522
Presentation Title: Thin-film Lithium Metal Manufacture by Room Temperature Electrodeposition
Principal Investigator: Alirio Liscano (Albemarle)

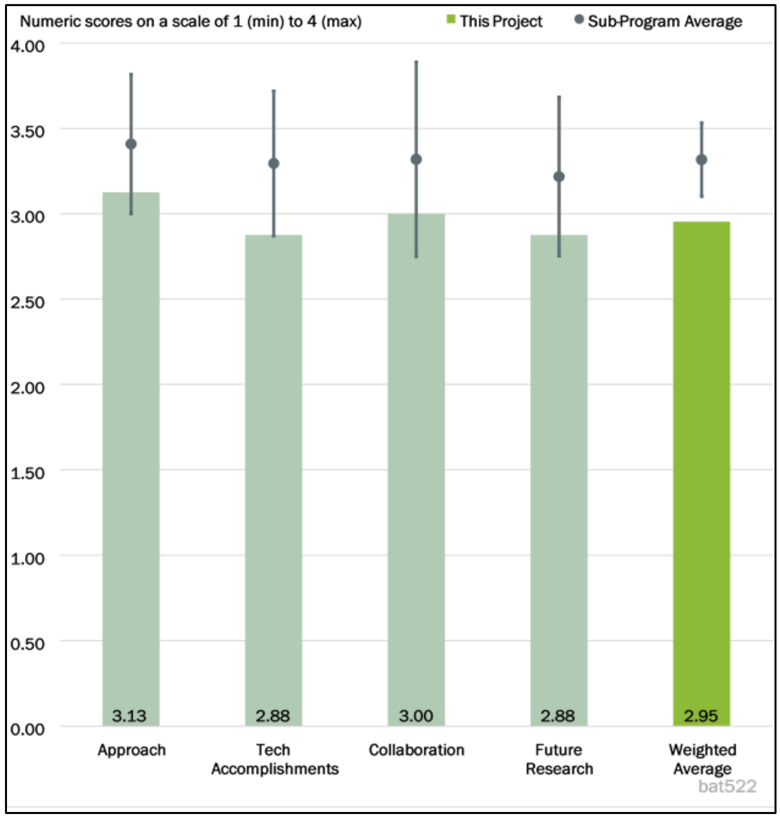


Figure 2-73 - Presentation Number: bat522 Presentation Title: Thin-film Lithium Metal Manufacture by Room Temperature Electrodeposition Principal Investigator: Alirio Liscano (Albemarle)

Presenter

Alirio Liscano, Albemarle

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the team conducted room-temperature electrodeposition method to produce thin-film Li metal, and the membrane and the device are optimized to improve the performance, safety, and cost-effectiveness. The approach is good, according to the reviewer.

Reviewer 2:

The reviewer said there are multiple critical components to this project. The stated target of this report is the development of electrochemically plated Li-metal anode structures as a low-cost alternative to commercially produced foil versions. This appears to be well thought out and a reasonable objective. The larger scope of this project involves a target cell design that uses a specialty membrane to provide essentially a two-compartment design. The reviewer noted water-based Li salts are a target for the anode side and non-aqueous based electrolyte systems for the cathode side. While the latter is probably the major gating item to the success of this approach, there is very little technical detail associated with this component as opposed to the Li-metal structure.

Reviewer 3:

The reviewer said the approach is clear and concise. Overall, the strategy is effective in depositing Li metal using a low-cost R2R method. While the barriers to the project were clearly stated, the poster could have quantified the amount of water crossover using the membrane. The reviewer said the presenter mentioned that the water was quantified using Coulometric titration, but it is difficult to determine if that concentration is "low" because no quantifiable information was provided. The second barrier was mentioned and clearly illustrated on the poster.

Reviewer 4:

The reviewer remarked the problem of generating Li metal from aqueous salt solutions is ambitious. It is unclear if a membrane that is selective for Li but not water can ever be made.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked out of the four milestones that were listed, the progress seems on a par with the timeline provided. The poster clearly showed that the electrodeposited Li outperforms the commercial Li. The cathode used was lithium cobalt oxide (LCO). It is known that the cathode and anode have crosstalk in the cell. This may influence the overarching performance. To make a fair comparison of the electrodeposited versus commercial Li, it would be best to test this with various commercialized cathodes to determine if the cycle life continues to be enhanced with the electrodeposited Li. The reviewer said it would also be great to move into using low-Co and Co-free materials because this would address geopolitical issues. In achieving performance measures for the Li anode, it may prove useful to cycle the cells at various C-rates. The milestone mentions that the battery capacity retention is equal or better than conventional foil after 50 cycles at C/5, but the data provided were cycled at 0.5C (or C/2). This is why it may be best to show the discharge capacity fading at different C-rates to illustrate the comparison.

Reviewer 2:

The accomplishments shown seem reasonable, but this reviewer was skeptical about accomplishment of the overall goal. It was difficult to decipher this submission, which seems to have a different format that is less readable compared to other submissions.

Reviewer 3:

The reviewer said the Li metal plating work appears to show promise. The concept of a high conductivity, low water crossover membrane is fairly opaque in this presentation. The technical progress of this component cannot really be evaluated in any depth.

Reviewer 4:

The reviewer commented the thickness of the electrodeposited Li metal is well controlled to be approximately 20 μm, while the surface is rough from the SEM image. As for electrochemical performance, the electrodeposited Li indeed shows a 50% longer cycle life compared with commercial Li; however, the cyclability (80% capacity retention for 30 cycles) still needs to be further improved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the PI shows clear collaboration with ANL and SolidPower, which are responsible for electrodeposition and battery manufacturing, respectively.

Reviewer 2:

The reviewer noted no issues.

Reviewer 3:

According to the reviewer, the presenter mentioned that there are ongoing active collaborations. Because the model system has now been developed, it is possible to further these collaborations with battery manufacturing. There was some concern regarding the thickness of the transport membrane. The presenter mentioned that the thickness was negligible. The reviewer stressed that further evidence from the collaborator would be useful to determine why that thickness does not matter. If Li-ion mobility is a challenge and the membrane thickness can promote or hinder the Li mobility, the thickness must have some properties or influences that make it negligible to the overall system. More collaborative thought could be used to rationalize this concept.

Reviewer 4:

The reviewer remarked the extent of collaboration between the participating institutions was reasonable, but difficult to quantify, based on the limited scope of the review document.

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 state project ended.

Reviewer 1:

The reviewer commented the proposed future research is effectively planned, and related to the objectives and current technical accomplishments.

Reviewer 2:

The reviewer said the stated goals, particularly the development of a prototype, are good.

Reviewer 3:

The reviewer remarked the goals associated with the development of a low-water crossover membrane are broad and vague.

Reviewer 4:

The reviewer stated that one of the remaining challenges is associated with developing a strategy for handling potential water crossover after the membrane synthesis has been scaled up for the prototype. While this is one of the challenges, nothing in the future work is stated to address this. The water crossover can potentially have a detrimental role on the cycle life of the cell. This is a major challenge that needs to be addressed with an appropriate strategy, yet the strategy was not mentioned. The reviewer asked if the membrane the membrane will have to be modified. During improved membrane development, will it be determined that thickness does have an influence on the uniformity of the deposited Li metal? There are quite a few challenges to overcome before determining the quality of the prototype and the resulting coin and pouch cells.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said methods for producing Li-metal foils are highly relevant to overall DOE objectives.

Reviewer 2:

The reviewer remarked that Li-metal systems of all flavors are being evaluated as a potential next-generation successor to traditional Li-ion. All reasonable system proposals should be evaluated. The reviewer pointed out that this particular concept seems very challenging.

Reviewer 3:

The reviewer commented the work is in support of the DOE objectives. The work is innovative and does support advancement of energy research and environmental cleanliness. As previously mentioned, using commercialized low-Co based cathodes would be one method to further move into the ongoing directions of Co-free materials in battery applications.

Reviewer 4:

The reviewer said the project is about Li-metal production, which 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:

The resources are sufficient for the project to achieve the milestones, according to the reviewer.

Reviewer 2:

The reviewer said resource allocation is reasonable, especially given the cost share.

Reviewer 3:

The reviewer saw no issues.

Reviewer 4:

The reviewer remarked it seems as though there are sufficient resources provided from DOE, the cost share from the company, and resources from collaborators to complete the project objectives.

Acronyms and Abbreviations

µm	Micron
3-D	Three-dimensional
AIMD	ab initio molecular dynamics
Al	Aluminum
ALD	Atomic layer deposition
AM	Active material
AMAT	Applied Materials
AMO	Advanced Manufacturing Office
ANL	Argonne National Laboratory
ARL	U.S. Army Research Laboratory
ASR	Area-specific resistance
ASSB	All-solid-state-battery
BN	Butyronitrile
BNL	Brookhaven National Laboratory
BR	Battery Resourcers
BTMS	Behind-the-meter storage
BTO	Building Technologies Office
BY	Budget year
BYU	Brigham Young University
CAMP	Cell Analysis, Modeling, and Prototyping
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CB	Carbon black
CCD	Critical current density
CE	Coulombic efficiency
CEI	Cathode-electrolyte interface
CFM	Complex framework materials
cm	Centimeter
CNF	Carbon nanofiber
Co	Cobalt
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019

Cu	Copper
CV	Cyclic voltammetry
DCFC	Direct-current fast charging
DCIR	Direct current internal resistance
DMBQ	Dimethoxy benzoquinone
DOE	U.S. Department of Energy
DOL	Dioxolane
DRX	Cation-disordered rock salt
E_a	Activation energy
EAM	Electrochemically active mono-layers
EC	Ethylene carbonate
EERE	Office of Energy Efficiency and Renewable Energy
EMC	Ethyl methyl carbonate
EOL	End of life
EV	Electric vehicle
FCE	First-cycle efficiency
FCTO	Fuel Cell Technologies Office
FEC	Fluoroethylene carbonate
FSP	Flame Spray Pyrolysis
FTIR	Fourier-transform infrared spectroscopy
FY	Fiscal Year
g	gram
GBL	gamma butyrolactone
GED	Gravimetric energy density
GHG	Greenhouse gas
GM	General Motors
GSE	Glassy solid electrolyte
HE	High energy
HFTO	Hydrogen and Fuel Cell Technologies Office
HOPG	Highly oriented pyrolytic graphite
HPPC	Hybrid pulse power characterization
HT	High-temperature

HVM	High volume manufacturing
ID	Identification
IL	Ionic liquid
In	Indium
INL	Idaho National Laboratory
IP	Intellectual property
IUPUI	Indiana University – Purdue University Indianapolis
IZ	Isoxazol
Kg	Kilogram
KIT	Karlsruhe Institute of Technology
KPI	Key performance indicator
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LCA	Life-cycle analysis
LCO	Lithium cobalt oxide
LFP	Lithium iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
$Li_7La_3Zr_2O_{12}$	Lithium lanthanum zirconium oxide
LIB	Lithium-ion battery
LIBRA	Lithium Ion Battery Resource Assessment
LIC	Lithium-ion conducing
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide
LiNO3	Lithium nitrate
Li-SIA	Lithium structurally isomorphic alloys
LLZO	Lithium lanthanum zirconium oxide
LMNO	Lithium manganese nickel oxide
LMO	Lithium manganese oxide
LNMC	Lithium nickel manganese cobalt oxide
LNMO	Lithium nickel manganese oxide
LNO	Lithium-nickel dioxide (LiNiO2)

LOE	Level of effort
LPF	Lithium plating free
LPS	Sulfide-based solid state electrolyte, Li_3PS_4
LPSCl	Halogenated sulfide-based solid state electrolyte
LT	Low-temperature
LTO	Lithium titanate (Li4Ti5O12)
M	Molar
mAh	Milliamp-hour
MD	Molecular dynamics
MERF	Materials Engineering Research Facility
mg	Milligram
MIC	Molecular ionic composite
MLPC	Multi-level porous carbon/multi-layer pouch cell
MS	Mass spectroscopy
MT	MegaTon
MW	Microwave
N/P	Negative-positive ratio
NASA	National Aeronautics and Space Administration
NCA	Nickel cobalt aluminum oxide
NCE	No-cost extension
NCM	Nickel cobalt manganese oxide
NECST	Nanomaterials for Energy Conversion Storage Technology
NF	Non-flammable
Ni	Nickel
NMC	Nickel manganese cobalt oxide
NMP	N-methyl-2-pyrrolidone
NREL	National Renewable Energy Laboratory
OE	Office of Electricity
OEM	Original equipment manufacturer
OIM	Organic insertion materials
ORNL	Oak Ridge National Laboratory
PAN	Polyacrylonitrile

PBI	Polybenzimidazole
PDF	Pair-distribution function
PEG	Polyethylene glycol
Penn State	Pennsylvania State University
PEO	Polyethylene oxide
pH	Power of hydrogen
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
PS	Polysufide
PVDF	Polyvinylidene difluoride
Q	Quarter
R&D	Research and development
R2R	Roll to roll
RCT	Charge transfer resistance
S	Sulfur
S@PAN	Sulfurized polyacrylonitrile
S@PC	Sulfurized porous carbon
SEI	Solid-electrolyte interface
SEM	Scanning electron microscopy
SETO	Solar Energy Technologies Office
Si	Silicon
SIMS	Secondary Ion Mass Spectrometry
SiO_x	Oxides of silicon
SLAC	Stanford Linear Accelerator Center
SN	Succinonitrile
SNL	Sandia National Laboratories
SOA	State of the art
SOC	State of charge
SPAN	Sulfurized polyacrylonitrile
SSB	Solid-state battery
SSE	Solid-state electrolyte
SUNY	State University of New York

T	Temperature
TEM	Transmission electron microscopy
Ti	Titanium
ToF	Time-of-Flight
TVR	Taylor Vortex Reactor
TXM	Transmission X-ray microscopy
U.S.	United States
URI	University of Rhode Island
USABC	United States Advanced Battery Consortium
V	Volt
VTO	Vehicle Technologies Office
Wh	Watt-hour
wt.%	Weight percent
XANES	X-ray absorption near edge structure spectroscopy
XCEL	eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries
xEV	An electric vehicle, including battery electric vehicle (BEV), hybrid xEV electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), etc.
XFC	Extreme fast charging
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
ZnO	Zinc oxide

3. Energy Efficient Mobility Systems

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Energy Efficient Mobility Systems (EEMS) subprogram supports research, development, and demonstration of innovative mobility solutions that improve the affordability, accessibility, and energy productivity of the overall transportation system. EEMS leverages emerging disruptive technologies such as connected and automated vehicles, information-based mobility-as-a-service platforms, and artificial intelligence-based transportation control systems to accelerate the transition to a zero carbon-emission transportation future. The EEMS subprogram also develops and utilizes large-scale transportation modeling and simulation capabilities to evaluate the impacts of new mobility solutions across multiple geographies and populations, ensuring that all Americans, especially underserved and energy communities, benefit from the development and deployment of clean transportation technologies.

The EEMS subprogram consists of two primary activities: Computational Modeling and Simulation, and Connectivity and Automation Technology. The subprogram's overall goal is to identify feasible system-level pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity for individuals and businesses when adopted at scale. The EEMS subprogram has developed a quantitative metric for mobility energy productivity, which measures the affordability, energy efficiency, convenience, and economic opportunity derived from the mobility system. The metric, while encompassing multiple vehicle classes and modes for passenger and goods movement, is used by the subprogram to evaluate success and by the transportation community to inform planning decisions. The EEMS subprogram's target is a 20 percent improvement in mobility energy productivity by 2040 relative to a 2020 baseline.

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
eems013	ANL Core Tools: AMBER and Autonomie	Phil Sharer (ANL)	3-5	3.25	3.13	3.50	3.13	**3.20**
eems037	Big Data Solutions for Mobility	Jane Macfarlane (LBNL)	3-9	3.25	3.25	3.00	3.00	**3.19**
eems041	ANL Core Tools-Hardware	Kevin Stutenberg (ANL)	3-11	3.00	2.88	3.38	3.13	**3.00**
eems061	Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility	Jiboananda Sanyal (ORNL)	3-15	3.50	3.33	3.67	3.33	**3.42**
eems062	Deep-Learning for Connected and Automated Vehicle (CAV) Development	Robert Patton (ORNL)	3-19	3.50	3.50	3.50	3.50	**3.50**
eems066	Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing	Lauren Spath-Luhring (NREL)	3-23	3.25	3.63	3.50	3.00	**3.44**
eems067	Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies	Dean Deter (ORNL)	3-28	3.38	3.38	3.38	3.00	**3.33**
eems069	Next Generation Intelligent Traffic Signals for the Multimodal, Shared, and Automated Future	Andrew Powch (Xtelligent)	3-32	2.83	3.00	3.50	3.17	**3.04**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems082	Validation of Connected and Automated Mobility System Modeling and Simulation	Reuben Sarkar (American Center for Mobility)	3-36	3.50	3.33	3.33	3.17	**3.35**
eems083	CIRCLES: Congestion Impact Reduction via CAV-in-the-Loop Lagrangian Energy Smoothing	Alexandre Bayen (University of California at Berkeley)	3-39	3.50	3.50	3.83	3.33	**3.52**
eems084	Energy-Efficient Maneuvering of Connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections	Sankar Rengarajan (Southwest Research Institute)	3-42	3.25	3.50	3.13	3.50	**3.39**
eems087	Computation of Metropolitan-Scale, Quasi-Dynamic Traffic Assignment Models Using High Performance Computing	Jane Macfarlane (LBNL)	3-46	3.50	3.50	3.00		**3.43**
eems088	Chicago Transit Authority: Transit Network Efficiency Using POLARIS	Omer Verbas (ANL)	3-49	3.17	3.33	3.33	3.00	**3.25**
eems089	Energy Efficient CAVs: Workflow Development and Deployment	Dominik Karbowski (ANL)	3-53	3.33	3.33	3.50	3.17	**3.33**
eems091	TCF: Ubiquitous Traffic Volume Estimation	Venu Garikapati (NREL)	3-56	2.83	2.83	2.83	2.83	**2.83**
eems092	BEAM CORE	Anna Spurlock (LBNL)	3-59	3.25	3.08	3.58	3.33	**3.22**
eems093	Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment	Aymeric Rousseau (ANL)	3-63	3.00	2.88	3.38	2.88	**2.97**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems094	Development and Validation of Intelligent CAV Controls for Energy-Efficiency	Dominik Karbowski (ANL)	3-67	3.50	3.25	3.50	3.25	**3.34**
eems095	Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use	Timothy Laclair (ORNL)	3-71	3.33	3.17	3.50	3.00	**3.23**
eems096	Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity	Thomas Wallner (ANL)	3-74	3.13	3.13	3.25	3.13	**3.14**
eems097	Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE)	Andrew Duvall (NREL)	3-78	3.38	3.00	3.38	3.00	**3.14**
eems098	Optimizing Drone Deployment for More Effective Movement of Goods	Victor Walker (INL)	3-82	3.25	3.00	3.00	3.00	**3.06**
eems099	Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems	Venu Garikapati (NREL)	3-86	3.50	3.38	3.75	3.38	**3.45**
eems100	Dynamic Curb Allocation	Chase Dowling (PNNL)	3-90	3.50	3.50	3.25	3.13	**3.42**
eems101	RealSim	Dean Deter (ORNL)	3-94	3.50	3.00	3.25	3.38	**3.20**
Overall Average				**3.29**	**3.22**	**3.38**	**3.17**	**3.25**

Presentation Number: eems013
Presentation Title: ANL Core Tools: AMBER and Autonomie
Principal Investigator: Phil Sharer (Argonne National Laboratory)

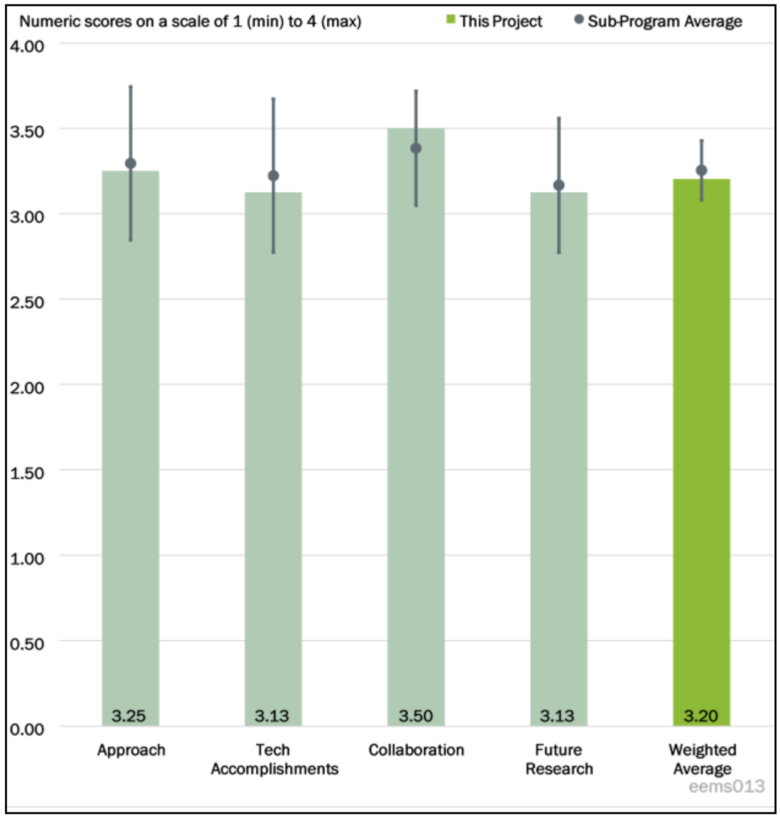


Figure 3-1 - Presentation Number: eems013 Presentation Title: ANL Core Tools: AMBER and Autonomie Principal Investigator: Phil Sharer (Argonne National Laboratory)

Presenter

Phil Sharer, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a strong approach with the Advanced Model Based Engineering Resource (AMBER) model-based design framework supporting any system simulation workflows and the Autonomie vehicle system simulation continuously collecting data and inputs from many different sources. Reference to this project and Core tools by many other Vehicle Technologies Office (VTO) Annual Merit Review (AMR) presentations—28 referenced them during the 2020 AMR—shows the effectiveness of addressing barriers.

Reviewer 2:

According to the reviewer, continuous improvements in the tool set, methods, available models, and distribution scheme address these critical issues in carrying out successful analyses—wider tool availability, ease of use of many moving parts, and good models.

Reviewer 3:

This reviewer noted the team has done a good job of addressing concerns that were expressed in previous reviews and has kept improving the tool chain and processes every year.

Reviewer 4:

The reviewer stated that this is a collection and integration of complex models. This level of layering and handoff always adds complexity and uncertainty and can reduce transparency and traceability in the model.

The reviewer indicated that a presentation with less marketing and more detailed discussion of the technical issues is needed to sufficiently understand how this is handled. The material did not appear responsive to prior concerns from the 2020 AMR, which should remain active and will need to be addressed moving forward. The reviewer noted that the narrative focuses too much on what it can do and does not effectively discuss constraints—for what it can or should not do or be used. How is the model useful and what are its bounds of usefulness?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that progress over the last year has been excellent; Autonomie EXPRESS is a very welcome addition for users who do not necessarily develop vehicle models but need to use them in analysis. The progress in adding new features that reflect new control schemes and powertrain configurations has been very good.

Reviewer 2:

The reviewer noted that many new accomplishments have been made over the past year highlighting several important additions to the Core models. More than 140 new features and enhancements have been added over the past year based on user feedback (including government, academia, and industry). Autonomie EXPRESS has been added as a new and faster version with a large number of predefined vehicles to increase tool adoption by targeted users, not just the developer. The new workflow has been developed to estimate energy and costs from the most commonly used microsimulation tools. Autonomie was also updated to evaluate new and emerging technologies with a focus on medium-duty (MD) and heavy-duty (HD) vehicle applications.

Reviewer 3:

The reviewer asserted that the slide deck focuses on the initiatives but does not clearly articulate the goals beyond two releases per year. Every year, the presenter(s) conveys how much the model has improved and how powerful it is. This implies that, in fact, there were a lot of weaknesses and gaps in prior years. The reviewer suggested that work needs to be more forthright with regard to the limits and gaps relative to the desired end state.

Reviewer 4:

Although excellent progress was observed, the reviewer did have some concerns about the direction that the overall project is taking. Specifically, commercialization of the tool and addition of multiple new features will require significant resources on the part of the ANL team to support customers (especially industry customers), which may be detracting from the key responsibilities of the national laboratories. On the one hand, the reviewer realized that commercial tools that can do the same job are unavailable; so, tools that address the specific simulation needs have to be developed. The ANL team has to find a way to balance the dual requirements of developing, maintaining, and supporting the tools, and using the tools to perform simulations and generate data that can be used to support and advise the DOE objectives and priorities.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the team has taken feedback from the user community and other stakeholders who need the results generated by the tool and has done a good job of addressing the needs of the community. The user base covers both academia and industry.

Reviewer 2:

According to the reviewer, the work is designed to foster alignment and collaboration and does it well. Collaborators contributed important input that was acted upon by the team.

Reviewer 3:

The reviewer said that the Core tools are developed and supported by Argonne National Laboratory (ANL). Users include companies and research and development (R&D) organizations. The collaboration takes place in terms of user feedback via technical support requests. Core tools are used by many VTO R&D projects (primarily in the Vehicle Analysis [VAN] and Energy Efficient Mobility Systems [EEMS] research areas).

Reviewer 4:

This reviewer referenced prior comments and indicated that the large number of users can provide useful feedback that allow the tools to be improved as well as plant seeds that could lead to future productive areas of 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future work is a natural outgrowth of the work done to date and supports EEMS ongoing objectives. The plan to support users appeared sound to the reviewer, given the expanding feature set.

Reviewer 2:

Proposed future work looked good to this reviewer, who commented that it would be worth ensuring that Autonomie Express can run using Octave besides Matlab, thereby making it truly "free." Of course, this assumes that Autonomie Express is available for anyone to use. Otherwise, this reviewer opined that institutional users of Autonomie Express probably would not have a problem because they would have access to Matlab.

Reviewer 3:

This reviewer reported that Fiscal Year (FY) 2021 was the last year of this project. Because many VTO R&D projects in VAN and EEMS area rely on the Core tools, the reviewer asserted that it is important to continue supporting these projects. The challenge with these increasingly sophisticated tools will be to maintain their support and licenses—over 25 different software packages are used. The reviewer commented that proposed future work includes expanding the workflow and model capabilities as well as expanding stakeholder engagement and deployment. If not used already, the reviewer suggested that perhaps a technical advisory committee comprised of several key stakeholders—U.S. Department of Energy (DOE), VAN and EEMS Technology Managers, key national laboratory researchers, automotive industry partners, and other research organizations—could be helpful to provide future development direction and ensure Core tools continue supporting the VTO R&D mission.

Reviewer 4:

The reviewer stated that there is good coverage of the "what" but not the "how."

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that this project directly supports VTO objectives by developing simulation tools and models that are widely used across the VAN and EEMS research areas. In AMR 2020, 28 projects were related to AMBER and Autonomie, which are the two main tools supported by this effort. The EEMS Core Tools project has supported VTO R&D target setting and benefits analysis across these program areas as well as the 21st Century Truck Partnership and United States Driving Research an Innovation for Vehicle Efficiency and Energy sustainability (U.S. DRIVE).

Reviewer 2:

The software tools generated by this project are some of the main vehicle and transport system modeling tools used for EEMS studies. The reviewer indicated that they are mission critical.

Reviewer 3:

The reviewer stated that the work is at the core of the VTO systems simulation. At a high level, the work is the type of activity that supports transportation energy efficiency.

Reviewer 4:

This reviewer stated that the core tools form a critical part of the Systems and Modeling for Accelerated Research in Transportation (SMART) mobility workflow.

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

Reviewer 1:

Resources appeared adequate to the reviewer. As the number of users grows, that may change. The team appears to have thought about this and made appropriate plans.

Reviewer 2:

Resources seemed sufficient to this reviewer, with the details covered in individual projects.

Reviewer 3:

Resources are sufficient from this reviewer's perspective.

Reviewer 4:

This project was funded at $1.25 million per year over 3 years, which seemed sufficient to the reviewer. However, future work in this area should be managed to ensure that Core capabilities are maintained and new capabilities are added, while not expanding the reach beyond efforts that support the VTO mission if VTO is the only funding source. With numerous software licenses and simulation platforms, the reviewer asserted that it can be very challenging to maintain all the systems without needing to increase funding.

Presentation Number: eems037
Presentation Title: Big Data Solutions for Mobility
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

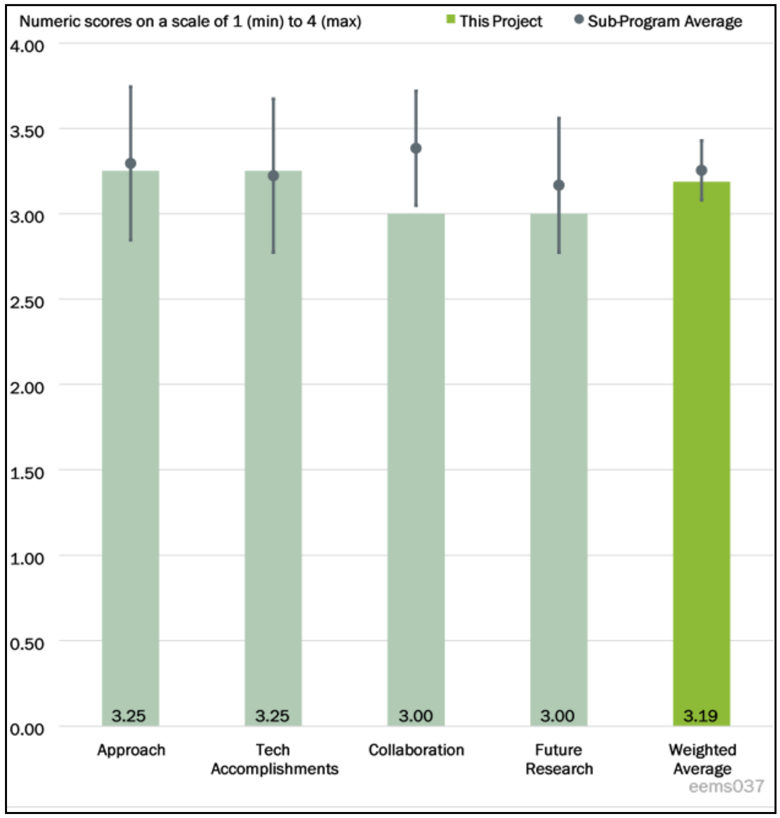


Figure 3-2 - Presentation Number: eems037 Presentation Title: Big Data Solutions for Mobility Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a fascinating concept and thought that the approach got caught up too much in the technology.

Reviewer 2:

This reviewer described the approach as well planned and timely in the face of increasing congestion. Looking forward, the reviewer wondered if the future is taken into account. For example, if traffic doubles, would the model be effective?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Although this project is just getting started, the reviewer found the choice of partnering with Uber interesting.

Reviewer 2:

The reviewer indicated that the project, which is on a timeline of 2 years, seems to show a 10% completion rate so far. The reviewer observed that the project team may need to increase the pace, taking into account a pandemic accounted for over a year of lost time. The integration of the Diffusion Convolutional Recurrent Neural Network DCRNN into Mobility was a major step in incorporating more ability to decipher data inputs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer reiterated that this is just getting started and was curious as to what the cities want out of this project. How can it really help them and how could this be used—for traffic routing when there are rolling blackouts, or if there is an earthquake? The reviewer expressed interest in seeing this tied to electrical grid concerns.

Reviewer 2:

It appeared to the reviewer as though the teams are very well organized and able to make great progress collaborating with each other. The reviewer noticed that there seemed to be a lack of another department of transportation that could lend valuable data on traffic, patterns, road conditions, and construction.

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 state project ended.

Reviewer 1:

The reviewer was also at "good" here. The reviewer thought there is more a fascination with the modeling versus asking what it can really do and what big problems the project team would like to see resolved. The reviewer thought that more work needs to be done on that and was unsure if this is going to be "handed over" to a user.

Reviewer 2:

This reviewer noted the first point on the Future Research slide was "Finding appropriate data to improve our data driven approach." The reviewer did not know what the appropriate data means. It sounds as though what the project team is currently using is not what it really wants, or not what it is really looking for.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the overall project looks for ways to reduce traffic congestion, which results in excessive idle time, energy inefficiency, harmful air pollutants, and motivation to entertain alternative fuel vehicles.

Reviewer 2:

The reviewer asserted that this project supports the overall DOE objectives, but suggested that this needs more thought. The reviewer was more interested in whether this can be used for rolling blackouts on the West Coast, if the grid crashes in a certain region, for EV charger modeling, disaster planning, and/or helping with autonomous vehicle (AV) roll-out.

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, but the reviewer believed that U.S. Department of Transportation (DOT) information would be helpful.

Reviewer 2:

Although the project is just getting started, the reviewer emphasized that the project team should think bigger.

Presentation Number: eems041
Presentation Title: ANL Core Tools-Hardware
Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

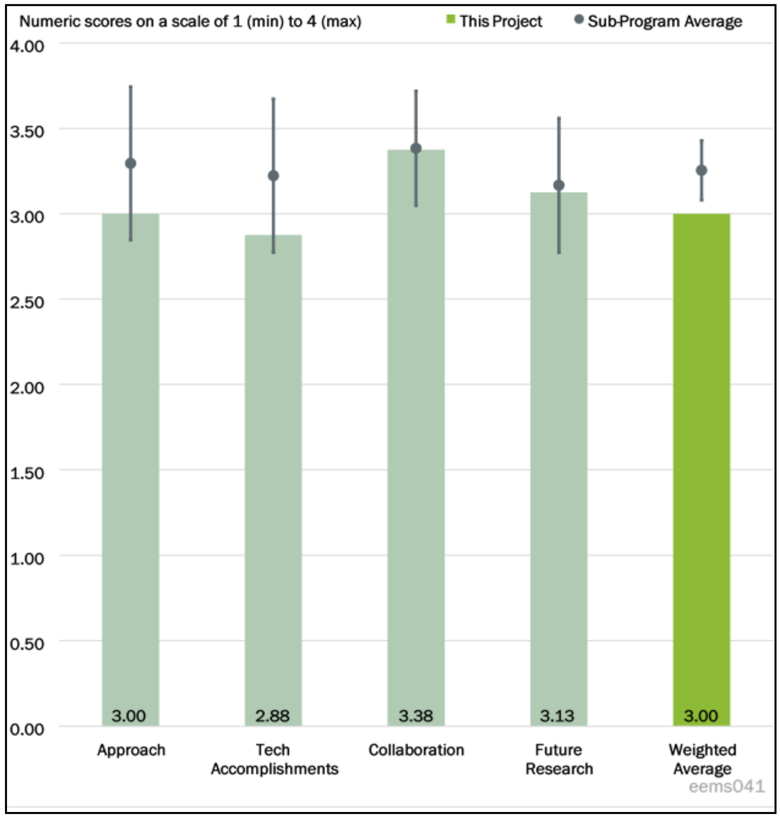


Figure 3-3 - Presentation Number: eems041 Presentation Title: ANL Core Tools-Hardware Principal Investigator: Kevin Stutenberg (Argonne National Laboratory)

Presenter

Kevin Stutenberg, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the approach of creating an advanced mobility technology lab on a four-wheel chassis dynamometer is an excellent foundational step to testing algorithms and control for connected and automated vehicles (CAVs).

Reviewer 2:

Given the constraints imposed by vehicle testing and the degree to which original equipment manufacturer (OEM) vehicle controls are accessible, the reviewer found that the approach taken is very good. The team has developed a good mix of techniques to get the data needed to assess a moving technology that is still at a nascent stage.

Reviewer 3:

The approach was reasonable to this reviewer, who commented that vehicle-in-the-loop (VIL) is necessary for calibrating and validating simulations.

Reviewer 4:

The reviewer indicated that the project is tackling relevant issues related to simulation versus the real world. As the reviewer noted in a prior review, there is a need to generalize findings. The response was insufficient and there remains concern over what this means for real-world data versus specific controlled experimental data and the relationship to system-wide energy impacts.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that work on VIL has been excellent and integral to related EEMS projects. The on-road test data acquisition process has been well done, and results—such as measurement of road load changes due to aerodynamics of platoons—is of great interest. The reviewer further observed good use of open-source solutions.

Reviewer 2:

The reviewer stated that accomplishments are solid and include the integration of direct override and actuator methods for the longitudinal dynamics of 15 experimental vehicles, alignment with the EcoCAR VIL system, use of the SMART 2.0 workflow for controls and model development, integration of open-source solutions (i.e., Simulation of Urban Mobility [SUMO] and Computer-Assisted Related Language Adaptation [CARLA]), integration of microsimulation (i.e., Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks [AIMSUN]) for multi-vehicle traffic, collaborative testing across facilities, and refinement of aerodynamic models.

Reviewer 3:

According to the reviewer, progress is satisfactory considering the delays due to coronavirus disease 2019 (COVID-19).

Reviewer 4:

The reviewer remarked that direct microsimulation testing results show a large difference—34.44%--and questioned if there is really this level of precision. This difference should be viewed as a substantial problem for the results and usability. The differences are likely to increase as more complexity is added with more vehicles. The ANL XIL data appear fitted to the chassis dynamometer results; so, the good match is as expected. How generalizable to the real world are the results and what is the real knowledge? The reviewer commented that aerodynamic results were unclear, better results at a wider gap are antithetical to the intended use of CAVs, and the explanation for not doing smaller gaps was insufficient.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer reported that this work is tied into several other projects and noted excellent collaboration to achieve the results demonstrated.

Reviewer 2:

The reviewer found that this project is foundational to a few other projects, indicating that the project team collaborates and coordinates with the broader community very well.

Reviewer 3:

There appeared to the reviewer to be good collaboration between ANL, EcoCAR, and DOT National Highway Traffic Safety Administration (NHTSA), on this project.

Reviewer 4:

The collaboration appeared to the reviewer to be sufficient to accomplish the work and provide necessary support.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed future research topics are well formulated and include testing methodologies with the VIL environment, incorporation of vehicle connectivity, standardized communication interfaces, driver-in-the-loop experimental methods, expansion of the vehicle fleet with various powertrains, lateral loads modeling, aerodynamic model refinement, vehicle platooning, etc.

Reviewer 2:

According to the reviewer, the proposed MD and HD work, along with electric powertrains, is likely to be high impact.

Reviewer 3:

The reviewer noted that the next steps follow logically from the work done so far.

Reviewer 4:

This reviewer indicated that future work topics seem appropriate but lack explanation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project aims to develop and refine an advanced VIL simulation environment that is targeted at simulating CAVs. This will help develop advanced algorithms and control strategies for efficient transportation systems that use less energy and reduce congestion and accidents.

Reviewer 2:

This reviewer asserted that the project supports the overall DOE objectives. Having VIL for simulations can help validate simulation results and ascertain energy impacts of control strategies.

Reviewer 3:

The reviewer said that vehicle testing and data collection are needed to establish ground truth for many of the simulation studies that are being done as part of EEMS.

Reviewer 4:

The reviewer remarked that the work supports the objective by trying to bring empirical calibration to DOE's models.

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

Reviewer 1:

Resources appeared adequate to the reviewer, given vehicle availability. The team has managed the COVID-19 disruptions of the last year fairly well.

Reviewer 2:

This reviewer commented that work is being accomplished despite COVID-19. The reviewer further explained that technical expertise and equipment needed are part of the project and no obvious gaps exist.

Reviewer 3:

The reviewer noted that the allotted funds of $750,000 for VIL work and $220,000 for aerodynamic work are adequate for the 2021 goals. The project will be completed in September of 2021.

Reviewer 4:

The resources are sufficient, according to the reviewer.

Presentation Number: eems061
Presentation Title: Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility
Principal Investigator: Jiboananda Sanyal (Oak Ridge National Laboratory)

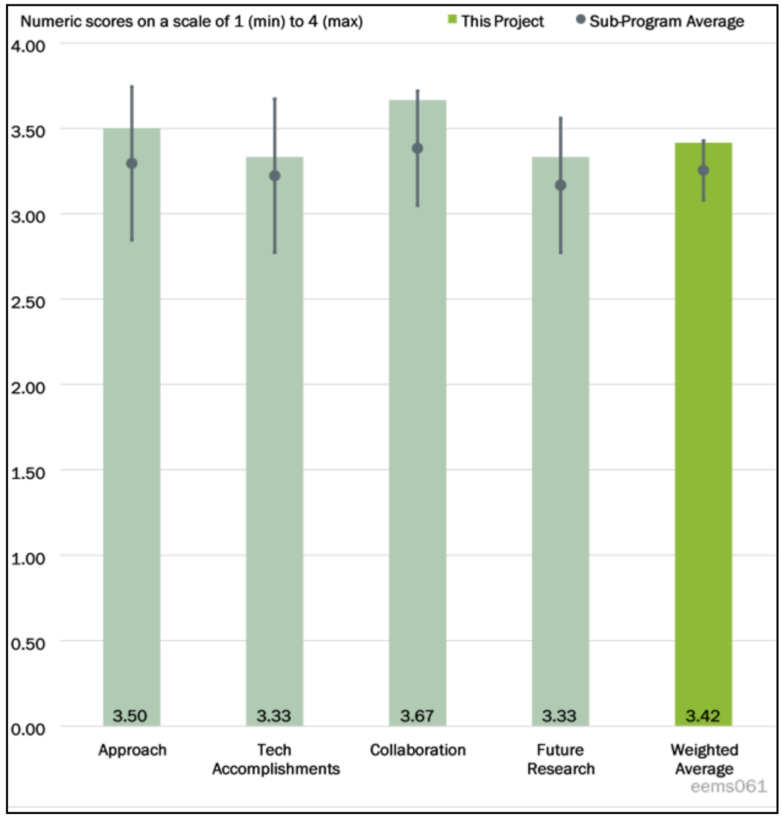


Figure 3-4 - Presentation Number: eems061 Presentation Title: Scaling up the Realtime Data, Simulation and Artificial Intelligence (AI) and Control for Optimizing Regional Mobility Principal Investigator: Jiboananda Sanyal (Oak Ridge National Laboratory)

Presenter

Jiboananda Sanyal, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer believed the project team is very thorough on what goals are being pursued. The time limit is extensive and covers short and long term. The team also has a good group of collaborating partners to draw from all aspects of near real-time data.

Reviewer 2:

The reviewer liked the approach of building a mirror model that will allow control schemes to be theorized. The one thing the reviewer thought about was a question from the previous review on trying to account for drivetrain changes. As propulsion types change with more electric and hybrid drive trains, the typical Mobility Energy Productivity (MEP) modeling metrics could change. Chattanooga is a good place to test this, given the abundance of Nissan LEAFs in the area. The reviewer would have liked to see some discussion on this with regard to how it could affect the approach. The overall approach is good.

Reviewer 3:

The project team has been able to coordinate across multiple jurisdictions and data sources to create a robust digital twin to better understand real-world conditions in and around Chattanooga. This addresses the identified challenges of disparities in gathering transportation data and getting real-time data. In addition, the project team has made strong progress in building a digital twin that addressed computational complexities to get to understanding regional energy savings. The reviewer called the work well done.

The reviewer commented that additional clarity and explanations between the digital twin and how they translate into energy savings would have been helpful. This was covered in the question and answer (Q&A) to some degree, but more information in the overall project description would be helpful, especially as it relates to the identified barriers of understanding energy savings at the regional level. Providing more highlights on the other MEP metrics (i.e., time and cost savings) could also be valuable for scaling up, translating this to other metropolitan areas, and gaining a better understanding of savings overall.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, progress on this project is remarkable considering that the project started with the pandemic and quick adjustments were needed to continue moving forward. The project team has completed milestones on time, including the development of the digital twin along with securing data. The progress to date has built a strong foundation for moving forward, fine tuning specific data (i.e., understanding the movement of HD vehicles), and understanding what types of data are critical for the real-time understanding of the system (i.e., balancing computational capacities). The progress to date has built a strong foundation for achieving other milestones identified over the next year.

Reviewer 2:

The reviewer graded this as excellent, given the pilot test that achieved 16% energy savings, which shows the project has some potential. The fact that this was accomplished shows progress to anchor the larger scale-up. The reviewer realized that tests were conducted in February of 2020 in the last phase, but thought the results point toward a good target and the progress being made.

Reviewer 3:

The best form of progress can be measured in the ability to use the tool. The reviewer stated that the project was able to combine real-time situational awareness combined with modeling and simulation to actually use that information in weak signal light software for energy savings of 18%.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project team has pulled together an impressive list of collaborators. The identified partners are truly impressive and include two state DOTs, research organizations, laboratories, and a local municipality. Coordination between these partners will make this project robust and provide a good template for translating this to other metropolitan areas in the country. This reviewer described the collaboration and coordination as well done.

Reviewer 2:

The reviewer thought the partners in this project were able to supply a lot of data by allowing all aspects of vehicle monitoring through sensors, signals, radar, and even incident reports. More information leads to better conclusions. The reviewer remarked that the DOT was probably the best source of information.

Reviewer 3:

The reviewer liked the fact that there are a lot of partners in supporting data at the city, state, and multi-state level. This will help in any future deployment and acceptance of the technology.

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 state project ended.

Reviewer 1:

The reviewer indicated that the future research proposal moves in the direction of putting into play what has already been learned. The reviewer suggested that the next logical step would be to scale it up and make it available to other regions for trial.

Reviewer 2:

The reviewer noted that there seemed to be an almost implicit modeling approach/objective about modeling existing controls to improve MEP metrics. The reviewer would have liked to see some discussion on using explicit modeling to determine what issues are caused by future stop lights and what controls get implemented at the city and regional level. The reviewer found that a lot of commuter delays are also caused by suburban growth and the addition of new traffic signals going in. Regarding future efforts, it would be interesting to see how this could be added to the modeling to evaluate those types of common changes as development increased in previously undeveloped and unpopulated areas.

Reviewer 3:

The reviewer said that the team's proposed future research and timeline are practical and logical. The identified challenges and barriers are clearly identified and are being addressed by the project team. This may be outside the scope of the project; however, this type of research is timely, and many state and local DOTs would find value in understanding where the weakest and/or most energy intensive parts of their system are located. The reviewer questioned if it would be possible to incorporate other MEP metrics (i.e., time and cost savings) to provide a more holistic picture of the metro study. The reviewer wanted to know what is needed to scale this project to other metropolitan areas and regions. It appeared to this reviewer that the Chattanooga regional area has a variety of data sources and a robust network of sensors. What data and sensors would be necessary to replicate this in other areas around the country to get a robust digital twin? Additionally, the reviewer asked if cybersecurity has been addressed in this project. There is an incredible amount of data, and if expanded, how would these data be secured?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that anytime there is a project to reduce traffic congestion, it is relevant to fuel savings, idle time, pollution, and so on. These issues make it perfect as a DOE project.

Reviewer 2:

The reviewer found that this as an interesting approach to model the control aspects, use data to anchor the model, and then use algorithms to see what can be improved. The reviewer thought that the approach is relevant for the stated objective.

Reviewer 3:

This project is aligned with DOE objectives and goals, according to the reviewer. Seeking to understand energy usage across a region to improve traffic flows to reduce petroleum use, to advance EEMS, and to advance coordination and collaboration across jurisdictions is aligned with VTO and 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 project appeared to be sufficiently funded to achieve the milestones and goals of the project.

Reviewer 2:

The reviewer thought the project team has all the data it needs at its disposal, based on the partners in the project.

Reviewer 3:

The reviewer did not have enough knowledge on the cost and resources needed for this project to really weigh in on this topic. Coding and data aggregation are typically complex, and $4 million seems adequate for the overall scope.

Presentation Number: eems062
Presentation Title: Deep-Learning for Connected and Automated Vehicle (CAV) Development
Principal Investigator: Robert Patton (Oak Ridge National Laboratory)

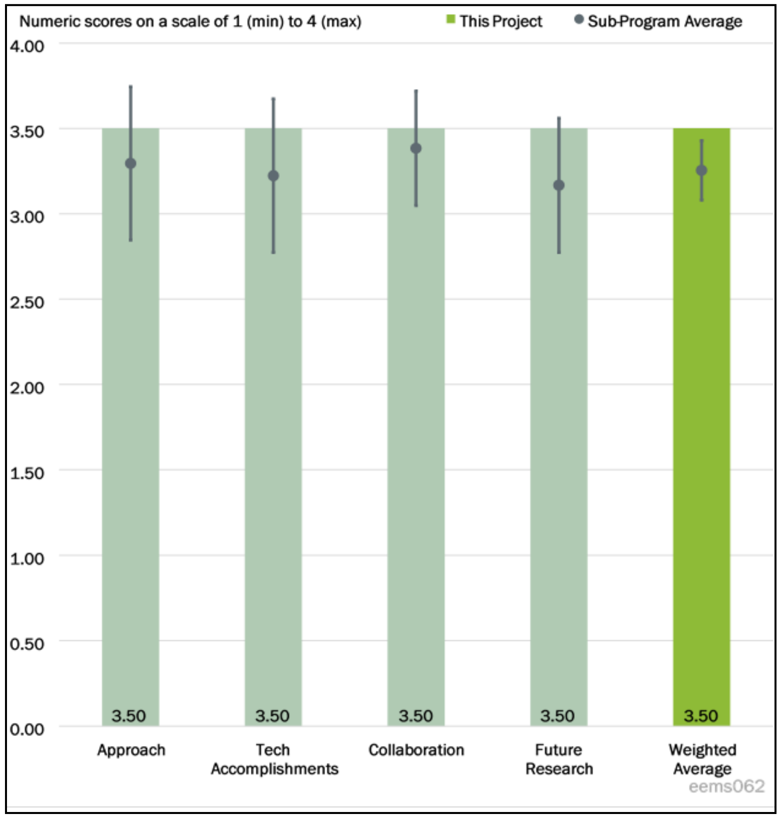


Figure 3-5 - Presentation Number: eems062 Presentation Title: Deep-Learning for Connected and Automated Vehicle (CAV) Development Principal Investigator: Robert Patton (Oak Ridge National Laboratory)

Presenter

Robert Patton, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the project has well defined objectives and an appropriate status. The project team has identified pitfalls and problems and developed ways to understand and deal with them opportunistically.

Reviewer 2:

The reviewer reported that the approach in this project has been to develop high-performance computing (HPC) for CAV perception, control, and communication. The reviewer stated that this is a good complement to current methods that use primarily real-world data collection.

Reviewer 3:

The reviewer referenced the presentation, which noted that "Further exploration of machine learning for energy efficient CAV operation is needed." The reviewer said that the approach is a necessary first step for finding energy impacts but stops short.

Reviewer 4:

The reviewer remarked that the Principal Investigators (PIs)have correctly identified key barriers to broadly applying machine learning (ML) and artificial intelligence (AI) to CAVs. In particular, the PIs have properly identified the proprietary nature of the existing tools and the amount of computational horsepower needed by those tools. The team also points out that most of the effort to date by others has focused on sensing and perception (object recognition in particular) with little or no effort directed to the downstream functions of path planning, actuation, and vehicle-to-anything (V2X). The reviewer believed that the team's approach and goals begin to address those barriers, some of which the team has demonstrated in the progress reported. The reviewer emphasized concerns regarding the limited amount of funding that is available for the project team to apply to the tasks at hand. More specifically, the $4 million listed for FY 2020 and FY 2021 seems to be quite small in comparison to the amounts that have been, and continue to be, directed to similar efforts (some even more narrowly focused) by the likes of Google, General Motors (GM), and other major OEMs, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed solid accomplishments that include synthetic image generation, training AI with synthetic data, evaluation of driving metrics, adversarial testing, reinforcement learning (RL), and fusing neural networks.

Reviewer 2:

According to the reviewer, the project has a clear schedule, objectives, and results thus far.

Reviewer 3:

The reviewer opined that the researchers have developed a metric for how well a car drives, which is not an energy efficiency metric. The energy efficiency metric that would make the most sense is kilowatt (kW) per passenger for a given trip at a given speed.

Reviewer 4:

The reviewer said that the PIs described a wide range of accomplishments toward their goals. Regarding training sets, generation of synthetic image data certainly seems to have significant advantages over real-world image data collection in terms of independently varying aspects of the same scene (i.e., combinations of weather and sun on a given physical landscape) as well as being able to construct corner cases that may be hard or impossible to obtain via real-world collection.

The reviewer emphasized that one key item not addressed was the comparison of training efficacy between using real-world data versus synthetic data. The use of a quantitative evaluation metric for simulated driving performance (in combination with a tiered approach to increasing complexity) was excellent, as is the use of Gremlin for adversarial testing to find and highlight failures and overall problem areas.

The discussion of RL applied to path planning, actuation, and subsequent tracking was well done. The reviewer believed that the value of this approach may be even greater than stated, in that many self-driving car algorithms calculate (simultaneously and in real time) an optimal path in addition to multiple acceptable contingency paths for a given environment. The simulated improvements (i.e., fuel efficiency, travel speeds, vehicle capacity, etc.) from RL in cooperative and infrastructure guided modes (the reviewer assumed this relies heavily on V2X) are impressive. However, the reviewer emphasized that it is not clear how much of the benefit is derived from RL applied to cooperative and infrastructure guided modes versus cooperative and infrastructure guided modes alone (without RL). The reviewer was curious if there can be a simple, preliminary opportunity to confirm one of these results in a real-world demonstration (perhaps as part of Milestone 4 in FY 2021 Quarter [Q] 4).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed clear collaboration between Oak Ridge National Laboratory (ORNL) and the National Renewable Energy Laboratory (NREL) based on the presentation and PDF. There is a natural split in scope and areas of focus for the team members. The linkages and dependencies between the elements are appropriately addressed.

Reviewer 2:

According to the reviewer, there appears to be good collaboration between NREL, ORNL, and GM.

Reviewer 3:

The reviewer noted that each team member is engaged and active in supporting the project.

Reviewer 4:

The reviewer stated that interfacing with the CARLA development team is limited. Solutions for CARLA driving have not been publicly released. It would be beneficial to get more input from the open-source community and increase collaboration with the CARLA developers.

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 state project ended.

Reviewer 1:

The research team presented proposed future research for FY 2021 as a series of research questions—logically grouped by topic area—rather than a research plan. The topics and individual research questions seemed appropriate to the reviewer and are important extensions to the work completed.

Reviewer 2:

The reviewer observed that researchers have developed a tool that can be applied to optimized CAVs for energy. It will be most effective when widely disseminated.

Reviewer 3:

The reviewer said that several good topics were proposed.

Reviewer 4:

The reviewer commented that future plans include energy efficient AI, scaling RL tools for driving simulators, and scaling scenario generation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project attacks the problem of creating better ML algorithms for automated driving, which would lead to more efficient and potentially safer transportation systems.

Reviewer 2:

The reviewer asserted that this project definitively supports DOE objectives. The combined efforts of ORNL and NREL are geared to the following: improving and accelerating the maturation of ML, AI, and RL techniques needed for CAVs to become a meaningful part of the vehicle fleet; and accelerating the potential efficiency gains (increased overall vehicle fleet fuel economy, reduced carbon dioxide [CO_2] emissions, etc.) that can be realized with sufficiently high CAV penetration.

Reviewer 3:

The driving metric is a prerequisite for measuring energy efficiency of CAVs, according to this reviewer.

Reviewer 4:

The reviewer commented that it is interesting to correlate directly, but it is very important for the vehicles to know where they are and not create any traffic disturbances in the AV world. Even though the quantitative analysis is very difficult, it is known that there will be a positive energy 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 observed that the project is on track and will soon be completed with the allotted funding of $1.8 million during FY 2021.

Reviewer 2:

There seems to be enough staff and knowledge, according to the reviewer.

Reviewer 3:

The reviewer's comment regarding insufficient resources is specific to the amount of money being applied (i.e., $4 million for FY 2020 and FY 2021) toward achievement of broadly applicable results that can be applied and leveraged to speed CAV development and implementation. The reviewer emphasized that the comment does not reflect on the researchers, ORNL, or NREL.

Reviewer 4:

Resources appeared adequate to the reviewer, though achieving an energy metric is problematic. It is unfortunate that GM did not contribute financially to the project, which may have provided GM with the motivation for better integration with CARLA.

Presentation Number: eems066
Presentation Title: Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing
Principal Investigator: Lauren Spath-Luhring (National Renewable Energy Laboratory)

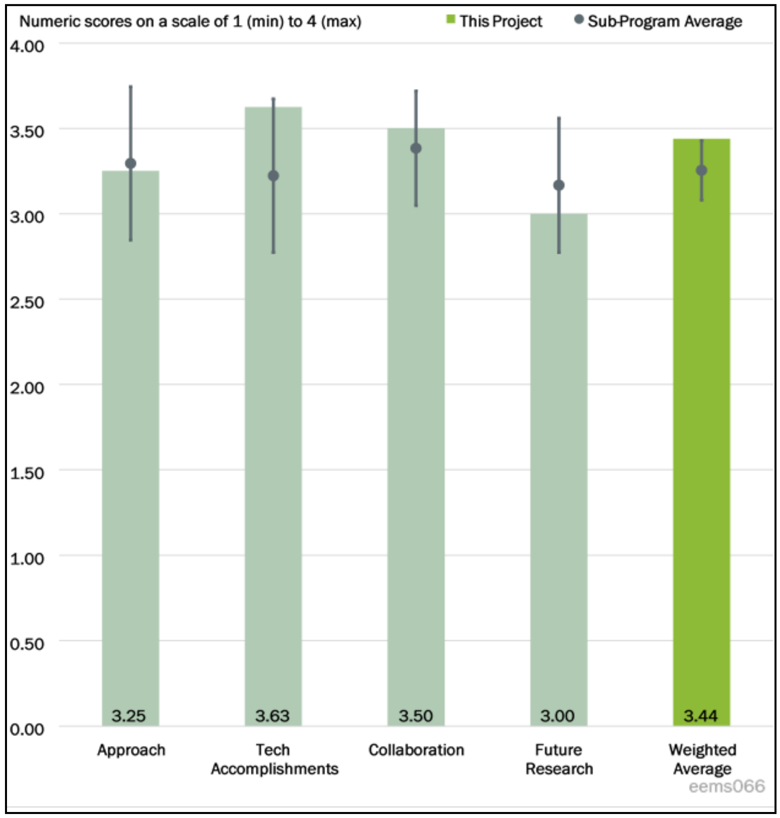


Figure 3-6 - Presentation Number: eems066 Presentation Title: Livewire Data Platform-A Solution for Energy Efficient Mobility Systems (EEMS) Data Sharing Principal Investigator: Lauren Spath-Luhring (National Renewable Energy Laboratory)

Presenter

Lauren Spath-Luhring, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer appreciated the project approach and responsiveness of the PI and core team to build a platform and system that could be used for sharing mobility data. The reviewer explained that the Livewire platform builds on the effectiveness of existing data-sharing platforms, which is appreciated and needed for EEMS research. The attention to detail in providing factor authentication was also an example of responsiveness to owner and user need. This will give leads and owners of the data assurances of who has access, especially for sensitive and proprietary data.

The reviewer described this type of data platform as timely because many cities, metropolitan planning organizations (MPOs), state DOTs, and others are seeking to better implement energy efficiency mobility systems and services. This type of data platform could allow for better cross collaboration with these entities, and they work on projects and modeling. This addresses a barrier to access to data and the owners of those data.

Reviewer 2:

The reviewer gave this project good marks for approach. The project team recently convened the EEMS Data Working Group to identify priorities, and the reviewer was pleasantly surprised to see that although this is a recent accomplishment, the team's remaining milestones on Slide 4 have space for the Livewire development team to develop some of the priorities identified by the Livewire Data Working Group (the reviewer wished the team would have given more information on exactly which priorities are being considered to tackle). Additionally, the PIs did a great job of being responsive to last year's AMR reviewers' feedback (particularly with respect to metrics). The reviewer did not completely see how the team's remaining milestones are going to help overcome the two barriers identified on Slide 2.

Reviewer 3:

The reviewer commented that the approach used by the team is to leverage prior successful data platforms and build a new platform that is easy to use and versatile in terms of allowing secure access, data quality measures, and broad collaboration.

Reviewer 4:

The overall approach to this project is well designed, especially to address the technical challenges, and to a lesser degree the people challenges inhibiting sharing of data. The reviewer asserted that the cultural, people, and organizational challenges are the toughest to overcome and, in the future, will require further sustained attention and diligence to truly surmount.

Leveraging existing platforms (e.g., a2e.energy.gov, api.data.gov, and the application performance interface [API] Umbrella) was the right approach, according to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the Livewire project appeared to have achieved all targeted milestones to date this year and is on track to achieve the remaining ones in the balance of FY 2021. Overall, a significant number of technical accomplishments have been achieved, including updated project and dataset pages for enhanced utility and user experience; development of detailed metadata and security; the establishment of role-based member engagement including a tiered role system to manage, upload, and download data; platform development including multi-factor authentication (MFA); implementation of a data quality assessment process; and establishment of the Livewire Data Working Group. Most notably, the reviewer opined that the strongest accomplishments and potentially most influential over the long-term are the establishment of the EEMS Data Working Group; development of new tools to facilitate the manipulation, analysis, and accessibility of data; and new security measures including implementation of a threat-based analysis of the platform.

Reviewer 2:

This project has made significant progress over the last year, especially with respect to improving metrics on project and dataset pages and adding role-based member management. The reviewer was particularly excited about the role-based member management and the opportunity that it creates by opening Livewire to .gov, .mil, and .edu email addresses.

Reviewer 3:

The reviewer noted that Core services are in place such as storage, security, access management, metrics, better search tools, and data visibility. Usage growth is at a healthy level. Project and dataset pages are updated. According to the reviewer, progress has been made on the development of tools to create detailed metadata and to secure sensitive datasets. Data quality assessment metrics are in place, and a broad-based working group has been established.

Reviewer 4:

The reviewer commented that the Livewire platform is making progress to completion. Further, the project appeared to be on schedule.

The reviewer appreciated the team's approach for making a data platform that focused on user experience and overall utility. The metrics and overview page is extremely helpful and includes the overview of the metadata.

The reviewer asked whether Livewire is available to communicate with the other data platforms—Atmosphere to Electrons and the API Umbrella. While the reviewer realized that all the data may not be crosscutting for the databases, an understanding of other data sets may be helpful for users, modelers, and researchers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project had an impressive list of collaborators from across DOE and outside organizations. The reviewer remarked that it was great to see a mix of non-governmental organizations (NGOs), cities, research institutions, and industry represented as participating organizations in the database. In addition, the Livewire Data Working Group's efforts to identify and prioritize data was helpful and appreciated.

The reviewer was unclear who was represented in the Livewire Data Working Group from the project slide deck. It would be helpful to detail the participants in this group.

Reviewer 2:

There is clearly great coordination across the internal project team itself—Idaho National Laboratory (INL), NREL, and Pacific Northwest National Laboratory (PNNL). But, perhaps even more noteworthy is the way that the core project team has involved EEMS and the Smart Mobility Consortium to ensure that Livewire is able to meet all the project's needs. The reviewer agreed with the project team on Slide 18 and thought that there are opportunities with other agencies like DOT and the U.S. Environmental Protection Agency (EPA) to expand the user group of Livewire and potentially diversify the datasets available on Livewire. For example, the project team mentions barriers that have caused difficulty in sourcing empirical real-world data applicable to new mobility technologies like connectivity and automation, but DOT currently has several test track and field projects collecting data about CAVs that might be able to be shared on Livewire (or linked to Livewire through hosting on *data.transportation.gov* or the Intelligent Transportation Systems (ITS) DataHub).

Reviewer 3:

Throughout the life of this project, collaboration and coordination appeared strong to this reviewer. The three national laboratories involved (NREL, INL, and PNNL) have all significantly contributed, utilizing their unique positions and strengths, and more recently Lawrence Berkeley National Laboratory (LBNL) and ORNL are adding their expertise and perspectives through the Livewire Data Working Group.

Moving forward, the reviewer suggested that it would be good to consider expanding participation within the Livewire Data Working Group to other entities. This could serve to provide new, non-laboratory and government perspectives on needs and requirements, as well as greasing the skids to expand the universe of potential data contributors to and users of the Livewire system.

Reviewer 4:

There is well-established collaboration within the project team between INL, NREL, and PNNL, as well as connections to EEMS, SMART, and Technology Integration (TI).

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 state project ended.

Reviewer 1:

The reviewer hoped that the project team pursues opening Livewire to .edu email addresses; it is not on the FY 2021 quarterly milestones but was mentioned on Slide 18 under "Proposed Future Research". The reviewer thought Livewire data would be a huge resource for Doctor of Philosophy (PhD) and master's students.

Reviewer 2:

Future work will require scaling up for larger and diverse groups. The reviewer opined that that may be challenging from a technology infrastructure, as well as a funding, perspective.

Reviewer 3:

The future research and next steps are well thought out. The reviewer appreciated the issue and topic areas that the Livewire team is considering and how to include additional users. It certainly seems that interdepartmental (DOT and EPA) collaboration (and potentially academic, state, and local government participation) may be a solution for the scaling up and longevity challenges for funding and demonstration of the importance of a data platform like Livewire.

How does DOE plan on marketing the platform in order to get more subscribers and data? Will this be marketed to practitioners (state and local DOTs, other federal departments, research institutions, etc.)?

For growing the scope, how does the Livewire team plan on training new users to ensure the platform is being used appropriately and that the data, once entered, are standardized (especially for use by and for local governments, transit organizations, and state governments)? Additionally, would Livewire be seeking to solicit input from these groups to help strengthen data that are housed on Livewire?

If proprietary data are downloaded, do users need to execute non-disclosure agreements (NDAs) for those data?

Reviewer 4:

The proposed future research indicates an intention to expand beyond the EEMS community to users from the .gov, .mil, and .edu domains. Additionally, the proposal is to look at other programs within DOE that have data-sharing and preservation needs. This seemed like a good approach to the reviewer, as well as considering interagency collaboration where possible with entities such as DOE and EPA. Specifically, what would be the best methods to reach out and understand the potential needs and requirements of these groups? Would it potentially be beneficial to include some entities from these communities in the Livewire Data Working Group and/or potentially survey them to gauge potential interest, needs, and requirements?

Future proposed activities include the evolution of platform capabilities, such as standardizing data across projects, enabling querying and filtering data before downloading, and offering the ability to download subsets of data. The reviewer opined that these options would appear to benefit users' ability to manipulate and analyze data, which could help incentivize greater Livewire participation.

The reviewer also asked if there are specific objective metrics for Livewire usage in the near future (in the next year or two).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer observed that the Livewire project does support overall DOE objectives to reduce energy consumption, reduce GHG emissions, and improve transportation mobility by providing a system to discover, share, and preserve transportation and mobility data. This project serves to advance transportation R&D and ultimately deployment- of advanced transportation vehicles.

Reviewer 2:

The reviewer noted that tools and platforms such as Livewire will allow broad-based collaboration and data sharing, which will accelerate the development of energy efficient transportation systems.

Reviewer 3:

This project promotes scientific research and technological innovation by creating a data platform for sharing up to date and innovative mobility data with modelers, researchers, and practitioners. According to the reviewer, this "one stop shop" allows practitioners to incorporate data into real-world projects and allows for creators of the data to collaborate to strengthen and improve on existing data.

Reviewer 4:

The reviewer commented that this project supports DOE objectives and more generally supports wider government initiatives to promote government transparency and private sector innovation (especially if Livewire is opened up beyond .gov email addresses through the role-based structure the team is currently developing and implementing).

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

Reviewer 1:

The resources to complete the building and milestones of the platform are sufficient. There should be conversations about funding this project over the long term, but the reviewer believed those discussions are outside the scope of this project.

Reviewer 2:

The reviewer stated that $3.25 million for 3 years appears to be an adequate level of funding, given the scope of the work.

Reviewer 3:

Resources provided for this project to date have proven to be sufficient to achieve targeted objectives, according to the reviewer.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: eems067
Presentation Title: Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies
Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Presenter

Dean Deter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

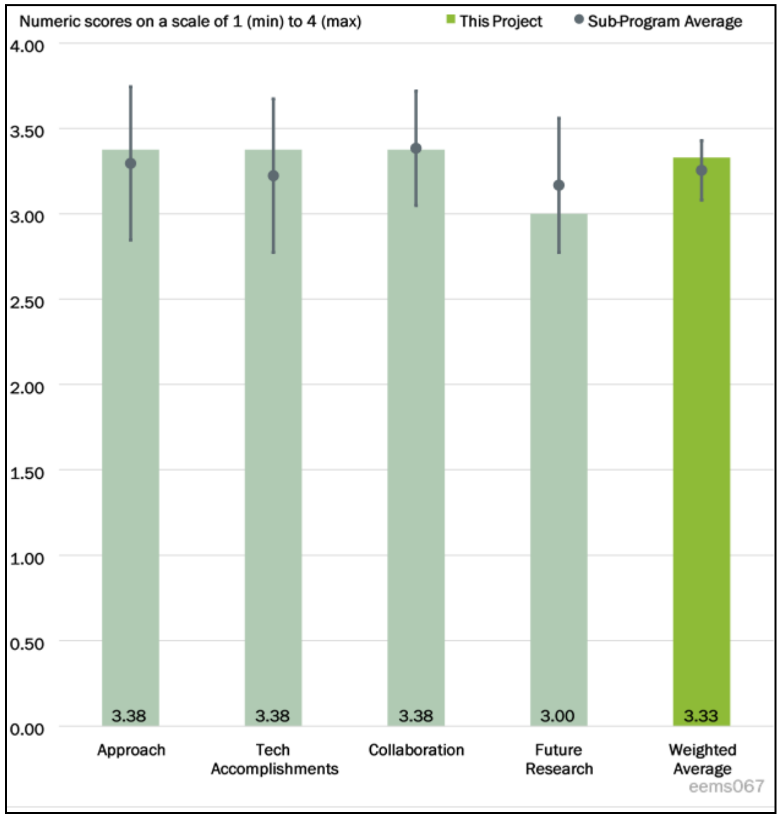


Figure 3-7 - Presentation Number: eems067 Presentation Title: Virtual and Physical Proving Ground for Development and Validation of Future Mobility Technologies Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project is following along with the approach already established in the past. The PIs also seem to have adequately addressed reviewer feedback from the previous year.

Reviewer 2:

The approach was realistic and appropriate, although large in scope (which was acknowledged by the presenter). The reviewer wanted to know if the approach can be translated to MD and HD vehicles and if the Connected and Automated Vehicle Environment (CAVE) Laboratory allows for translations to MD and HD.

Reviewer 3:

The reviewer commented that the ORNL team has done a great job of identifying a need and addressing it.

Reviewer 4:

With the leveraging of ORNL's capability and the support from partners, the project approach (divided into two tasks) made sense to the reviewer. The reviewer believed that the project team would address most of the technical barriers, especially on Task 1. Regarding Task 2, how to address the V2X communication modeling in a realistic manner with such a virtual-physical testbed was not so clear to the reviewer. Collecting real-world data from the experiments at the American Center for Mobility (ACM) definitely helps mitigate this concern, but how to generalize the communication model built on this dataset to the other sites or scenarios would need further investigation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the accomplishments of the project are on target, even considering technical and mechanical challenges with the testing equipment.

Reviewer 2:

This reviewer indicated that the project seemed to be progressing well, per the project plan.

Reviewer 3:

The reviewer stated that the technical accomplishments and progress are reasonable, considering the potential interruption by COVID-19. The laboratory equipment failure could be expected, and a backup solution or risk mitigation techniques could be considered and deployed to ensure the progress.

Reviewer 4:

This reviewer remarked that there is good progress in integrating the various software. It may, perhaps, be worthwhile to talk with various software vendors, researchers overseas, and perhaps OEM labs as well to have them share what non-proprietary information they can share on how they intend to perform the same tasks laid out in the scope of this project, because it does seem that a process such as the one this project is developing would be of great interest to OEMs working on advanced driver-assisted systems (ADAS) and autonomous vehicles (AVs).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration and coordination across the project teams is good. The reviewer was curious if there are other laboratories that could help support the work related to CAV technologies and testing. This does seem like an area of cross-laboratory collaboration that could be explored.

Reviewer 2:

The partners were properly identified, where the physical environment facilitator (ACM) and virtual facilitators (dSPACE and CARLA) are involved with the support from both hardware (e.g., Cummins and dSPACE) and software (e.g., dSPACE and CARLA). The reviewer expected that the project would have fruitful results with the collaboration and coordination of these strong partners.

Reviewer 3:

Collaboration between the project team seemed efficient and effective to this reviewer.

Reviewer 4:

This reviewer suggested that the project could benefit from collaboration with an automotive OEM that is working on ADAS/AVs. It would help define the needs better and would ensure project success. Perhaps the team has already reached out to OEMs and was unsuccessful in enlisting their involvement.

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 state project ended.

Reviewer 1:

The project team has identified a clear pathway for continued research throughout 2021, according to the reviewer.

Reviewer 2:

The reviewer indicated that it would be nice to tie the specific future tasks (virtual physical proving ground [VPPG] proof of concept, etc.) to some higher-level goals and outcomes that would advance the industry's pool of knowledge.

Reviewer 3:

Considering that the project will end in another 3 months, the reviewer commented that proposed future research efforts may be a bit challenging to complete. The reviewer suggested focusing more on the V2X wireless communications part, as this part seems to be missing or at least not well addressed. The reviewer acknowledged this portion is very challenging for such a virtual-physical platform, but it is a key enabler for cooperation among CAVs and boosting the system efficiency. Besides the V2X wireless communications, another important part is the human-in-the-loop simulation. The project team touches on this topic a bit but not too much. To the reviewer, future research should highlight this area as it is of pragmatic value within the foreseeable time span and involved with more interesting research questions.

Reviewer 4:

The reviewer referenced prior comments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project definitely supports the overall DOE objectives. More in-depth research on CAVs requires more advanced modeling and evaluation tools. This has been an emerging trend. Thanks to the advances in computing and communication technologies, digital twins or physical-virtual environments are considered as a viable solution to decision-support processes in a variety of areas, including transportation and energy. The reviewer asserted that this project is timely and results, if successful, should be very helpful for VTO's blueprint.

Reviewer 2:

The reviewer remarked that this project is aligned with EEMS and DOE objectives by creating a framework to evaluate vehicle level testing for V2X technologies.

Reviewer 3:

Research conducted in the project is certainly relevant to CAVs, which in turn are one of the focus areas for DOE.

Reviewer 4:

The reviewer stated that this project would help with validating the various modeling tools that form part of the SMART Mobility workflow.

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 project funds are sufficient for the scope of this project.

Reviewer 2:

From this reviewer's perspective, the project seemed to be doing well for the recourses allocated.

Reviewer 3:

Sufficient resources were observed by this reviewer.

Reviewer 4:

The reviewer believed the resources are sufficient for the project to achieve its stated milestones, although the breakout of COVID-19 may bring about some hiccups.

Presentation Number: eems069
Presentation Title: Next Generation Intelligent Traffic Signals for the Multimodal, Shared, and Automated Future
Principal Investigator: Andrew Powch (Xtelligent)

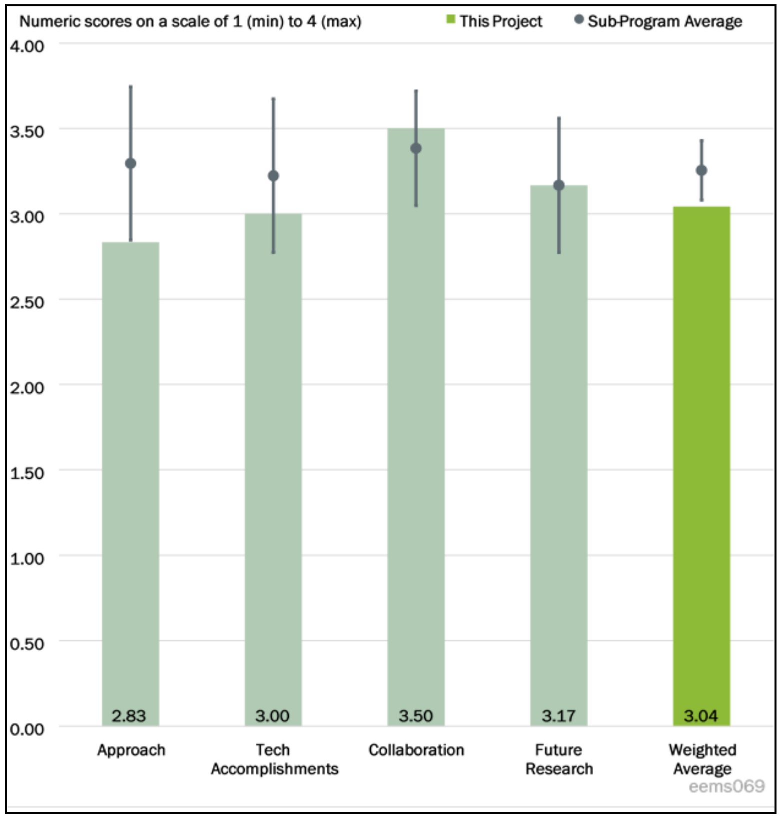


Figure 3-8 - Presentation Number: eems069 Presentation Title: Next Generation Intelligent Traffic Signals for the Multimodal, Shared, and Automated Future Principal Investigator: Andrew Powch (Xtelligent)

Presenter

Andrew Powch, Xtelligent

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that one of the main barriers was the impact of COVID-19 and repercussions this had on the work (from its impact on data to partner timelines). In spite of this challenge, the work seems to have been conducted and advanced thoughtfully (with, for example, a 5-day data baseline, hourly data comparisons, and net flush-time comparisons to compare and evaluate the impact of different control systems on queue length, normalizing for differences in traffic volume). The reviewer observed that the data updates recognize the results and associated limitations (for example, low penetration or difficulty aggregating certain types of data), which put findings in context.

Reviewer 2:

Although the approach seems novel, the reviewer noted that the lack of market penetration seems to be a weakness in this approach. The project change to incorporate physical sensor data to help overcome this issue points to this problem.

Reviewer 3:

The reviewer stated that the approach of augmenting infrastructure sensors with streaming and connected vehicle sensors is good. This provides information to the proportionally fair (PF) adaptive traffic control system (ATCS) along the entire road and not just where the physical sensors are deployed.

According to the reviewer, the team's approach to work with the National Transportation Communications for ITS Protocol (NTCIP) Management Information Base (MIB) is a strength even though the different existing traffic signal controller manufacturers have interpreted and implemented the NTCIP MIB in different ways.

The approach for achieving Objective 4 relies on the ability to capture enough streaming and connected vehicle data to support the traffic signal control algorithms without relying on physical and infrastructure-based sensor data. However, there was not enough market penetration of vehicle data sources and/or availability and access to this type of data to achieve Objective 4. This may have been COVID-19 related, but the reviewer commented that there is not a new or updated approach to overcome this shortcoming for Objective 4.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that this project is slated to end August of 2021. Though Objective 4 is not possible at this time and the project faced delays, the impacts of COVID-19 were far outside the control of this project. For example, the project team had to wait for the COVID-19-related reductions in traffic volume to lesson before researchers could test and establish a meaningful baseline. Given the setbacks presented by COVID-19, the reviewer thought that the team did an excellent job at advancing the work in a reasonable way in the manner possible.

Reviewer 2:

This reviewer noted that the team's baseline testing was impacted by COVID-19 and light traffic volumes. The participating agencies even reverted their signal timing plans to run in an uncoordinated "free" mode. This exaggerated the improvement to the baseline of the PF ATCS control. When traffic began to return to normal, the team was able to work with the participating agencies to implement a more normal time-of-day control so that a more robust baseline comparison could be made. The reviewer remarked that this accomplishment demonstrates the team's adaptability and strong working relationship with local traffic control agencies. Additionally, a user interface to the PF ATCS system was developed outside of the grant funding, which may improve commercialization prospects.

On the negative side, the reviewer indicated that the team was unable to obtain adequate location data services to test the traffic control system using connected vehicle data only. COVID-19 impacted the willingness of data providers to participate in the project.

Reviewer 3:

Once again, the lack of market penetration seems to hold back the technical accomplishments and progress. Given the unfortunate impacts caused by the timing with COVID-19, the reviewer suggested that extending the period of performance might be something to consider if a strong commitment from some OEMs can be achieved for data streams.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project pulls in a variety of partners. Based on project progress and achievements thus far, particularly given the challenges presented over the past year, the coordination seemed solid to the reviewer.

Reviewer 2:

The reviewer commented that there is good collaboration with the city agencies where the PF ATCS is being implemented. Two sites have currently deployed the PF ATCS traffic control system, and a third is planning to start soon.

Reviewer 3:

The reviewer liked the diversity of locations and partners in the project. Having those California urban location areas in combination is important.

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 state project ended.

Reviewer 1:

According to the reviewer, the project articulates the current progress and barriers, as well as identifies areas for potential future follow-up. For example, streaming location data integration was notably impacted by COVID-19. Xtelligent recognizes that they will not be able to test the full integration of these data within the project period of performance but remains committed to pursuing this as location data become more readily available.

Reviewer 2:

The reviewer thought that the project evolution to incorporate some physical sensors is good. In the reviewer's opinion, the market timing for the onboard OEM data is still just a little bit early. The reviewer would have liked to see if some specific vehicles could be instrumented so they can be tracked through the physical sensors and then compared to the OEM EV data. That would provide a much clearer picture and validation of the OEM data for modeling purposes.

Reviewer 3:

It was not clear to the reviewer how ANL is approaching the evaluation of the pilot. Will the lab solely base the analyses on the data collected during the pilot deployments, or will the lab also be using data collected in the pilot deployments to develop better inputs and parameters for a simulation-based analysis? A high-level description of the ANL evaluation approach would be beneficial.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports DOE objectives by incorporating new sources of data into traffic signal control systems to make them more responsive to current traffic demand and reduce energy usage at intersections and along corridors. And, by designing the PF ATCS system to be low cost, the goal is to make it widely deployable.

Reviewer 2:

This project is exploring ways to improve the energy productivity of the overall transportation system and increase the affordability of transportation systems by avoiding installation of costly physical sensor infrastructure. As increasing mobility energy productivity and building "an affordable, efficient, safe, and accessible transportation future" is the mission and vision of EEMS, the reviewer asserted that this work supports DOE objectives.

Reviewer 3:

The reviewer responded affirmatively and felt that this is a novel approach in trying to use a new data platform that could be of value, especially for those areas and regions that are low on physical sensors. Given COVID-19, the timing for this project seemed early to the reviewer and would probably have a better chance when connected vehicle (CV) data become more commonplace.

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

Reviewer 1:

While more time and resources could help to further gather data and better capture associated real-world complexity, the reviewer stated that overall resources seemed to be sufficient to provide value, COVID-19 constraints aside.

Reviewer 2:

Given where this is, if the period of performance were extended to pick up non-COVID-19 impacted data, the reviewer stated that more resources would probably be necessary.

Reviewer 3:

Resources are sufficient to conduct this current pilot. However, the scope of the pilot had to be reduced due to lack of access and availability of streaming data. If this is something that could be overcome by additional funding, the reviewer suggested that it could be considered.

Presentation Number: eems082
Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation
Principal Investigator: Reuben Sarkar (American Center for Mobility)

Presenter

Reuben Sarkar, American Center for Mobility

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

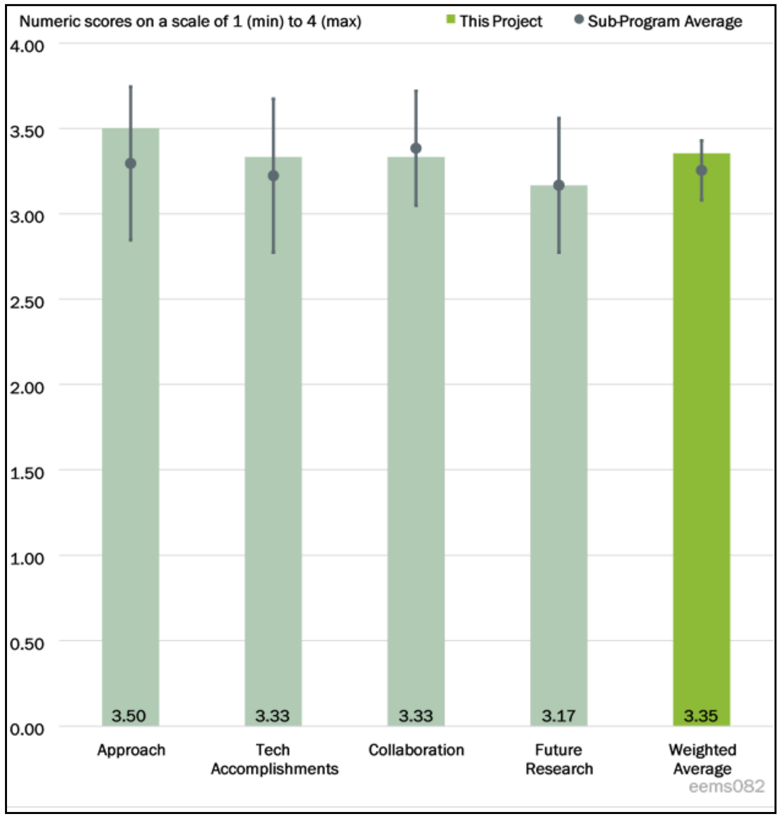


Figure 3-9 - Presentation Number: eems082 Presentation Title: Validation of Connected and Automated Mobility System Modeling and Simulation Principal Investigator: Reuben Sarkar (American Center for Mobility)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is well thought out, according to the reviewer. It involves preparing lab algorithms for implementing in vehicles, building vehicles and infrastructure, testing vehicles with lab algorithms, and comparing against simulation results.

Reviewer 2:

It appeared to this reviewer that great care has been taken to achieve statistical validity; all the data have been recorded to ensure that a complete data set is available. Having been a user of data that have been acquired on various road trips, the reviewer appreciated how hard it is to have a set of data that can be used for future projects as well. The data show excellent repeatability, which is critical when testing and comparing short-duration driving scenarios with a real vehicle on roads rather than a dynamometer.

Reviewer 3:

The project has a strong approach to improving models through the incorporation of physical testing results. For the approach, the reviewer asked the project team to please clarify what the human driver model for speed harmonization is representing. Is this based on a project engineer who is trying to match the same speed profiles as the controlled vehicle, or will the team be using test subjects to try to match the speed profiles? This reviewer additionally asked whether the speed commands to the human driver will be transmitted and communicated via display or audio command in the vehicle, or whether the speed profile will be given to the human driver at the start of the test. Also related to approach, will dedicated short-range communication (DSRC) be the sole communications technology that will be tested on the test track for the duration of the project, or will the approach include testing of cellular vehicle-to-anything (C-V2X) technology?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Accomplishments to date include automated vehicle controls and instrumentation, baselining, lab model integration, implementation of lab controllers, testing, and data generation. The reviewer said that the accomplishments are very impressive.

Reviewer 2:

The project was granted a time extension due to delays caused by COVID-19 restrictions. Given this, it appeared to the reviewer that the project team is making very good progress toward the project goals.

Reviewer 3:

Good progress, overall, was noted by this reviewer. Understanding the network latency and delay is an important aspect of the project. The investigators state that network support for real time control is feasible but may be affected by traffic density. The reviewer asked whether there is a level of traffic beyond which this becomes infeasible. Additionally, are the three cases listed—speed harmonization, merging, intersections and eco-driving—the only scenarios being investigated? If so, on what basis were these chosen? It appeared to the reviewer that other cases may be considered in the future.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer emphasized that there appears to be excellent collaboration across a large team, including ACM, Michigan Technological University (Michigan Tech), ORNL, ANL, and NREL.

Reviewer 2:

The reviewer found that good project collaboration is evident by the slide on "Vehicle Testing Overview" showing ACM, Michigan Tech, ORNL, and ANL components being incorporated and tested. Weekly meetings of the project team also serve a collaboration function.

Reviewer 3:

Good collaboration between academia, national laboratories, and ACM was highlighted by this reviewer. California Partners for Advanced Transportation Technology (PATH) is listed as a collaborator, but its role/responsibility 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed work plan is sound. Future work includes an experimental study of merging, intersections, and eco-driving. Beyond that, the reviewer observed that the workplan includes experimentation on public smart roadways, dynamic wireless transfer, congestion studies, etc. The reviewer asserted that this is a sound plan and suggested that it would be a good idea to compare data and results with Ohio State University's study on similar topics (energy savings from eco-driving, platooning, etc.).

Reviewer 2:

The reviewer stated that extension to include a variety of use cases would add value to the project. Also, including extreme weather conditions—snow, heavy rain (which is becoming more common)—would be a good extension as well. Finally, the reviewer further recommended that evaluating network performance under stress such as very heavy traffic, emergency situations, etc., would be helpful as well.

Reviewer 3:

The proposed future research meets the objectives of the project and appears to be reasonable. However, from the presentation it was not clear to the reviewer whether any simulation studies will be conducted using the improved models to assess the potential energy savings of speed harmonization, merging, and eco-driving on a corridor, arterial, or some other highway network segment. Is this part of the future research plans?

In Budget Period 2, the reviewer wanted to know if testing of eco-driving using a single vehicle traveling through a traffic signalized road will be conducted without any other vehicles present. If so, does Budget Period 3 include adding other vehicles to the eco-driving scenario so that the equipped vehicle must consider them in its speed profile?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project is very relevant to the goal of developing improved models to assess the energy impacts of CAV technology.

Reviewer 2:

The reviewer stated that the topic under investigation will provide algorithms and strategies to reduce energy use and enable more efficient transportation.

Reviewer 3:

The reviewer indicated that this project helps understand the real-world energy consumption benefit of connectivity and autonomous driving, supporting the 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 allotted budget of $7.6 million over 2½ years for this type of software, hardware, and vehicle project involving multiple collaboration and partners seemed reasonable to the reviewer.

Reviewer 2:

The reviewer commented that resources appeared sufficient to achieve the stated milestones.

Reviewer 3:

This reviewer asserted that resources are sufficient.

Presentation Number: eems083
Presentation Title: CIRCLES: Congestion Impact Reduction via CAV-in-the-Loop Lagrangian Energy Smoothing
Principal Investigator: Alexandre Bayen (University of California at Berkeley)

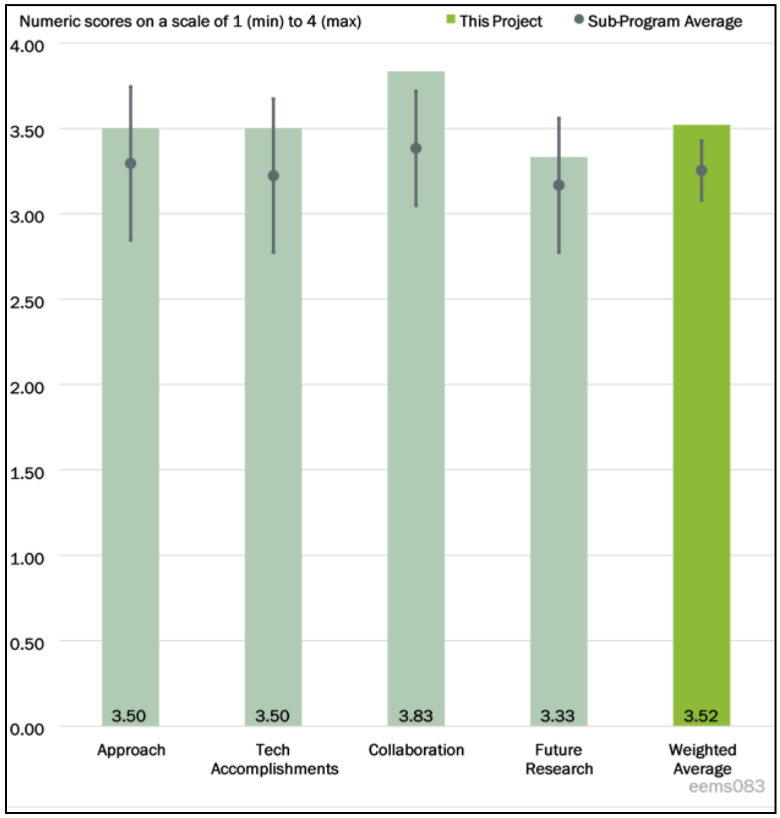


Figure 3-10 - Presentation Number: eems083 Presentation Title: CIRCLES: Congestion Impact Reduction via CAV-in-the-Loop Lagrangian Energy Smoothing Principal Investigator: Alexandre Bayen (University of California at Berkeley)

Presenter

Alexandre Bayen, University of California at Berkeley

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found this to be a well-designed experiment with clear schedule and deliverables.

Reviewer 2:

The reviewer remarked that the approach addresses a key barrier to accurately measuring the potential for system-wide energy benefits of CAVs in the traffic stream. Typically, these types of benefits are measured with models, but this project is attempting to use a large number of vehicles (e.g., 100) in the traffic stream to directly measure the trajectories of all vehicles using pole-mounted video capture of all vehicles traveling on the highway.

Related to the approach, the reviewer asked whether the team has developed the approach for processing and cleaning the vehicle trajectory data. Initial trajectory data generated from video capture typically require “cleaning” to remove errors that result in unrealistic trajectories. Given the size of the proposed data both in terms of length of the segment and the volume of trajectories, this “cleaning” process will be very extensive.

Reviewer 3:

The work seemed to the reviewer to have been thoughtfully designed, including field tests of multiple scenarios (evaluating, for instance, the cumulative effect of traffic smoothing down the roadway and measuring the effect of adjacent lanes smoothing traffic). During the presentation, the reviewer believed it was also mentioned that the team is working with approximately 10 vehicle classes. Remaining challenges and barriers were addressed later in the presentation as well. As a minor note regarding slide and presentation design, a couple of the color-coded schemes—such as on the "Components of the Approach" and the first "Technical Accomplishments and Progress" slide—may be hard to read and somewhat inaccessible to individuals with red and green color blindness. The reviewer suggested avoiding use of these colors as differentiators in slide visuals.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project started at the beginning of 2020 and is scheduled to end at the end of next year. At 55% complete, the project team appears to have largely stayed on track with their timeline thus far. The presentation tracked goals and respective progress, as well as also laying out the next steps for advancing the work (for example, further model validation, testing, fine-tuning, etc.). The reviewer found the team's progress to be particularly notable, given the degree to which the past year has been potentially disruptive to work and research.

Reviewer 2:

The team has been making progress in all aspects of the project and is planning to execute small- and medium-scale field tests in the summer of 2021. According to the reviewer, these results and lessons learned from the smaller field tests will be invaluable to the team's continued progress toward the 2022 large-scale field test.

Reviewer 3:

The reviewer indicated that there is still quite a bit of work required on the corridor and experiment itself.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer explained that this project pulls in a variety of partners (including various universities, as well as a representative from government and industry). The roles seemed well delegated and have resulted in collaborative work that is on track (which is particularly notable given unexpected challenges since early 2020).

Reviewer 2:

The reviewer commented that the team's collaboration is strong, as evidenced by the accomplishments to date in all areas of the project scope.

Reviewer 3:

The reviewer noted that all partners are involved, and their roles are 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer reported that the project has outlined proposed tasks delegated to FY 2021 and FY 2022, respectively (such as first executing small-scale and then medium-scale field tests, followed by a 100-CAV demonstration in 2022 and evaluating findings). The plan seemed to have a clearly planned, logical structure broken out by milestone. It also budgets for logistical tasks, such as submitting the work for approval. The reviewer was interested to learn about the results.

Reviewer 2:

The proposed future research is in line with the objectives of the project. The reviewer made one recommendation—begin the collaboration with the Tennessee Department of Transportation (TDOT) and the Institutional Review Board (IRB) as early as possible for the large-scale test as this process may take a long time and may require additional levels of approval beyond the approvals required for the smaller scale tests. The submission for approval could incorporate lessons learned from the smaller scale tests.

Reviewer 3:

There are many follow-ups that could be possible, but at this stage in the experiment, it is probably difficult to name them clearly. The reviewer would expect to see more next year.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project is working to advance CAV technology and control algorithms to smooth traffic and save energy. As increasing mobility energy productivity and efficiency is part of the mission and vision of EEMS, the reviewer indicated that this work supports DOE objectives.

Reviewer 2:

According to the reviewer, this project is very relevant to the DOE objectives of using CAV technologies to provide smoother and more energy efficient traffic flow.

Reviewer 3:

Although it will be difficult to measure, in theory, the reviewer opined that the traffic smoothing should have a positive impact on energy usage.

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

Reviewer 1:

While microsimulation is challenging and it was mentioned during the presentation that there is no certainty about certain data type availability—both of which could perhaps be improved with additional time and resources—overall, the available resources seemed sufficient to the reviewer. The project has made what seems like reasonable progress for where it is in its timeline and seems generally on track with current resources.

Reviewer 2:

There are enough people in academia and industry to make this a complete team, and the reviewer commented that the presentation showed that the resources are being well used.

Reviewer 3:

The reviewer indicated that resources appeared to be adequate to complete this test.

Presentation Number: eems084
Presentation Title: Energy-Efficient Maneuvering of Connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections
Principal Investigator: Sankar Rengarajan (Southwest Research Institute)

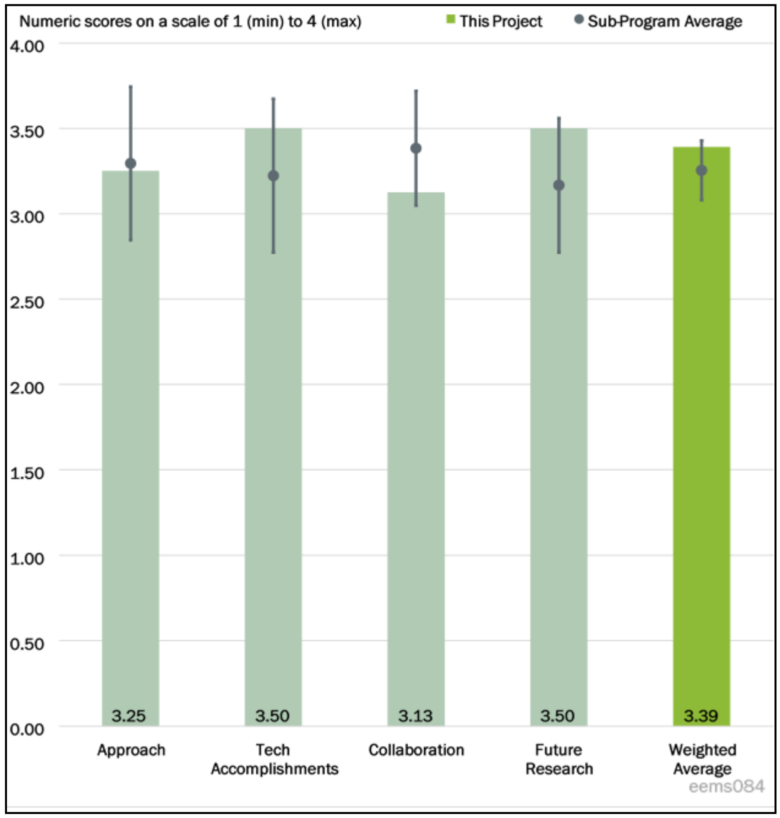


Figure 3-11 - Presentation Number: eems084 Presentation Title: Energy-Efficient Maneuvering of Connected and Automated Vehicles (CAVs) with Situational Awareness at Intersections Principal Investigator: Sankar Rengarajan (Southwest Research Institute)

Presenter

Sankar Rengarajan, Southwest Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer affirmed that the overall approach is sound and uses a combination of simulation, dynamometer, and test track. With respect to reporting the simulation results from High Street, it seemed that, from the short description and the small image of an intersection on High Street (both on Slide 27), High Street may have some configurations and traffic patterns that are not representative of a "typical" traffic signalized road. Is the research team planning on generalizing the High Street simulation results as representative results, and, if so, what is the approach for this?

Reviewer 2:

The research is a practical and reasonable approach to a difficult problem. The reviewer suggested that the researchers should clarify and address how the improvements in the corridor affect perpendicular and parallel routes. The steps to create more realistic scenarios in the model, like bottlenecks, is important.

Reviewer 3:

The project was designed to provide validation across a range of simulations (including road network for traffic simulation, macroscopic traffic simulation, traffic simulation with intersection functionality, vehicle and powertrain models for energy consumption on transient drive cycles, etc.) The research team also accounts for different powertrain types and levels of automation. This design breakdown allows for more nuanced analyses of an urban corridor and the impacts and benefits of CAVs. The approach taken seemed thoughtful to the reviewer, and various barriers are addressed in detail. As a minor design note regarding the presentation slide deck itself, graphics, such as the table on Slide 12, that leverage a green and red color scheme could be difficult for individuals with red and green colorblindness to differentiate. The reviewer suggested switching to an alternate color scheme to make the presentation more accessible.

Reviewer 4:

This is a very interesting project and there are a number of variables to be addressed. There seem to be so many variables that it may be difficult to reach a sound conclusion. If the control scenario is clear, then the variables will be defined well. So far, this was not clear to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project started in October 2019 and is scheduled to end at the end of 2022. With approximately 50% of the work complete, the research team seemed to be fully on track to the reviewer. Only one milestone has not yet started. This is particularly notable, given the unexpected hurdles to work and changes in mobility patterns over the past year. In the presentation, the team provided a detailed breakdown of technical accomplishments and progress pertaining to corridor traffic simulation, vehicle powertrain modeling and validation, intersection stack validation, and software-in-the-loop [SIL] testing, among other updates and breakdowns.

Reviewer 2:

Researchers are clear on what has been accomplished and where challenges exist. Researchers provided good detail to assess the merit and quality of the results and progress. More details on the possible intersection maneuvers, including factoring in pedestrian behavior, should be provided, according to the reviewer.

Reviewer 3:

The reviewer stated that the project is well managed and on track.

Reviewer 4:

The reviewer described technical accomplishments to date as good. The intersection stack validation results on Slide 12 show that the average speed error of less than 7.5% can only be achieved if speeds lower than 10 miles per hour (mph) are filtered out. Given this, the reviewer wanted to know if the vehicles will be more susceptible to low-speed crashes? Or, because the actual magnitude of the speed differences is small, will this have little impact on the number of low-speed crashes?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project pulls in a variety of partners, each with a different role that is articulated in the presentation deck. While only modest details were provided regarding the specifics of group coordination—based on project progress and achievements thus far and particularly given the challenges presented over the past year—the reviewer asserted that the collaboration and associated delegation seem to be solid.

Reviewer 2:

The role of each partner is clear and additive. The reviewer opined that how coordination and hand-off happen need more detail.

Reviewer 3:

The other partners' roles were discussed briefly, but it seems Southwest Research Institute (SwRI) is the lead and doing most of the work. The reviewer would like to have seen the industry involved more.

Reviewer 4:

The reviewer would like the research team to elaborate on goals for engaging the city of Austin. The reviewer wanted to know if the team is looking for the city to deploy this technology during the project time frame. If not, what are Austin's plans with respect to this technology?

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 state project ended.

Reviewer 1:

The presentation included future plans, both via dedicated summary slides and across other themed slides. An example is referencing that tech-to-market highlights will be updated semiannually, or that in FY 2022 the team will transition from dynamometer to track testing (among other plans). According to the reviewer, the team also addresses select barriers, such as barriers related to penetration characterization and associated metrics. This future research seems logically articulated and communicated in an organized manner.

Reviewer 2:

There will most likely be additional research in this area needed due to the complexity. The reviewer found that these topics were listed and explained well.

Reviewer 3:

Future work has a clear, rational, and measurable objective. In addition to higher traffic flux conditions, the reviewer suggested that more complex conditions would add useful output.

Reviewer 4:

For the future test track demonstration, given the recent Federal Communications Commission (FCC) ruling, the reviewer would like to know if the research team will need to change from DSRC technology to C-V2X? If the team plans to change communications technology, will this impact cost or schedule? For future reporting, the term "traffic flux" is not typically used in traffic-related studies. A term such as "traffic volume" might be more appropriate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project is working to better understand and quantify the impact of CAVs as well as the impact and benefit that smart and eco-vehicles could have across an urban corridor, particularly with respect to energy efficiency. This supports VTO's mission to improve transportation energy efficiency—"The EEMS Program conducts early-stage R&D at the vehicle, traveler, and system levels, creating new knowledge, tools, insights, and technology solutions that increase mobility energy productivity."

Reviewer 2:

The reviewer indicated that, yes, this is well aligned with DOE objectives of using CAV technologies for more energy efficient traffic.

Reviewer 3:

This reviewer noted a very interesting project to see the total merit of penetration smart vehicles for energy savings. The variables and dynamic movement of the vehicles will greatly influence this, and it will be good to see if there is a solid conclusion.

Reviewer 4:

The reviewer opined that the work clearly contributes to improved vehicle efficiency. Continuation of this rating will depend on real-world testing following completed validation of the dynamometer. If the value is in the low single digits, this may indicate no real 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 remarked that the partners bring the necessary resources through direct or in-kind contribution.

Reviewer 2:

Workforce and members are well managed and right sized, according to the reviewer.

Reviewer 3:

While more work could be done to supplement existing efforts, this reviewer noted that the project appeared to be on track and progressing well with the allocated resources. Given this, the current resource level seems sufficient.

Reviewer 4:

Resources appeared to the reviewer to be sufficient to meet the project milestones.

Presentation Number: eems087
Presentation Title: Computation of Metropolitan-Scale, Quasi-Dynamic Traffic Assignment Models Using High Performance Computing
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

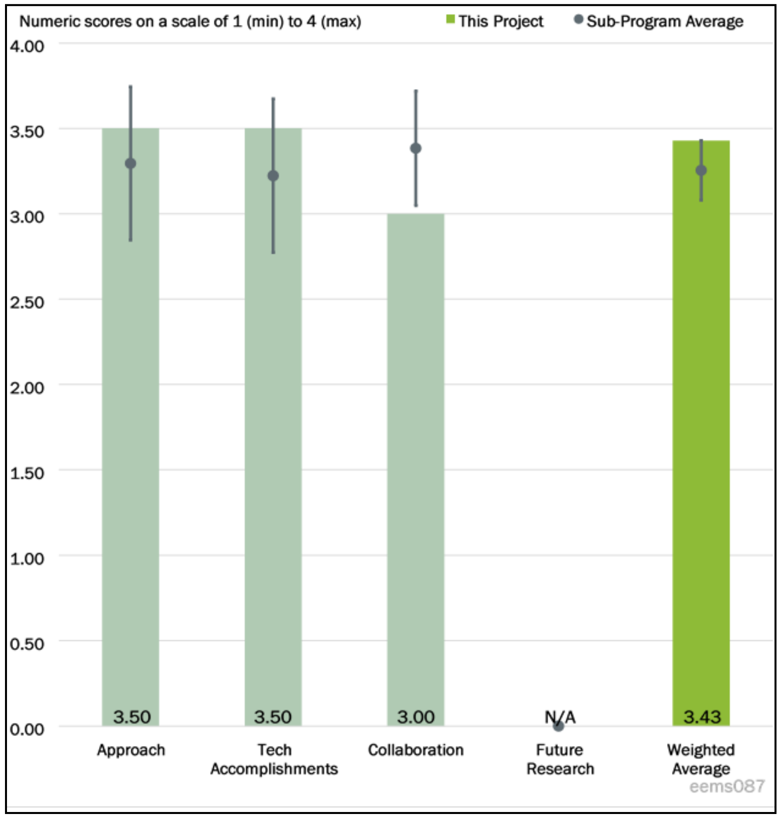


Figure 3-12 - Presentation Number: eems087 Presentation Title: Computation of Metropolitan-Scale, Quasi-Dynamic Traffic Assignment Models Using High Performance Computing Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer praised the research approach as excellent in addressing multiple barriers, including assessment of energy use at the system level, and addressing the scalability and computational limitations of dynamic traffic-flow modeling. The research approach was aimed at developing a metropolitan-scale, dynamic traffic-flow model with significantly shorter computational run time using parallel algorithms through the support of high-performance computing (HPC). Model development focused on the ability to evaluate both time-based and energy-based use scenarios at the system level.

Reviewer 2:

The project seems to have been able to resolve technical HPC issues to arrive at the relatively quick results in different urban regions. The reviewer commented that dividing time into 15-minute blocks was a smart move.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer noted research that made significant progress in addressing the original technical barriers cited. The quasi-dynamic traffic assignment (QDTA) algorithm developed under the project was shown to generate more realistic results than the static traffic assignment (STA) algorithms as far as representing the temporal nature of demand, ensuring only active demand assignment per time interval, and carrying over residual demand across time intervals. The reviewer observed that the "parallelized" computing approach to traffic assignment using HPC resulted in significantly reduced run times for large metropolitan networks like San Francisco and Los Angeles. The research's evaluation results for socially aware metrics—neighborhoods, safety, mobility, equity, and environment—were effective in visualizing impacts for following three model optimization functions, including user equilibrium travel (UET) time, system optimal travel (SOT) time, and system optimal fuel (SOF) use. These results also showcased the utility of model results for comparing impacts across different metropolitan areas.

Reviewer 2:

Project and progress seemed complete to the reviewer with respect to objectives being met.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The researcher provided an interesting list of collaborators, including national laboratories (LBNL), universities (the University of California), commercial entities (HERE and Uber), government agencies (the City of San Jose and the San Francisco County Transportation Authority), and associations (the Southern California Association of Governments). However, the reviewer asserted that the particular roles and contributions of these collaborative parties were not clearly defined by the researcher.

Reviewer 2:

According to the reviewer, coordination and collaboration among partners appear to be well coordinated based on information gleamed from the presentation.

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 state project ended.

Reviewer 1:

The reviewer commented that this question is not applicable since the project was completed in May of 2021.

Reviewer 2:

The reviewer stated that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that this project advances the knowledge base and toolset for evaluating large-scale metropolitan system-level traffic, user mobility experience, emerging technologies and practices, and the resulting energy use.

Reviewer 2:

The reviewer indicated that this project supports improving transportation energy efficiency at the traveler and system levels through the creation of tools.

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 was successfully completed on schedule and within budget.

Reviewer 2:

The reviewer stated that $300,000 for this project was sufficient.

Presentation Number: eems088
Presentation Title: Chicago Transit Authority: Transit Network Efficiency Using POLARIS
Principal Investigator: Omer Verbas (Argonne National Laboratory)

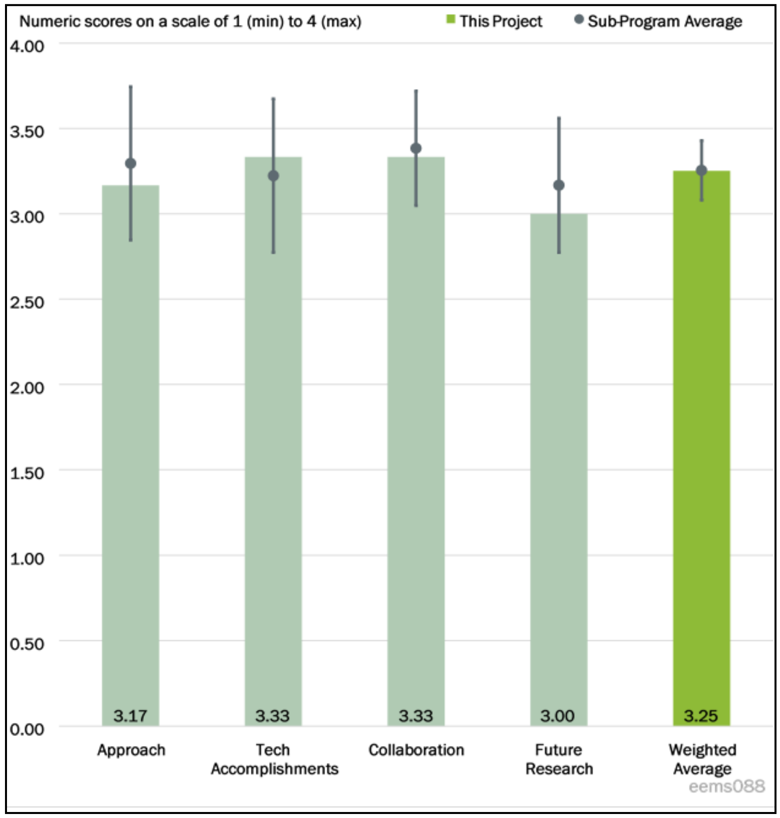


Figure 3-13 - Presentation Number: eems088 Presentation Title: Chicago Transit Authority: Transit Network Efficiency Using POLARIS Principal Investigator: Omer Verbas (Argonne National Laboratory)

Presenter

Omer Verbas, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the overall approach has proven relatively sound. Quantifying the impact of the proposed strategies is necessary to simulate the entire transportation system (or system of systems). This requires HPC to enable analysis of a large number of scenarios, conducting predictive scenario assessment, and implementing ridership recovery scenario analyses, ultimately leading to the quantification of potential impacts. Optimization algorithms have proven critical to this process in order to evaluate improved transit strategies, including new routes, reallocating frequencies, and so forth.

The project has provided a reasonable list of barriers, including computational models and design and simulation methodologies. It also includes COVID-19-related shifts in Chicago Transit Authority (CTA) focus and altered user behavior resulting from COVID-19.

Reviewer 2:

The reviewer commented that the technical approach to this project appeared to be well laid out for addressing computational and knowledge barriers due to the impacts of COVID-19 on the Chicago transit system. Using the Planning and Operations Language for Agent-based Regional Integrate Simulation (POLARIS) platform, the research set out to model risk perception for shared transit modes and improve the telecommuting model based on survey data, calibrating mode choice, routing, and timing choice parameter based on ridership data. It also modeled risk perception to validate traffic count data based on roadway data. The research plan prescribed

HPC attributes for supporting predictive scenario analysis related to COVID-19 impacts on agency budget reduction, increased telecommuting, and increased modal risk perception, as well as analysis of ridership recovery scenarios for optimizing modal frequencies and adding bus rapid transit (BRT)lines. Through this approach the research team planned to quantify system impacts on ridership, congestion, economy, user experience, energy, emissions, and equity.

Reviewer 3:

The approach to this research is solid, though some aspects did not seem to be well balanced to the reviewer. Among other questions, if the researchers need HPC, this suggests this is a rather advanced and sophisticated modeling and computational environment. However, to the reviewer's knowledge, the information for the COVID-19 impacts is based on only a few hundred respondents from the University of Illinois at Chicago (UIC) study. Is that enough to extract valid information to inform COVID-19-related scenarios? What sample sizes can the researchers count on? Is this enough to account for the heterogeneity in behaviors with respect to public transit use and teleworking? Also, the assumptions made to model COVID-19 scenarios are not clearly displayed. Are the researchers assuming that the fundamentals of travel (e.g., model coefficients) in POLARIS will not change, but only the values (e.g., variable levels) are modified? The fact that the model seems to substantially overestimate rail ridership during COVID-19, but to underestimate bus ridership during the same time seems to suggest that the model is not properly capturing different behaviors among various groups of riders (e.g., higher income rail riders who are more likely to telecommute, while captive bus riders continue to ride transit, as it seems to be evident from the American Public Transportation Association [APTA] and other public transit data). Also, the reviewer would like to know how the researchers plan to evaluate the type of service improvements considered as most effective. Does the team have a module to evaluate cost effectiveness of the improvements? For example, doubling frequency can be very expensive, and the results show that BRT takes riders away from the subway, so these solutions might not be very appropriate recommendations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project has successfully achieved a respectable list of technical accomplishments and results:

- Development of an optimization algorithm and simulation to improve transit service, including transit route design and redesign, new transit route frequencies and timetables, and service cuts under predictive scenarios.
- Results have determined that telecommuting and COVID-19-10 risk perception have more impact than service cuts on transit ridership. COVID-19 risk perception has the potential to disrupt ridership more than deep service cuts or telecommuting.
- Analyses have quantified that the increase in fuel use and GHG emissions per day in the Chicago metropolitan area are a result of the loss of ridership under various scenarios.
- Under the ridership recovery scenario analysis, modeling has identified optimized service cuts, assuming scenarios with budget cuts of 20% and 55%. Service improvements through increasing frequencies of routes and the addition of BRT lines have been identified.
- Results further indicate that optimizing route frequencies shifts service and ridership from bus to rail without impacting total ridership and improving overall user experience. Increasing route frequencies or adding BRT lines induces transit ridership and shifts travelers from rail to bus.

Reviewer 2:

This reviewer remarked that the research team presented meaningful results as related to the original goals and objectives of the work. As part of its predictive scenario analysis, results indicated that telecommuting and COVID-19 risk perception have more system level impacts than Chicago transit service cuts alone, and that COVID-19 risk perception had a greater impact on demand than either deep service cuts or telecommuting. In regard to ridership recovery scenario analysis, results showed optimizing frequencies shifted ridership from bus to rail but had no impact on total system ridership and improved overall user experience. Increasing frequencies or adding BRT induced overall system ridership and shifted modal use from rail to bus. The reviewer suggested that it would seem these results could be useful for extrapolation to other transit systems as well.

Reviewer 3:

According to the reviewer, the researchers made a great effort in customizing the research to account for the mutated conditions during the COVID-19 pandemic in a rather solid way.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the research appeared to receive valuable data and insight from multiple collaborative partners, including CTA for ridership and fleet data, modeling scenario input, and results analysis; Chicago Department of Transportation (Chicago DOT) for roadway data and modeling scenario input; and UIC for COVID-19 impacts and user behavior modeling.

Reviewer 2:

The project team is well rounded and has proven appropriate for the task at hand, including ANL, CTA, UIC, and the Chicago CDOT. The reviewer stated that roles and responsibilities of each partner have been identified.

Reviewer 3:

The team seems to be collaborating well across the national laboratory, the academic team at UIC, and the public transportation agencies. The reviewer suggested that it would be desirable to link this framework to the new mobility options too, something that had been in the original proposed work but not in the COVID-19 modified work.

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 state project ended.

Reviewer 1:

The researchers are aiming to address a very complex topic with the combination of the future transit planning and route selection. The reviewer opined that more details on how the project team wants to accomplish that would be required, as it is a very complex problem (in particular in the formulation given by the researchers, including both fixed route transit but also first-mile and last-mile (FMLM) options with ride hailing, which would return almost infinite possibilities for change in the future public transportation network). The evaluation of cost effectiveness of the future solutions should be an important priority.

Reviewer 2:

The reviewer reported that this project concluded in May 2021. Remaining challenges and barriers have been identified satisfactorily: risk perception models need to be continuously updated; frequency optimization by itself is not sufficient to recover or increase ridership; and optimizing route design and frequencies jointly is necessary to dramatically increase ridership. Proposed future research include joint optimization of route design and frequency setting; transit signal priority; timed transfers; transit bus electrification; and integration with FMLM services.

The reviewer believed that the first and last items are spot on, especially within the context of aiming to increase ridership. However, it was unclear how the aforementioned items the middle three items will directly impact ridership in a significant way, as these elements seem to work more at the margins.

Moving forward, it may be good to consider unique approaches to how these analyses and future efforts can be combined with and augment CTA's traditional route analysis and optimization processes.

The reviewer believed that it is questionable that in the current COVID-19—and soon post-COVID-19—environment it is feasible to re-establish pre-COVID-19 ridership levels, much less improve upon them in the near future. Furthermore, these analyses may prove useful to rationalize CTA expectations for increasing ridership.

Reviewer 3:

The reviewer noted that the project was completed in May 2021.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer found the project to be relevant due to the need to re-envision the future of transit services as a result of COVID-19 and subsequent steep losses in ridership. Transit is the most energy efficient transportation mode on a passenger-mile basis and means to stabilize and regain ridership are badly needed in the post-COVID-19 environment. Improving transit efficiency and increasing ridership reduces energy consumption and GHG emissions.

Reviewer 2:

According to the reviewer, the research expanded the use of the existing POLARIS platform to evaluate and understand the pandemic's impacts on a major metropolitan area's transit system for improving future mobility, user experience, and energy resiliency for the system and other similar systems.

Reviewer 3:

The project is clearly linked to the future of transportation and its impacts on energy consumption and environmental emissions. The reviewer commented that the electrification of public transit is probably the easiest part to model in terms of assumptions to introduce in the future work.

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

Reviewer 1:

From the reviewer's understanding of the work, it seems that the available resources are appropriate.

Reviewer 2:

The reviewer said that resources have proven sufficient to achieve the required project objectives.

Reviewer 3:

The project was successfully completed on schedule and within DOE's budget. The researcher did indicate that additional National Virtual Biotechnology Laboratory (NVBL) funding was used to support completion of the project.

Presentation Number: eems089
Presentation Title: Energy Efficient CAVs: Workflow Development and Deployment
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

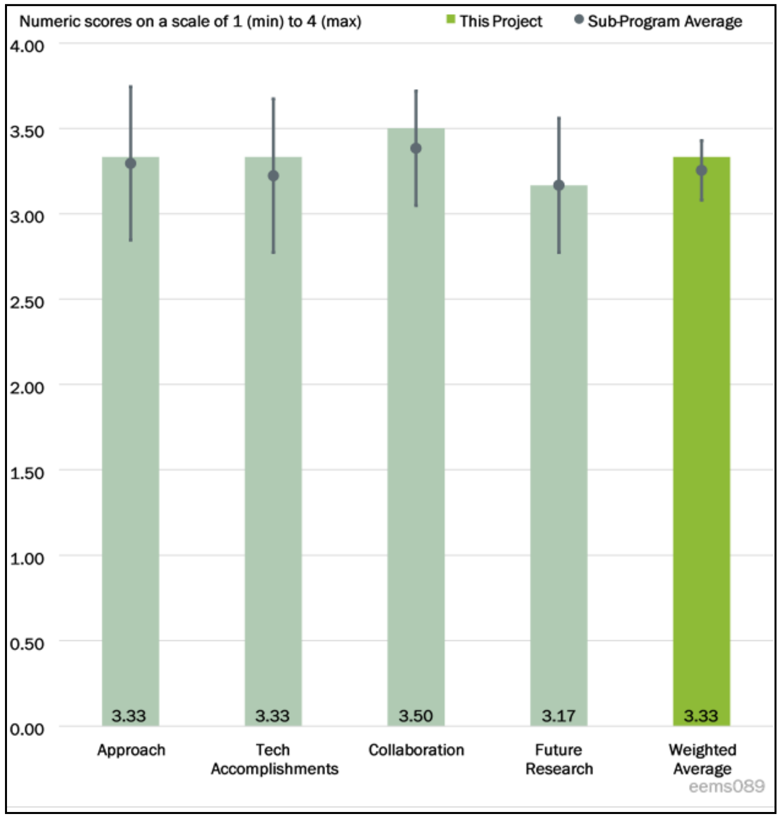


Figure 3-14 - Presentation Number: eems089 Presentation Title: Energy Efficient CAVs: Workflow Development and Deployment Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach successfully addresses gaps in the study of CAV technologies, which is somewhat of a moving target. For that reason, the maximum flexibility in tools is required, and the reviewer asserted that the project team did well in managing to attack the uncertainties involved.

Reviewer 2:

This reviewer has been familiar with the workflows that are being developed in this project and agreed with the statement that energy efficiency has not been a primary motivator for companies developing AVs. There is significant potential to improve energy efficiency as well as increase capacity of the transportation system network, to mention a couple of things. The reviewer asserted that this project is developing the tools and workflow to understand these aspects.

Reviewer 3:

The approach was reasonable to the reviewer. However, the software development portion of the scope appears to be excessive.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Making the tools useable is critical to success. The integration of stochastic vehicle trip prediction (SVTRIP) into AMBER is a major milestone, according to the reviewer. The addition of anything-in-the-loop (XIL) and vehicle-to-vehicle (V2V) features also advances the capability to analyze CAVs in the mobility environment.

Reviewer 2:

Progress is satisfactory. The optimization results seemed particularly encouraging to the reviewer.

Reviewer 3:

The reviewer reported that several improvements to the models and workflow processes have been made, including driver model and automated calibration. Model calibration is typically a time-consuming process, and this should help speed up the workflow significantly.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project involves three distinct aspects and requires streamlined project management and coordination. The reviewer opined that the progress indicates that the project team is collaborating and coordinating well.

Reviewer 2:

Proving out the driver model simulation results with real vehicle testing is very valuable, and the reviewer found collaboration with OEMs to be a good step here.

Reviewer 3:

Successful collaboration with an OEM to obtain data for model validation was noted by this reviewer. However, these cover relatively low levels of autonomy. Perhaps more data from vehicles with higher levels of autonomy—possibly the Tesla Autopilot—could help improve the models 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The next steps made sense to the reviewer. It should be interesting to see how lateral dynamics impact the system results.

Reviewer 2:

Although the proposed future research appeared reasonable to the reviewer, the software development efforts appear excessive. Those tasks are beyond research and best left to the private sector.

Reviewer 3:

Several features are being released or developed, and this reviewer had similar concerns that have been expressed previously on other Autonomie projects. Specifically, is the software development and support (to non-government users) taking up too much time so as to affect execution of the other projects? How does ANL balance the requirements of software support and executing DOE projects?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that the CAV technology modeling work is a critical part of assessing these new features of the transport infrastructure and their impact on transport energy consumption.

Reviewer 2:

The reviewer commented that the models and processes developed here support the SMART workflow.

Reviewer 3:

The reviewer affirmed that, yes, the workflow ensures that energy efficiency is considered in CAV controls 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 said that the work is progressing well with the available resources.

Reviewer 2:

According to the reviewer, the resources dedicated to software development appear to be excessive.

Reviewer 3:

Sufficient resources were noted by this reviewer.

Presentation Number: eems091
Presentation Title: TCF: Ubiquitous Traffic Volume Estimation
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

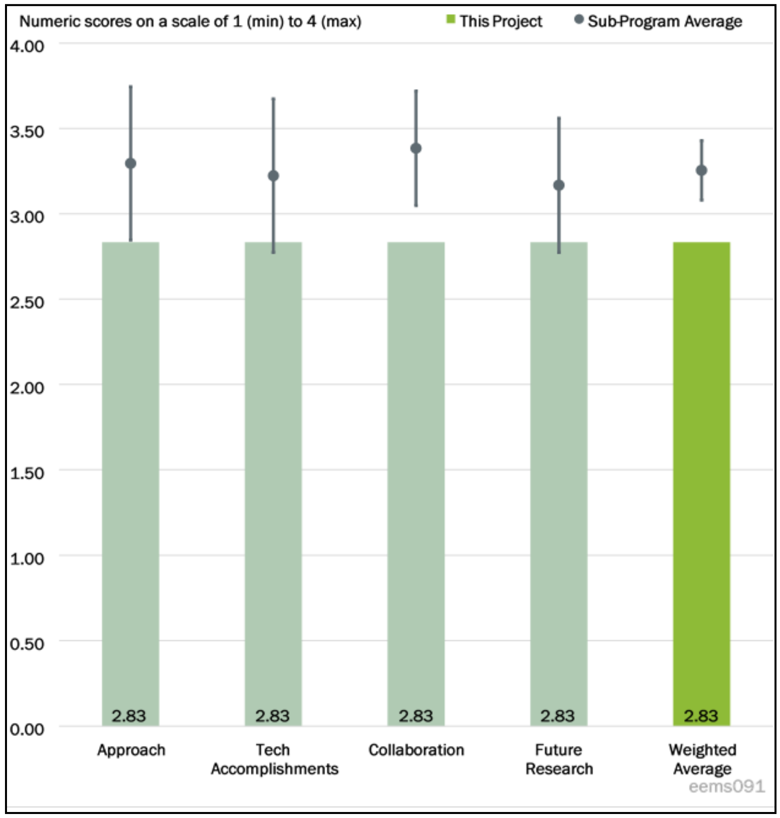


Figure 3-15 - Presentation Number: eems091 Presentation Title: TCF: Ubiquitous Traffic Volume Estimation Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked the approach here, especially of comparing model data developed from one city and applying them to another city. The only thing the reviewer recommended for this is trying to project some of the modeling to a much larger or smaller city to see what the potential is for that type of extrapolation.

Reviewer 2:

Traffic volume estimation techniques already exist. Startups are already using these techniques to improve signal timing. The reviewer was not sure what core technologies this Technology Commercialization Fund (TCF) project is commercializing and how that fills a gap.

Reviewer 3:

The project seemed well designed to the reviewer, but suffers from unforeseen obstacles (e.g., lack of data availability and latency and inability to detect traffic anomalies).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer liked the progress made to date.

Reviewer 2:

This reviewer commented that progress seemed on track, except the last milestone is probably more difficult to meet given the lack of a method to identify true traffic anomalies.

Reviewer 3:

The local outlier probability (LoOP) procedure does not appear to work well. The spatial transfer results seem less than satisfactory. The results shown on Slide 15 are also not too impressive.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer liked the good range of partners across different states and the partnership with private entities that provides a pathway to market development of this technology.

Reviewer 2:

The reviewer was not sure how exactly the project team is obtaining advice from university partners.

Reviewer 3:

The reviewer said that this question is hard to judge.

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 state project ended.

Reviewer 1:

The reviewer liked the planned future research, especially with the different vehicle classifications. The reviewer went on to say that it would be important for future research to also compare the relative percentage of MD and HD vehicles to the light duty vehicles in the different cities to ascertain the impacts these vehicles have for the city-to-city data transfer. Correlating those data to areas that have significant goods movement traffic will also be needed in the future to make the model more robust.

Reviewer 2:

The reviewer was worried about the lack of a proven method to identify real traffic anomalies with respect to the last milestone.

Reviewer 3:

According to the reviewer, this work just appears to be behind the times. The proposed work is already being done in industry.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer believed that this project supports the overall relevance to the topic area given the commercialization potential, which also provides more value for this effort and makes it usable for industry.

Reviewer 2:

The reviewer said that the project supports early-stage R&D to develop innovative technologies that enable energy efficient future mobility systems (although the energy consumption part is not a component of this project).

Reviewer 3:

Traffic volumes are critical in energy modeling, according 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:

This project seemed to the reviewer like good "bang for the buck," with good progress being made for the budget to date.

Reviewer 2:

The reviewer remarked that $500,000 seems sufficient, but it is hard to judge.

Reviewer 3:

The project seemed excessive to the reviewer, considering the extensive existing work that is already out there.

Presentation Number: eems092
Presentation Title: BEAM CORE
Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

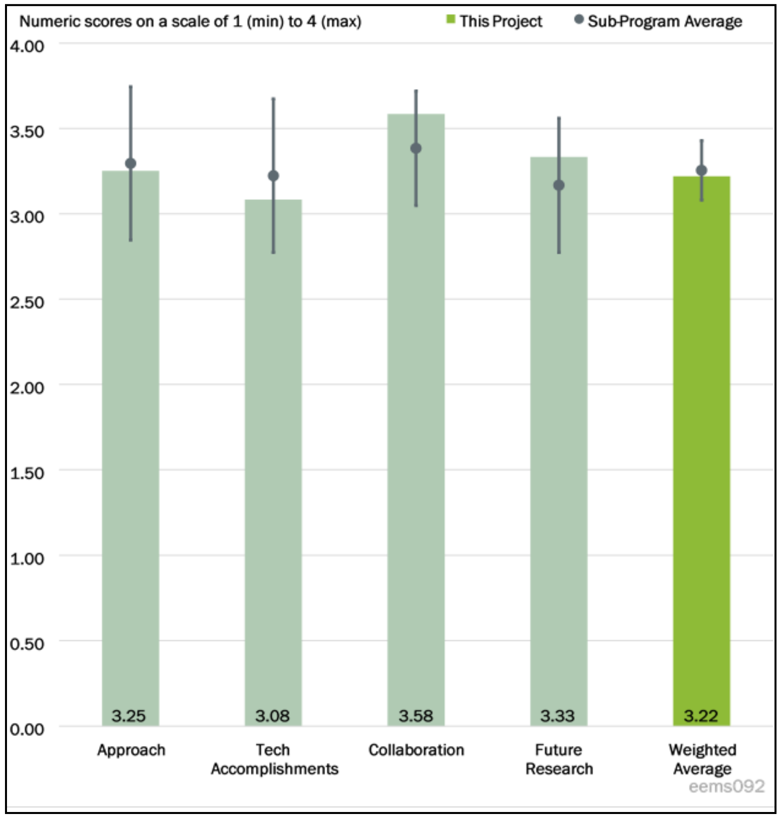


Figure 3-16 - Presentation Number: eems092 Presentation Title: BEAM CORE Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

Presenter

Anna Spurlock, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer was very impressed with the progress and vision laid out for Behavior, Energy, Autonomy, And Mobility (BEAM) at AMR. The reviewer believed that the approach that is outlined makes significant contributions to current modeling barriers, and the reviewer especially looked forward to hearing the results of the comparison with POLARIS and some of the new equity-related analyses that can be conducted with updates to BEAM. On Slides 29 and 30, it appears that all Q3 and Q4 milestones are on track, so the reviewer had no concerns to document here.

Reviewer 2:

The continued development of BEAM and its companion pieces is well planned. The short-term and long-term effects are addressed well with the ongoing and planned work. The reviewer asserted that BEAM Comprehensive Regional Evaluator (CORE) is an excellent synthesis of these pieces to answer regional questions in a more thorough manner.

Reviewer 3:

Having seen the Polaris-based projects and the BEAM-based projects, it was good for this reviewer to see the slightly different approach (and perhaps a stronger focus on longer term modeling) used by BEAM. The reviewer was initially of the opinion that it was a waste of valuable resources to duplicate the effort but has since changed positions. The different approach to addressing (more or less) similar problems can actually yield valuable insights and the BEAM team is doing an admirable job along with the POLARIS team. The longitudinal focus also helps answer several questions as we try to understand the future of mobility.

Reviewer 4:

The modeling approach is comprehensive. The concern that the reviewer had is how much the comprehensive system can integrate with other existing modeling tools already in use. It is unlikely that a planning organization will adopt an entirely new modeling system from scratch (even though it does happen from time to time).

Reviewer 5:

At a high level, the approach made sense to the reviewer. There are a lot of interactions and handoffs between the models and insufficient transparency needed to help users understand and interpret the results and manage uncertainty. The presenters spoke to transparency. However, there is substantial room for improvement. The computational complexity makes it hard to see how changing a lever or multiple levers that interact changes the results. The researchers answered a question on scenario versus forecasting. This needs to be reconciled further. The research questions like future fleet composition suggest a predicted outcome versus a scenario, with implications for how the results should be used and interpreted.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that excellent progress is being made on making the software system more useable with speed improvements, greater automation, and more regional simulations. Household and vehicle ownership models are more difficult to pull off but handled well, given the data that are available.

Reviewer 2:

The choice to go open source was an interesting one to this reviewer. Because software like BEAM is not something that is easy to use, this presents a big problem in terms of support. Is the software going to be offered as-is with a user manual and no support? This would limit the usefulness of the software. The reviewer presumed that the main users of the software will be governmental agencies, planning authorities, and the like. However, the more it gets deployed outside of LBNL, the more support it will need for it to be successful and for it to provide useful feedback to the BEAM team. The reviewer added that deploying the models in multiple regions is good and asked whether the software takes into consideration resource availability as it is used to model land use evolution. For instance, extended drought causing a scarcity of water resources in the west, and its effect on land use.

Reviewer 3:

The project appears to be making good progress. However, it does not appear as if all the recent progress has been committed to the GitHub repository. The reviewer encouraged the project team to commit often to accelerate technology transfer.

Reviewer 4:

For Task 2, the reviewer noted that the research team completed model formulation with data but did not show validation runs.

Reviewer 5:

Again, based on the reported milestones, it appears that this project is on schedule. The reviewer did not see any discussion of performance indicators (beyond the defined milestones), making this question a little challenging to answer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project has many moving parts across a number of organizations and is well managed.

Reviewer 2:

The team seemed well integrated to the reviewer and is functioning as a cohesive unit.

Reviewer 3:

According to the reviewer, the project team appears to collaborate well.

Reviewer 4:

On Slide 57, it appears that collaboration is working well across the project team. The presenter seems to have identified all the important stakeholders and has them involved in the research. The reviewer encouraged the research team to think more about technology transfer (in addition to stakeholder engagement, which the reviewer expanded upon previously).

Reviewer 5:

Great collaboration between various labs, universities, and other organizations was observed by this reviewer. It would, perhaps, be worthwhile to engage with universities and organizations outside the US to get fresh perspectives on these problems. The reviewer was not sure if similar work is being performed elsewhere, but it seemed that it would be beneficial.

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 state project ended.

Reviewer 1:

The reviewer noted that the freight module and the stakeholder engagement efforts are definitely of high value.

Reviewer 2:

The proposed next steps were logical to the reviewer and are needed to achieve future modeling goals and get wider usage of the tools.

Reviewer 3:

It was clear to this reviewer that BEAM is still evolving to address a variety of issues, and the plan laid out by the team appears to be appropriate.

Reviewer 4:

The reviewer thanked the research team for including the top takeaways from the listening sessions and found it insightful to read them to understand stakeholder feedback and how that will inform BEAM CORE and BEAM CORE Application and Collaboration Tool (ACT) moving forward.

The reviewer stated that the only piece of constructive feedback for the BEAM team at this point is to encourage the team to start thinking about technology transfer sooner rather than later. The reviewer was glad to hear that BEAM is pivoting to focus on open-source tools but has found that sometimes open-source tools are a bit hard to work with (e.g., documentation may not be easy to follow, there is not as much support, sometimes there is not a graphical user interface, etc.). The reviewer thought that the work BEAM is doing is incredible and will enable planners to answer a lot of new and important questions. Is the team thinking about how to transfer the final model to an MPO planner? Will the planner require additional skillsets or training?

What is the BEAM development team doing to ensure that, once the model is developed, it can be easily deployed?

Reviewer 5:

Future work appears to be targeted at challenges such as run time. The reviewer opined that the research team needs to clarify if the 30% runtime cut includes full population runs or if adding the full run will overwhelm the runtime savings.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that BEAM CORE provides a mobility system modeling capability that complements other tools and may be uniquely positioned to answer certain "what-if" questions posed in the EEMS work.

Reviewer 2:

The reviewer affirmed that, yes, the transportation activities have important energy impacts.

Reviewer 3:

The reviewer remarked that the results aim to inform real-world decision-making, with and impact on transportation energy use.

Reviewer 4:

The reviewer stated that this project is aimed at understanding how mobility is going to evolve in the future, and as such, supports DOE objectives.

Reviewer 5:

Without advanced modeling tools like BEAM, DOE cannot explore many of the important questions surrounding energy use and consumption. The reviewer commented that the questions are too complex for models that are commercially available today.

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

Reviewer 1:

Progress has been excellent in the first year without reported delays due to lack of resources. The reviewer concluded that the resources are adequate.

Reviewer 2:

The resources are sufficient, according to the reviewer.

Reviewer 3:

Resources were described by this reviewer as sufficient.

Reviewer 4:

The monetary resources are at least sufficient and could be excessive. It was clear to the reviewer that the partners have access to the necessary tools like HPC clusters.

Reviewer 5:

Not applicable was indicated by this reviewer.

Presentation Number: eems093
Presentation Title: Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

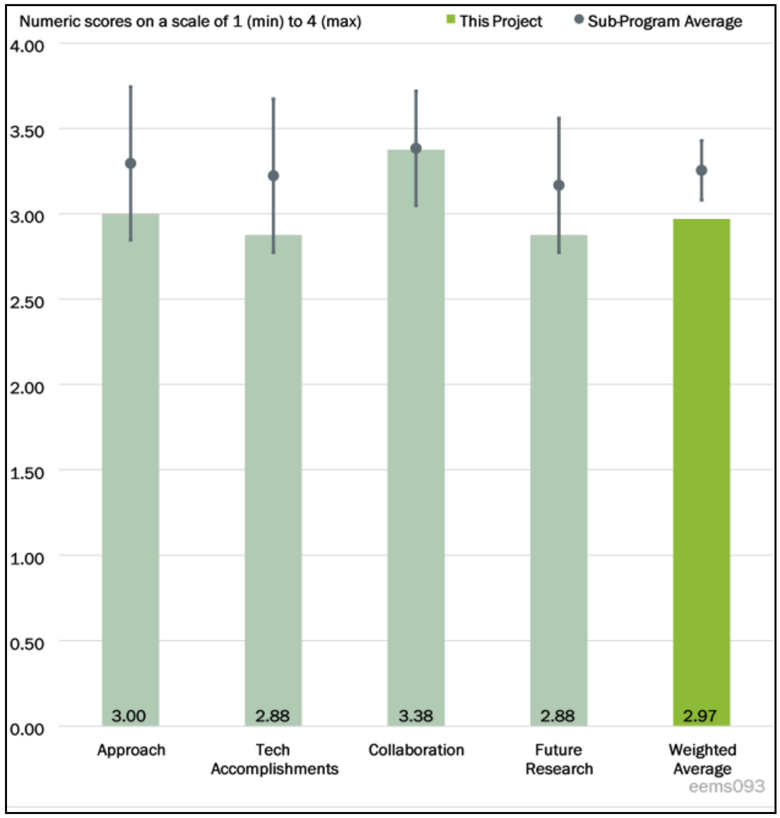


Figure 3-17 - Presentation Number: eems093 Presentation Title: Transportation System Impact: POLARIS Workflow Development, Implementation and Deployment Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 50% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer was very impressed with the work completed by the POLARIS team. The work seems very well designed and systematic. The reviewer had no concerns about the feasibility of the work proposed.

Reviewer 2:

This reviewer has been looking at the various results coming out of the Polaris software, and the team has been addressing the issues and concerns raised by the stakeholders and doing so very well. The software is unique in its scope and the reviewer commented that the team has worked hard to make its capabilities more relevant to addressing DOE needs.

Reviewer 3:

Researchers should consider if trying to integrate and add functionality in many areas simultaneously is more or less effective than focusing on adding and ensuring robustness in a limited area. The reviewer questioned what work needs to happen in parallel, what work can happen serially, and what is the rank order. On Slide 6, it is usually better to have the stakeholders define the desired new features, not the other way around.

Reviewer 4:

The reviewer had serious concerns about how the POLARIS model system has ballooned into such as massive and costly effort, yet it is a closed system that the wider community cannot access. Yes, the model can be licensed and the team is working with stakeholders, but the cost is prohibitive for most medium and smaller areas. Also, the speed of technology transfer is limited to the team's ability to expand. The transportation agencies have long had issues with DOE models because they are costly and cumbersome to use. This issue is only getting worse. If DOE headquarters (HQ) is serious about addressing the barriers listed in this presentation, it should urge the laboratories to release POLARIS as open source. POLARIS developers should develop training materials and democratize the model and its underlying algorithms. As is, there is no way for any reviewer to judge whether or not the algorithms are accurate or practical because everything is closed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noticed that the team explicitly mentioned the limited validation of the standalone tools but was surprised not to see more discussion of completed or planned validation of the workflow. The reviewer was also glad to hear that the team is starting to tackle more automated connections between the various model components. Overcoming this limitation will be important toward final deployment.

Reviewer 2:

From what this reviewer can see, running Polaris is a very involved process and requires a diverse set of inputs. Setting up a Polaris model for a region is a months-long endeavor. In order for Polaris to be more effective, a few things have to happen—it has to run faster and produce results quicker, and more importantly, it should be quicker to set up the models themselves. These points have been/are being addressed in the work that has been done to date on the project.

Reviewer 3:

This reviewer noted the content on Slide 22 was too high level. The real output was difficult for this reviewer to confidently understand; for example, the reviewer was unsure if the model considers consumption that happens in days, weeks, or months later. The reviewer stated that the predictive models seem to be conflated with scenario analysis, and highlighted that scenarios are not predictions.

Regarding Slide 23, the reviewer indicated that results seem to be mixing existing and under-development content. There is enough work to focus on what has been done, not what will or might be done. If the under-development content is relevant, then the reviewer asked the team to provide sufficient details on why and what has been learned and accomplished to date. This extends to other work like the new API design on Slide 25.

A prior review noted a lack of performance indicators, which remains the case. A lack of clear indicators and metrics made it difficult for this reviewer to fully assess the accomplishments.

Reviewer 4:

Although the project seemed to have made decent progress, there was no way for the reviewer to really know. There are not enough peer-reviewed articles on modeling details.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The stakeholder group that the research team has assembled is impressive. The reviewer appreciated the increased participation of MPOs in the stakeholder engagement groups. The reviewer thought that it will make the end product much more usable to engage end-users this early in the process.

Reviewer 2:

The reviewer remarked that the project team seems to be collaborating well.

Reviewer 3:

The reviewer reported that the team has involved a very large number of partners, including some outside of the United States. The very diverse set of viewpoints should improve the project outcome significantly.

Reviewer 4:

The stakeholders guided the study design. As described, more active engagement in the creation and execution of the study may help improve the work. It seemed to the reviewer that the researchers are aware of this need based on the response to prior years' comments. However, there appears to be additional room for improvement.

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 state project ended.

Reviewer 1:

The reviewer indicated that proposed research continues to address improvements in process flow while also putting the model to work by looking at several new and different scenarios. This reviewer looked forward to results of the new studies.

Reviewer 2:

The reviewer stated that the proposed future research is an expansive coverage or relevant topics but lacks detail to evaluate the merits and consider them in the context of alternative options and ongoing work.

Reviewer 3:

The only piece of constructive feedback that the reviewer had for the POLARIS team at this point is to start thinking about technology transfer sooner rather than later. The reviewer thought that the work POLARIS is doing is incredible and will enable planners to answer a lot of new and important questions. However, the reviewer wanted to know if the team is thinking about how to transfer the final model to an MPO planner. Will the MPO planner require additional skillsets or training? What is the POLARIS development team doing to ensure that once the model is developed, it can be easily deployed? This model is so powerful (and complex) that the reviewer was concerned about MPOs having the necessary skillsets to be in control of this model once it is ready for deployment.

Reviewer 4:

The direction of proposed future research is good. However, the reviewer emphasized that the model should be open source if DOE HQ is serious about advancing the field. Transportation is a public good. Transportation agencies are public agencies. It does not make sense to require that public agencies should use taxpayer money to license a laboratory-developed technology that is also funded by taxpayer money.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that, of course, this project supports the overall DOE objectives.

Reviewer 2:

The reviewer affirmed, yes, but to answer the larger questions of interest to DOE, more complex models are necessary.

Reviewer 3:

The reviewer opined that the project is relevant to DOE objectives but not if the model continues to be closed.

Reviewer 4:

The reviewer responded affirmatively that, yes, it does, but the presenters did not sufficiently address how. It requires familiarity with the work over the years to understand why.

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

Reviewer 1:

The resources appeared sufficient to this reviewer.

Reviewer 2:

Without specificity of the future work, the reviewer asserted that it is hard to justify this much open-ended funding.

Reviewer 3:

The funding level seemed extremely excessive to the reviewer.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: eems094
Presentation Title: Development and Validation of Intelligent CAV Controls for Energy-Efficiency
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

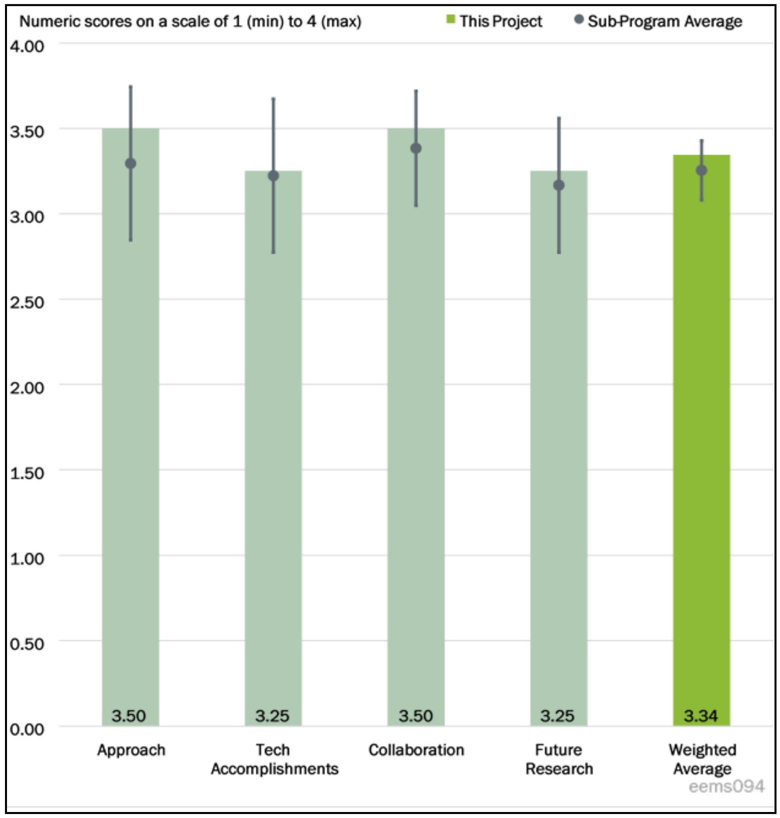


Figure 3-18 - Presentation Number: eems094 Presentation Title: Development and Validation of Intelligent CAV Controls for Energy-Efficiency Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the dynamometer track testing sequence as well thought out and the overall project approach as solid.

Reviewer 2:

The reviewer commented that the research team has excellent methods and an execution plan to obtain answers to questions related to CAV technology when true CAVs are not readily available for testing and researchers do not have access to OEM proprietary control systems.

Reviewer 3:

Although this reviewer agreed with the statement that development of AVs has not been driven by energy efficiency, there are energy consumption benefits to be had, and this project aims to quantify those benefits that may be achieved by using appropriate controls. The reviewer explained that there is vehicle-to-vehicle variation when it comes to propulsion system efficiency (as in any product that is produced in volume), and this variation would be higher in conventional (ICE) powertrains compared to EV powertrains. It may, perhaps, be worth looking at these variations in efficiency and evaluating whether the developed controls and calibrations have a measurable effect on energy efficiency.

Reviewer 4:

This reviewer stated that the overall project approach appears to represent a strong mix of simulation, laboratory, and on-track development, which should be a promising approach for robust and realistic controls and insight creation. The presenters stated that the inclusion of realistic traffic conditions will be a key component for continued development as it is imperative to include this analysis for the realistic assessment of CAV strategies. As the project has just begun, it was not expected for this presentation, but later discussions would benefit from more detail about how the GM-provided, real-world data will be used within the overall project. Additionally, it would be helpful to the reviewer to understand how some of the evaluation cycles and scenarios were determined and if these will be updated as more real-world data are obtained and when validation challenges are highlighted from laboratory and track testing. As mentioned earlier, the sensitivity of the expected 6% gain within the context of an overall scenario with realistic traffic would be of great interest in this project and DOE's research goals. For the energy benefits shown, it would also be helpful to highlight the powertrain type used to estimate these benefits and if this would be expected across different powertrain types.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the research team has made great progress and accomplishments appear to be somewhat ahead of plan. V2V and vehicle-to-infrastructure (V2I) control simulations coupled with VIL validation tests are great examples of what can be done.

Reviewer 2:

The research team has shown strong preliminary accomplishments across multiple project focus areas, with a clear indication that the project is on track and already producing insights and progress. While timing may slow as experimental and integration issues arise, tasks are clearly progressing well with an emphasis on continued development and creation of research insights. The detailed Future Work slide is also helpful to clarify for the reviewer what items are being executed within the overall project timeline, strengthening the impression that the project is moving along smoothly with objectives.

Reviewer 3:

The project seems to be progressing well, and the reviewer was looking forward to learning about the energy benefits.

Reviewer 4:

The results shown with various scenarios (V2V, V2I, multi-light versus single light) were very interesting to this reviewer. Is the 6% improvement in energy savings the results of 100% CAV penetration or lower? Also, are all vehicles controlled by the same algorithm? In reality, the reviewer explained that vehicles from different manufacturers will likely have different control strategies. Is there a possibility that this could reduce the achievable benefit? Are there scenarios where this could possibly worsen the outcome?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there is excellent collaboration between the software and hardware teams to achieve these results. It is good that the project has a source of OEM real-world data to study.

Reviewer 2:

At this early stage in the project, the collaborator roles appear to be sufficiently defined and detailed. Inclusion of other relevant DOE research projects is helpful to better understand how this project supports and is supported by multiple research projects, highlighting additional collaboration and integration with the overall

EEMS research portfolio. As the project transitions to more experimental and validation efforts, these roles may need to be detailed to a greater degree, but, for early-stage project development, the roles for various collaborators seemed adequate to the reviewer.

Reviewer 3:

The reviewer said that the project team seems to be collaborating well.

Reviewer 4:

The reviewer remarked that validation data from GM with supercruise should help improve model quality. Are there plans to include data from vehicles with higher levels of autonomy in the validation process? Also, would the work-at-home due to the pandemic adversely impact the amount of driving data that would be 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research clearly outlines next steps for the project across all phases and subcomponents. It was clear to the reviewer where the project is headed, and, at this time, the future research clearly aligns with the stated overall project objectives.

Reviewer 2:

Proposed research looks good and is a full slate.

Reviewer 3:

The next steps are appropriate extensions of the current work done so far. The reviewer looked forward to more results from this project.

Reviewer 4:

The reviewer stated that proposed future research is reasonable and appeared to be in line with the original project scope.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that the way AVs are controlled can potentially improve energy efficiency significantly. Understanding the impact of controls on energy efficiency directly supports the DOE objective of improving energy efficiency.

Reviewer 2:

According to the reviewer, the stated project objectives of developing, refining, and demonstrating CAV strategies are strongly in support of overall DOE research goals. The later project objective of integrating these controls into realistic traffic scenarios is also important to further refine and validate developed controls to ensure overall system improvements and avoid unexpected system-level complications.

Reviewer 3:

The reviewer said that the project demonstrates reduction to practical implementation of ideas for improved mobility system efficiency (e.g., energy and congestion reduction) when CAVs are considered in it.

Reviewer 4:

The reviewer noted that the project supports overall DOE objectives by adding energy efficiency considerations to CAV controls.

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

Reviewer 1:

The project is operating well with the available resources. The reviewer had no indication that some tasks cannot be completed with the current allocations.

Reviewer 2:

The budget appeared adequate to the reviewer as the project integrates additional effort from several other DOE research efforts and projects.

Reviewer 3:

Resources appeared sufficient to the reviewer.

Reviewer 4:

Sufficient resources were noted by this reviewer.

Presentation Number: eems095
Presentation Title: Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use
Principal Investigator: Timothy Laclair (Oak Ridge National Laboratory)

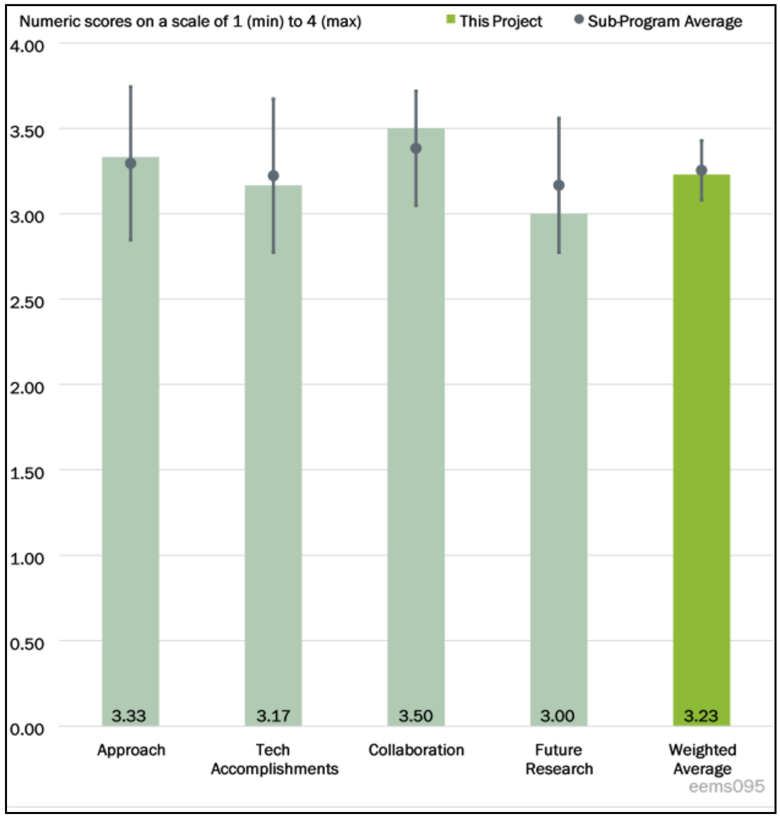


Figure 3-19 - Presentation Number: eems095 Presentation Title: Integrated Control of Vehicle Speeds and Traffic Signals for Reducing Congestion and Energy Use Principal Investigator: Timothy Laclair (Oak Ridge National Laboratory)

Presenter

Timothy Laclair, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project approach is solid. The reviewer suggested that the team should place less emphasis on Vissim simulation and more emphasis on on-road field evaluations.

Reviewer 2:

The reviewer commented that the overall project approach seemed to be very strong, with a mix of partners and parallel project development tasks. Integrating both vehicle and infrastructure controls within a realistic environment is a strong overall direction for this project. Integration of a spectrum across simulation, laboratory, and in-field work shows promise for strong conclusions and support for the project's stated objectives of understanding CAV technologies in real-world operation. Project partners also provide a strong avenue for implementation of development insights and controls as the project includes both a vehicle OEM, infrastructure provider, and department of transportation. Work is set to address the challenges highlighted in the discussion, but it remains to be seen how difficult these actual implementation challenges will be within a real-world set of conditions.

Reviewer 3:

While this project has similar objectives to several other projects that address CAV benefits, it appeared to the reviewer that it achieves the objective differently—by controlling traffic signals. The targets for energy/fuel savings would actually depend on how efficient the vehicles are in the first place, and this reviewer did not necessarily agree with the hard targets such as 15% or 0.09 L of fuel, without specifying the reference vehicle. Obviously, a Toyota Prius would not achieve the same reduction in fuel consumption as a Dodge Ram 3500 truck.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer stated that the project appears to be on schedule and several accomplishments have been provided at this early stage within the project. Parallel and later tasks appear to be progressing well.

Reviewer 2:

Although the project has been underway for a short time only, this reviewer stated that good progress appears to be made with the traffic signal control algorithm. Presumably, this is specific to the particular stretch of road under consideration, and would have to be developed separately for a different stretch of road.

Reviewer 3:

The project appeared to be progressing well from this reviewer's perspective.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project has a very strong set of collaborators, and roles and responsibilities appear to be well defined during these early phases of project execution. As the project progresses, the reviewer noted that it will be interesting to understand how the different groups interact for decisions and engineering that crosses into multiple domains, such as integrated vehicle and traffic control. At this point, the roles seem well defined and matched to contributors' strengths.

Reviewer 2:

A good mix of companies/organizations in the team was noted by this reviewer. Because there are other, similar projects underway at other labs, the data that is collected/generated in this project may be used for those other projects as well.

Reviewer 3:

The team has a clear delineation of tasks for each organization. The reviewer remarked that the collaboration and coordination seem to be going 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed plan looked good to this reviewer.

Reviewer 2:

The reviewer indicated that, at this point, future research and highlighted challenges seemed adequate to address future project execution and plans discussed in the initial Approach slide, but current discussion appears more focused on the development of the controls and simulation efforts. While it is likely already planned, a detailed set of gate and debugging phases for the transition from simulation to hardware development and in-field execution would be helpful to highlight how some of the difficult implementation challenges will be addressed without delaying the project significantly if any sizable issues arise. The CAVE Laboratory is likely an avenue for the vehicle side of these efforts, but it would be helpful to see some possible steps within the corridor discussion as well since it does begin within the discussed timeframe. Items mentioned for the controls development and Real-Time Mobility Communications and Control System (RyThMiCCS) preparation appear to support overall simulation project goals.

Reviewer 3:

The proposed future research appeared to be reasonable to the reviewer. As mentioned above, it would be nice to see more field evaluation than the Vissim simulation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Research efforts for understanding, developing, and validating CAV-enabled strategies within realistic operating scenarios and traffic conditions are directly applicable to DOE objectives. The inclusion of both vehicle and infrastructure systems is also highly relevant to DOE objectives as the project team works toward an overall systems approach for energy savings. The reviewer noted that identifying and addressing the practical challenges associated with CAV strategies is of great importance to both the research and industrial communities.

Reviewer 2:

According to the reviewer, CAV controls for energy efficiency are relevant to DOE's overall objectives.

Reviewer 3:

As with several other CAV projects, the reviewer indicated that this can contribute directly to improving energy efficiency.

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

Reviewer 1:

Resources seemed adequate to the reviewer for a large and multi-faceted project. The cost share also shows a strong interest from industry that this is a relevant and important project. As in-field testing progresses, unexpected costs may arise, but integration with the CAVE facility and other related projects may help offset expected budget issues without significantly reducing research outcomes by balancing simulation, laboratory, and in-field efforts.

Reviewer 2:

This reviewer described resources as sufficient.

Reviewer 3:

The reviewer said that resources are sufficient.

Presentation Number: eems096
Presentation Title: Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity
Principal Investigator: Thomas Wallner (Argonne National Laboratory)

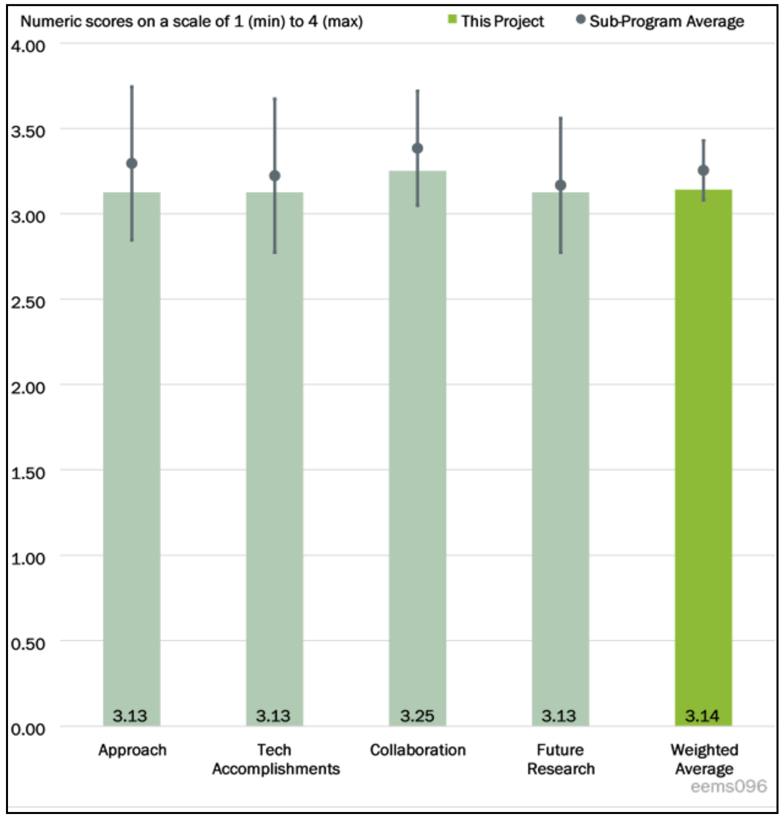


Figure 3-20 - Presentation Number: eems096 Presentation Title: Characterizing Behaviors and Capabilities for Emerging Connected and Automated Vehicle Technologies, Sensors, and Connectivity Principal Investigator: Thomas Wallner (Argonne National Laboratory)

Presenter

Thomas Wallner, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is well designed to obtain the necessary data, given the limitations on availability of vehicles with the CAV technology to be studied. The reviewer stated that the project also overcomes the accessibility of information in vehicles with CAV-related technologies.

Reviewer 2:

The reviewer explained that this project is somewhat similar in scope to some of the other projects involving CAVs/AVs, and addresses the aspect of improving existing models with data available for production CAVs. One interesting aspect of this project is that it utilizes a Tesla Model 3 Autopilot, which perhaps has a higher automation level than vehicles that some of the other projects propose to use. The reviewer indicated that the data obtained here (with Tesla and the Cadillac CT6) could be very valuable for several other projects that are looking to evaluate energy efficiency benefits of CAVs, or are trying to develop better CAV/AV models for use in the SMART workflow.

Reviewer 3:

The reviewer noted that the overall approach is good and seeks to address barriers in the real-world use of CAV technologies. This research is timely because of the rapid advancements in CAV deployment and interest in the technologies. The reviewer appreciated centering the voice of the customer in the project design, which will help with scaling up the research and deployment.

With rapidly expanding CAV technologies from OEMs like Tesla, this reviewer asked how the project team will incorporate software updates and advancements in on-board technologies.

Does the scope of the project become too large with factoring in available CAV technologies for light-duty vehicles (LDVs) versus available CAV technologies for medium-duty vehicles (MDVs) and heavy-duty vehicles (HDVs)? In addition, does the project team expect to test on-road MDV and HDV CAV technologies?

What metrics will be used to define success or progression on the project? Understanding the identified key metrics may help with finding the sweet spot for balancing data collection and management.

Reviewer 4:

Although the approach is reasonable, the reviewer wondered how representative the project findings will be of the wider range of available technologies.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer opined that great progress has been made on identifying the data that need to be collected, developing a means to collect those data, and adding sensors to get data (e.g., light detection and ranging [LIDAR]) where data are not readily available.

Reviewer 2:

The reviewer commented that the project as described is on track and hitting milestones. Results of the industry and stakeholder CAV status and research survey were fascinating and eye opening. Some of the feedback is behavioral, and the reviewer asked how the project team will incorporate these findings into the overall research. The reviewer also asked what the project team will be using to measure energy efficiency and energy savings for the project.

Expanding on the MDV and HDV research for on-road and lab studies will be helpful as the project continues moving forward. The reviewer understood that agreements were being negotiated at the time of the presentation submission.

Reviewer 3:

The reviewer indicated that the project appeared to be progressing well.

Reviewer 4:

Although the project is relatively new, this reviewer noted that the completed survey shows some interesting results on CAV adoption. Test results of the CAV sensors should be compared with the claims of the manufacturers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed excellent collaboration with the Society of Automotive Engineers (SAE) and other laboratories that would utilize the data collected.

Reviewer 2:

This reviewer observed good collaboration with other labs, SAE, and other organizations.

Reviewer 3:

The collaboration between the labs is coordinated and moving forward. However, with the challenges and barriers identified in the survey, additional industry and fleet partners may strengthen the overall outcomes, especially for getting fleet and driver acceptance on wider scale deployment of CAV technologies.

Reviewer 4:

The reviewer did not see any issues with collaboration or 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research is defined and seeks to address challenges that have be identified, especially with MDVs and HDVs. It was encouraging for the reviewer to hear that the agreement with Cummins and the Colorado DOT has been executed and work will begin with those two entities.

Reviewer 2:

Proposed future research looked good to this reviewer, who indicated that there is ample opportunity to provide valuable data to several other DOE-funded projects with the proposed research.

Reviewer 3:

The reviewer commented that the next steps are a logical extension of the current work.

Reviewer 4:

Proposed future research appears to be in line with the remainder of the project scope. As mentioned above, the reviewer would have liked to see the team address the sample representation question in the remainder of the project. What can the broader community learn and generalize from the findings of this study?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that CAV technologies are being developed and adopted at increasing rates. This project seeks to narrow assumptions and uncertainties from existing and theoretical data. This is aligned with DOE and EEMS objectives of data sharing, increasing understanding of new and innovative technologies in transportation, and understanding the transformations in this technology.

Reviewer 2:

Data collection on CAV technologies that is not proprietary to OEMs allows DOE to study technology without constraints. The reviewer noted that this is valuable for ongoing DOE studies involving CAVs.

Reviewer 3:

The reviewer commented that results of this project could provide valuable information to other projects that are working to understand the energy efficiency benefits of CAVs/AVs.

Reviewer 4:

According to the reviewer, the energy consumption characteristics learned from this project are relevant to DOE's overall objectives.

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

Reviewer 1:

Resources appeared adequate to the reviewer. The team has done a good job considering this information is not readily obtainable.

Reviewer 2:

Resources appeared to be aligned with the project scope from this reviewer's perspective.

Reviewer 3:

The reviewer said that resources are sufficient.

Reviewer 4:

Resources were sufficient to this reviewer.

Presentation Number: eems097
Presentation Title: Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE)
Principal Investigator: Andrew Duvall (National Renewable Energy Laboratory)

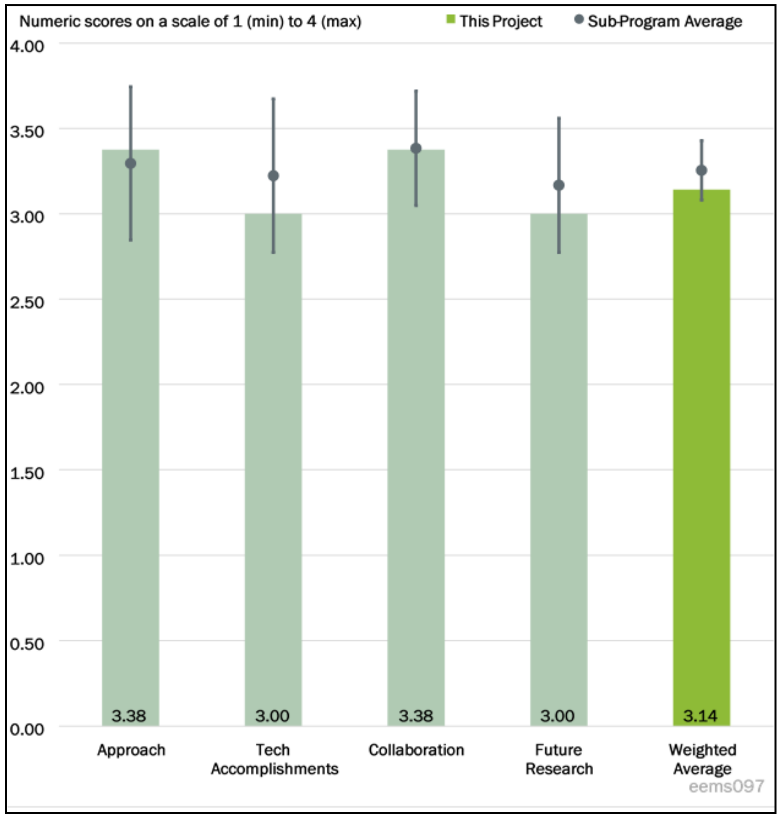


Figure 3-21 - Presentation Number: eems097 Presentation Title: Micromobility-Integrated Transit and Infrastructure for Efficiency (MITIE) Principal Investigator: Andrew Duvall (National Renewable Energy Laboratory)

Presenter

Andrew Duvall, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked this research topic and approach and though that it will be important to get the overall energy usage quantified for these micromobility modes. Those data could also be used to anchor some of the energy costs in the business models to determine viability. There has been come consolidation and turnover in some of the commercial entities so that could help to stabilize some of the operations.

Reviewer 2:

According to the reviewer, the researchers have a good approach to addressing a complicated issue in which there are generally limited data. The first stage of this work is nearly completed, with the important next stage of model development ongoing.

Reviewer 3:

The approach focuses on areas of micromobility that are not yet well understood, such as energy use, integration with transit, energy optimization, and micro-freight. The reviewer asserted that integration of findings with SMART Mobility Comprehensive Regional Evaluator (CORE) tools will enhance workflow models, add micro freight, and impact on curb space.

Reviewer 4:

The approach indicates thoughtful design of scenarios and an overall analytic process that is designed to provide data for the MEP metric. The reviewer suggested that an additional design aid may be to show how the selected scenario parameter bounds generate variability and sensitivity in the MEP metric and the degree to which the potential MEP parameter is addressed by the scenario parameters chosen.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

While this project was just started in FY 2021, the reviewer said that good progress has been made in all five tasks, including literature review, sample vehicle instrumentation, industry stakeholder connections for freight micromobility data collection, and analysis of trip-level micromobility data from a dozen cities.

Reviewer 2:

It appeared to the reviewer that the research has made good progress in gathering baseline data and developing a model framework in an area where information is limited to date. The project team has already developed a number of publications and presentations on this research that supports that the work is being accepted as relevant within the technical community.

Reviewer 3:

The reviewer stated observed that this project is really just getting started. Completing the literature survey was good before getting to the rest of the program elements.

Reviewer 4:

It may be useful to add an analysis of the possible correlation, dependencies, and orthogonality relationships of the scenario independent variables. Micromobility may be significantly affected by the seasons and weather events. The reviewer suggested that scenarios designers may want to consider adding weather parameters as independent variables.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that collaboration is well covered and includes co-PIs from LBNL and ANL as well as complimentary research from PNNL. Collaboration also includes two universities (Colorado and Massachusetts Institute of Technology [MIT]) and EPA as well as nearly a dozen industry stakeholders that help inform the approach, contribute data, and provide valuable insights on this fast-changing industry.

Reviewer 2:

The team incorporates a good group of researchers, and they have built solid collaborations with a number of cities and other stakeholders. It will be exciting for the reviewer to see how the model can be integrated into city planning as it continues to develop.

Reviewer 3:

According to the reviewer, there is a good and wide diversity of partners and data sources that will lead to more robust modeling.

Reviewer 4:

The reviewer commented that the project stakeholders that are providing insights and data appear to be a diverse 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Future research areas are well laid out but the challenge, as acknowledged, will be collecting detailed trip data from ongoing micromobility operations due to the business sensitive nature of the information. Additionally, the micromobility industry is evolving very rapidly and it is important to stay on top of the latest trends (i.e., complete shift from docked bicycles to dockless electric scooters in less than 3 years). Nevertheless, the reviewer asserted that the data planned to be collected over the next 2 years of this project will provide great insights for modeling and the different micromobility scenarios for the BEAM CORE tools.

Reviewer 2:

It looked to the reviewer as if the researchers have made good progress toward developing a modeling framework and preparing for the initial scenarios for micromobility. It will be interesting to see how far the researchers will get with the model framework over the next year, which will feature some of the key milestones in the project. It will also be interesting to see the extent to which the model can be expanded in Year 3.

Reviewer 3:

The reviewer recommended that the research team approaches some of the corporate partners to develop a cell-phone based market survey that could help support some of the Fundamental Influencing Factor (FIF) data. The application could pop up at the end of a ride or usage and help get more customer input on the mode selection.

Reviewer 4:

The reviewer found that the proposed future work is logical for contributing to the overall project objectives.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer believed that these are important and new transportation options for urban and suburban applications. More research in this area is very relevant. Research in this area appears to just be getting started and understanding the energy picture and decision-making on what influences mode selection will be important to help these new transportation modes migrate to other cities and communities.

Reviewer 2:

The area of micromobility is going to be an important piece of developing an overall strategy for improving mobility options going into the future. There are still limited data, but these data will be important for developing strategies around FMLM solutions for bus and rail transport users. This project should provide some important information on filling the gaps on micromobility.

Reviewer 3:

According to the reviewer, this project supports energy efficient systems modeling by collecting and studying data of micromobility modes whose energy impacts have not been well understood. Indirectly, the findings of this research will contribute to reduced energy use, increased energy security, and use of clean energy to move people and goods.

Reviewer 4:

The reviewer said that this project supports DOE's objectives to explore potential energy characteristics and impacts associated with advanced mobility concepts.

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

Reviewer 1:

The project has an annual budget of nearly $1 million, which seemed appropriate to the reviewer and given the importance and breath of scope as well as multi-partner collaboration and coordination.

Reviewer 2:

The researchers appear to have made good progress toward data collection and the micromobility area where limited data are available. The reviewer stated that the researchers have used on appropriate share of the funds during the first year to allow for a successful completion of the project.

Reviewer 3:

The reviewer asserted that the project has been productive in producing scenario parameters with the resources provided.

Reviewer 4:

The reviewer did not have a good feel for the resources needed on this project in order to provide any objective comments. Being that this is fairly early in the project cycle, the reviewer rated resources as being sufficient without much knowledge.

Presentation Number: eems098
Presentation Title: Optimizing Drone Deployment for More Effective Movement of Goods
Principal Investigator: Victor Walker (Idaho National Laboratory)

Presenter

Victor Walker, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

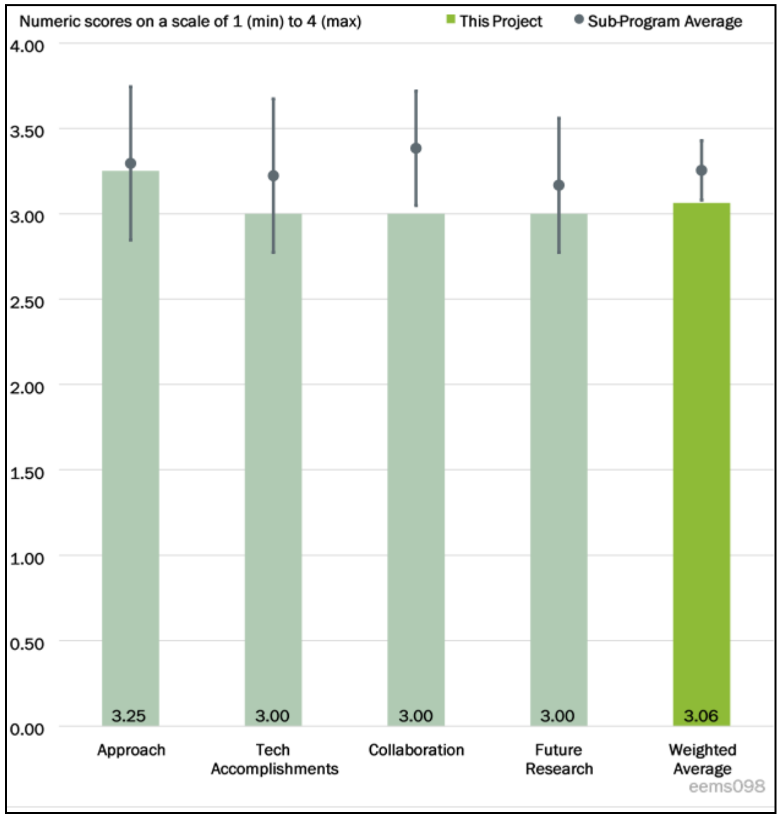


Figure 3-22 - Presentation Number: eems098 Presentation Title: Optimizing Drone Deployment for More Effective Movement of Goods Principal Investigator: Victor Walker (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer stated that the research is timely and needed in understanding goods movement using drones. The reviewer appreciated the timeliness of seeking to understand the need for open data and an understanding of the most energy efficient way to manage and deploy drones for goods movement. This information and research will assist in making regulations and understanding the total impacts of this technology. The reviewer wanted to know what metrics the research team will be using to understand total energy usage for drone delivery scenarios and asked whether these metrics will be built out with industry input.

Reviewer 2:

Subject to availability of additional industry partners, the reviewer noted that work detailed in the presentation matches the stated project goals well. The integration of both laboratory and in-field work should provide a unique and robust set of data not typically offered for these types of systems. While not entirely clear from the presentation, the optimization work should also benefit from the ability to validate and iterate upon real and emulated scenarios. One area for additional development and reporting would be the techniques expected to be used for the drone simulation itself, as it was not entirely clear to the reviewer how this will be handled within this project. This detail will likely be refined in future presentations as work continues, so at this early stage of project execution this is acceptable as an initial overview. The selection of future airframes and mission profiles to support industry and researcher-centric questions will be important going forward to ensure that the developed data and insights are most applicable to solving the project objectives of available data, uncertainty reduction, and risk mitigation.

Reviewer 3:

Although the project intent has merit, the reviewer noted the number of independent variables in real-world operations is too large, given the available resources. The reviewer suggested that the project team should consider rescoping to focus on calibrating a suite of sensors with a drone and validating a smaller set of energy consumption models and algorithms in a wind tunnel environment where variables can be accurately measured and controlled. After the wind tunnel phase is completed, the project team could consider moving to uncontrolled and real-world environments.

Reviewer 4:

The reviewer said that this is a good approach for the specific drone freight movement needs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project team is clearly making progress in performing work on the stated plan. In doing the work, the reviewer opined that the team is discovering the significant complexities associated with the experiments.

Reviewer 2:

Progress to date is good, but there were challenges with the drones and components. It was clear to the reviewer that the challenges with the drones and equipment were causing some delays in the drone testing. In addition, limited industry engagement was flagged (e.g., Kroger and Walmart) as a barrier that would need to be addressed.

Additional information on battery cycling and performance may be helpful for decision-making, especially over varied geographies and terrains.

Reviewer 3:

The reviewer indicated that the project has just started, objectives and progress seem to be on track as experimental work has begun. Based on the presentation, it was not entirely clear to the reviewer how far along the individual experimental pieces are in the debugging, experimental development, or execution phases. For the optimization portion of the work, it is not clear if this is just beginning or waiting for input from the experimental results to begin development. Although the presentation mentioned specific scenarios of interest and that energy is impacted for the scenarios, the reviewer was unclear if this has been estimated through the optimization work or if it represents expected performance to be validated later.

Reviewer 4:

In the past few years, the reviewer has seen a decrease in evidence presented in these AMR reviews to confidently share that technical accomplishments have been made. Specifically, more metrics on efficiency are needed. The reviewer liked the suggestion for freight efficiency, which was kilowatt-hours per pound (kWh/lb).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer opined that additional collaboration with industry partners will be helpful and necessary as the project moves forward, especially as the team begins to consider delivery routes and options. Feedback from vendors (e.g., Kroger, Walmart, Amazon, etc.) will be helpful as they will have inputs on business models related to the three major scenarios for deliveries.

The PI did mention several barriers with current regulations related to the Federal Aviation Administration (FAA) and that may be one of the biggest challenges to wider scale development and future research. The reviewer indicated that it may be beneficial to include more coordination and collaboration with the FAA to address the regulatory and policy challenges as this project moves forward.

Reviewer 2:

The plan to coordinate the work of the partners appears to be balanced throughout the project. The reviewer suggested that the project may want to introduce another partner with extensive aerodynamics testing experience as an advisory consultant.

Reviewer 3:

While the multi-laboratory approach appears promising, more detail about Carnegie Mellon University's (CMU) role in the overall project would be helpful. Also, additional collaborators from delivery operators or industry would help highlight any relevant items and considerations that may need to be updated or refined within the later experiments. The presenter mentioned challenges with obtaining industry collaborators and input, but the reviewer stated that this is likely an area for continued effort as it would add strong additional inputs to the research team. It would be helpful to also highlight if and how these efforts will inform other ongoing DOE drone efforts and projects.

Reviewer 4:

There seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed there should be more effort on fleet and other engagements in these 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that the team has good plans.

Reviewer 2:

This reviewer commented that proposed future work may have merit after a more structured set of experiments and model validations have been accomplished.

Reviewer 3:

The proposed future research is targeted at overcoming identified challenges. The reviewer appreciated that this project will build a foundation for developing drone regulations, understanding drone energy usage, and identifying data for industry needs. The reviewer asserted that one area that needs strengthening is inclusion of more industry partners and collaboration with the FAA on regulations. These partnerships and collaboration will assist in moving this project from the laboratory to real-world deployment.

Reviewer 4:

As the project is just beginning, areas of future research are still developing; areas highlighted for emphasis include more industry collaboration and additional airframes, which seemed reasonable to the reviewer. In future years, it would be desirable to highlight areas of the most energy uncertainty and where the DOE research investment might aid in reducing the largest degree of uncertainty relative to drone delivery and related maneuvers. While difficult, more industry participation would likely strengthen the identification of additional research needs as well. In future presentations, more detail regarding the next steps would be helpful within the discussion as the current future topics are a bit open ended. For example, aside from just the topic title, the optimization side of the project is not directly mentioned within the Future Work slide or discussion.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The timeliness of this project is aligned with the DOE objectives of accelerating the development and deployment of advanced technologies. In addition, the research is focused on optimizing routes and energy for goods movement, which is aligned with DOE objectives and goals. The reviewer praised the work as well done.

Reviewer 2:

According to the reviewer, this project has the potential to be very relevant to achieving the DOE objectives of characterizing the energy consumption characteristics of advanced mobility concepts (e.g., commercial drone deliveries). The project's objective of performing experiments to inform energy consumption models is relevant to achieving DOE's overall goals.

Reviewer 3:

The project supports the increasing need for accurate data and characterization of drone operation to enable an accurate and robust assessment of the energy implications of drone delivery within the context of an overall transportation system. While it was unclear to the reviewer if providers of drone delivery will consider the energy implications of drone delivery (versus speed, cost, etc.), this is an important item for DOE to understand and provide research upon.

Reviewer 4:

The reviewer affirmed that, yes, the project supports 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:

The reviewer found that project resources are sufficient.

Reviewer 2:

The resources are sufficient to achieve the scope of the project and the milestones outlined in the 2-year project. The reviewer said that further research or continuation of this project will need to be addressed.

Reviewer 3:

Resources seemed appropriate to the reviewer for current research directions discussed in the presentation. As additional, larger air frames begin to be considered, the overall cost of obtaining new and relevant airframes may begin to pressure some of the overall budget depending on the desired directions.

Reviewer 4:

The reviewer remarked that additional resources are needed to successfully achieve the stated objectives of the project. As stated earlier, the complexity of the field of study and the large number of independent variables requires more structured experiments and model development than current funding levels afford.

Presentation Number: eems099
Presentation Title: Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

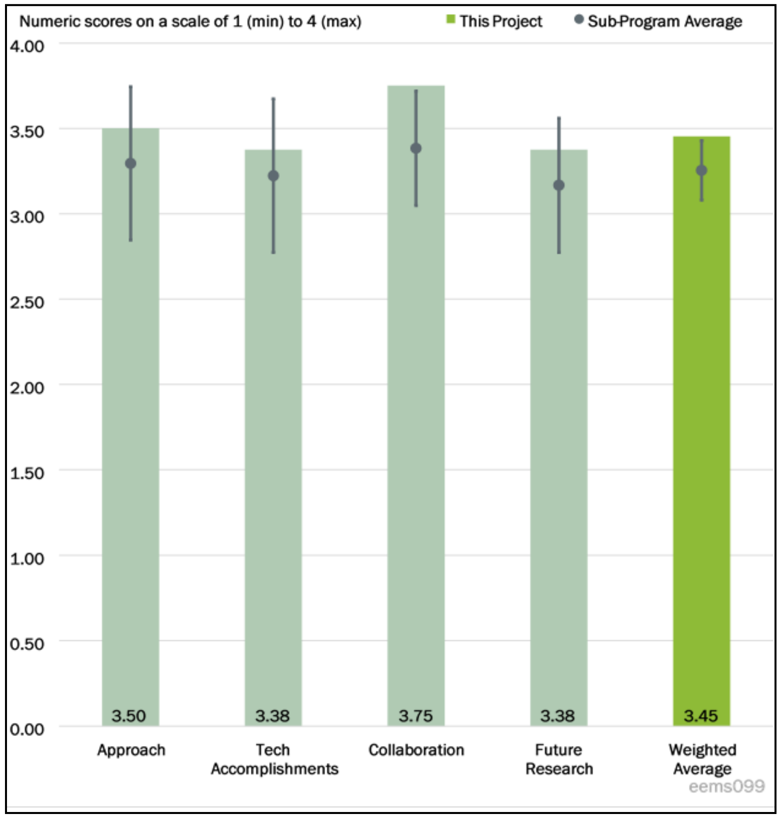


Figure 3-23 - Presentation Number: eems099 Presentation Title: Metrics for Assessing the Impacts of Energy-Efficient Mobility Systems Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer applauded the project's approach for this period of performance as excellent because it addresses cohort-specific preferences and utility functions when calculating the MEP metric. This approach adds a new level of sophistication to the MEP metric analysis.

Reviewer 2:

MEP provides a unified framework for quantifying the mobility and energy impacts of transportation investments and technologies. The reviewer opined that the new, person-based Individual Experience Utility-based Synthesis (INEXUS) metric is an interesting concept that seems to complement the location-based MEP metric well.

Reviewer 3:

The researchers seem to have a thoughtful approach to performing the work and have made good progress on gathering data to allow for the development of the calculations. The reviewer stated that this data analysis is worthwhile in breaking down technical barriers in understanding questions related to mobility.

Reviewer 4:

This project seemed adequate for the research from this reviewer's perspective. With the organizations that are lining up to use the MEP metric, it will be important to evaluate the application in a wide enough set of cities and mobility situations to create a robust model that can be of value across the nation, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project team has been making several enhancements to the MEP metric. The calibration of travel time coefficients for different trip purposes and travel modes seems like a step in the right direction. The reviewer looked forward to seeing the results of further enhancement from calibrating travel time coefficients for travelers with different sociodemographic characteristics or different values of time.

Reviewer 2:

The presentation provides clear explanations of theory and examples of analyses results. The reviewer commented that the results reflect significant progress and accomplishments toward the project objectives.

Reviewer 3:

It appeared to the reviewer that the performance metrics have been met for this project or are on track to be met. The completion of the activities for the first year should provide a good foundation for further development and enhancement of the methodology going into the second and third years.

Reviewer 4:

According to the reviewer, this seems like a good project that appears to be just getting started.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There are collaborations with organizations both inside and outside the SMART Mobility Consortium. The outside collaborations span across multiple types of organization (e.g., government, non-profit, university, and industry). The reviewer found the extent of some of the collaborations to be impressive.

Reviewer 2:

The reviewer observed an excellent set of partners on the project. As previously mentioned, having many of the American Council for an Energy-Efficient Economy (ACEEE) and other organizations wanting to use this metric is good for technology transfer and creating a market pull, which puts more value on this research.

Reviewer 3:

According to the reviewer, the examples of the collaboration with institutions indicate that this project is having a significant impact on mobility science in multiple parts of the United States.

Reviewer 4:

The team has good coordination and cross collaboration. It will be interesting to the reviewer if the researchers can look to continue widening partnerships with other DOTs and universities as the project evolves.

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 state project ended.

Reviewer 1:

Several enhancements to MEP are planned, which will lead to more refined and useful metrics. As the metrics grow more complex with additional factors (e.g., safety and infrastructure quality) taken into account, the reviewer asserted that it is important to ensure that the resulting metrics are meaningful and can be understood by policymakers.

Reviewer 2:

The reviewer commented that the researchers seem to have a good plan for moving forward with the work to an individual-level MEP metric and enhancements on emissions and safety.

Reviewer 3:

Although the reviewer did not have too much to say regarding proposed future research, it looks like it is on a fast track for adoption. As the reviewer stated previously, it would be good to evaluate a wide array of cities and transportation variables to make this into a robust model that will work wherever it is applied in the future.

Reviewer 4:

The future work proposed addresses additional MEP factors that include “common sense” attributes that resonate with real-world experience, according to the reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the ability to quantify and compare mobility and energy impacts of transportation investments and technologies is critical to DOE in assessing those investments and technologies. In addition, MEP has been a key metric used in projects within the EEMS program.

Reviewer 2:

Overall, it appeared to the reviewer that this metric is getting exposure and making a useful impact on characterizing mobility. Given the importance of understanding mobility in changing the landscape of transportation options through the country, this work appears to be well positioned to support DOE’s overall objectives.

Reviewer 3:

This reviewer explained that having metrics allowing comparisons between different transportation modes, situations, and options seemed like exactly what is needed to help transportation planners make relatively objective decisions.

Reviewer 4:

The reviewer said that this project directly supports DOE’s objectives to assess the energy characteristics and impacts of advanced modes of mobility.

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

Reviewer 1:

The project results presented are significant and reflect an efficient and productive use of resources, according to the reviewer.

Reviewer 2:

It appeared to the reviewer that the researchers have made good progress in the first year of the project with the allocated project funds.

Reviewer 3:

The reviewer found that the level of project funding is reasonable.

Reviewer 4:

The reviewer was not too familiar with this modeling and, given that this project is just getting started, the reviewer rated the resources as sufficient for now.

Presentation Number: eems100
Presentation Title: Dynamic Curb Allocation
Principal Investigator: Chase Dowling (Pacific Northwest National Laboratory)

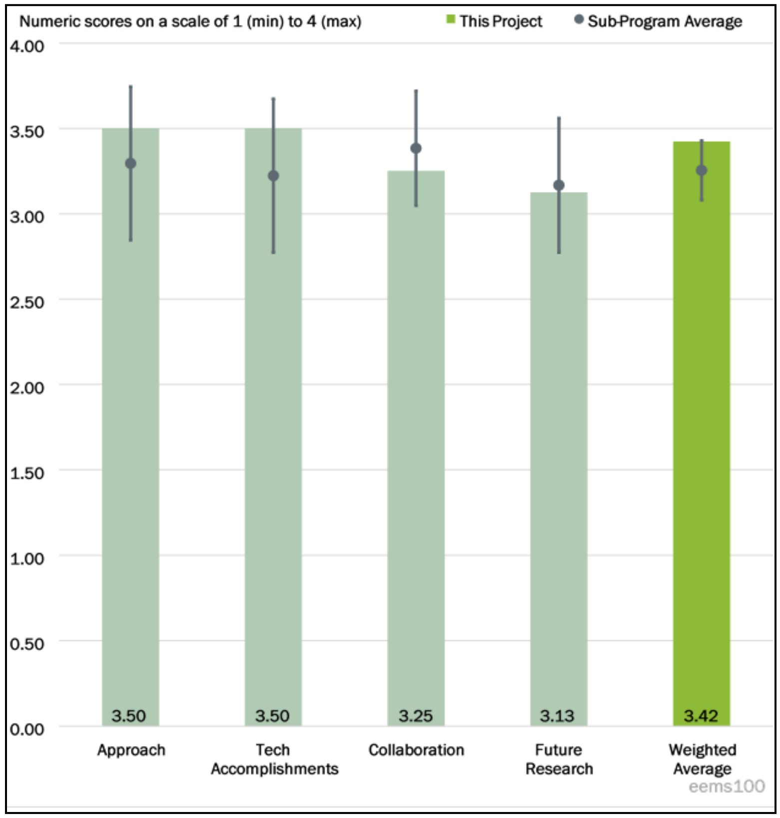


Figure 3-24 - Presentation Number: eems100 Presentation Title: Dynamic Curb Allocation Principal Investigator: Chase Dowling (Pacific Northwest National Laboratory)

Presenter

Chase Dowling, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the presentation as well done and great. The reviewer appreciated the level of detail and the attention to curb metrics for internal and external user utility. This project seeks to address increasing complexities of curb usage in the United States and the impacts of energy usage and congestion and, as well as understand how curb utility can be translated across the country. The project team is making good progress on the development of the scope and simulation.

The reviewer wanted to know if the project team will be developing metrics for energy efficiency between different vehicle fuel types. Will the team be building in metrics for cost and time savings? Is the project team considering energy savings and use between an LDV, MDV, and HDV, and how will the curb zoning be used? It seems that measuring changing curb dynamics throughout the day, vehicle types, vehicle flow, and other factors could create a large amount of data to process. Has the team considered this? If this is determined to be a challenge, how will the team address finding the right amount of data for processing?

Reviewer 2:

According to the reviewer, the researcher laid out a thoughtful research plan for addressing technical barriers and issues associated with curb space management and its impacts on traffic flow and energy use. The approach utilizes previously developed performance metrics for defining optimal curb zoning, developing a microscale simulator for assessing fundamental diagrams associated with various curb configurations, and using an existing tool (BEAM) for assessing broader system-level impacts. Later phases of the project will involve stakeholder input (municipal and commercial partners) to test simulations of optimal curb space allocations. The approach includes reasonable milestones for meeting overall project objectives.

Reviewer 3:

The reviewer enjoyed seeing the team's approach to the work and liked how the team outlined the approach on each page, making it very easy to follow.

Reviewer 4:

The reviewer commented that the research team has a good overall approach to implementing the microsimulation tool. The approach includes the development of the microsimulation, its validation, integration into BEAM, and then the partner engagements. It seemed that the researchers will go full circle by the completion of this effort.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project team has made excellent progress on the project. The presentation covered the development and deployment of the microscale simulator, which has yielded interesting data. The reviewer also appreciated the progress and explanation of the net user utility from the system and user perspective. For the project being in its first year, great progress has been achieved to this point.

Reviewer 2:

The research seems to have made good progress in the first year of the study with the development of the microsimulation tools. The researchers were able to provide a visual aid for the work, which the reviewer found useful. The presentation did include a lot of mathematical terms that might not necessarily be common knowledge to a broader audience, so that might be something to consider in the presentation for next year.

Reviewer 3:

The team has an interesting approach on modeling. The reviewer had not thought about this problem before, but can see how this "change in business approach with deliveries" can truly impact fuel usage, EV charging, pollution, DOT issues, etc.

Reviewer 4:

The reviewer noted that the research team has made reasonable technical progress to date as related to project milestones. The team reported completion of two milestones to date, including the selection of the microsimulation tool and development of microsimulation results by vehicle type. The team is also currently planning and scoping the validation process and has initiated the integration of the microscale simulation outputs into the BEAM tool, which will serve as the primary go/no-go activity for the project. The researcher estimated that about 25% of the project effort has been completed thus far, which is generally in line with a project completion of September 2023.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The research team exhibited excellent and well-coordinated collaboration involving other national laboratories, a university, and an urban mobility data company. The reviewer stated that the roles of each partner were well defined and integrated into the research plan for providing services, tools, and data for supporting project objectives.

Reviewer 2:

The reviewer thought that cooperation and collaboration are a good place to start. The reviewer was familiar with the streets of Seattle, making it easy to understand.

Reviewer 3:

This project has good collaborations between national laboratories and other partners (about 35%) and a strong team. The reviewer suggested that the researchers could emphasize some of the collaborations with cities, such as Seattle and Bellevue, as well as mentioning Miami during the presentation. It will be interesting to see if the number of cities can be expanded over the next few years as the work develops and as city and commercial partner engagements are expected to be expanded.

Reviewer 4:

The collaboration and coordination between the team is good, but there may be room for additional collaboration between users (delivery companies, transportation network companies [TNCs], etc.) to understand the need and use of curbs throughout a given timeframe. The reviewer understood that Bellevue and Seattle are the two target cities but wanted to know if there are other cities that will be included in the study in other states. How will these stakeholders be engaged to account for different laws and regulations that dictate curb usage?

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 state project ended.

Reviewer 1:

Overall, the reviewer noted that researchers have made good progress in the microsimulation development that will allow its refinement and broader implementation going into the future. The researchers appeared to have a well-thought-out plan on how the microsimulation validation will be carried out, as well as the integration into BEAM. Finally, the researchers have incorporated engagements with city and commercial partners as well as test simulations for curb allocation policies into the planning, which could allow for the implementation of this microsimulation upon the completion of the program.

Reviewer 2:

The reviewer commented that the future research plan included appropriate milestones that build off pervious work as well as a go/no-go decision point. The project team has attempted to address remaining challenges in its research plan. To maximize the transferability of stateful fundamental diagrams (FDs), the team is considering effective sampling strategies or a more general governing function. To complete validation efforts in Milestone 3, the researchers are collaborating with stakeholders to gain access to specialized data. To facilitate achievement of Milestone 4, the team will be garnering input from municipal stakeholders. The researchers may also incorporate other exogenous factors like weather, topography, and vehicle mix into future research plans.

Reviewer 3:

According to the reviewer, the project team has identified future research and how to build on the findings from this project.

Reviewer 4:

The reviewer opined that the proposed future research is satisfactory and needs more thought, especially with V2I at both the "V" and "I," in terms of sensors, standardization of sensors, non-hackable sensors, etc. This could be an interesting boundary diagram.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Although this might be a newer area, curb allocation can be an important issue in bigger cities where there are many competing interests for curb space. As the scope of mobility expands going into the future, the reviewer said that this project will generate important information that can be used in conjunction with other mobility modeling tools to provide a comprehensive assessment of how mobility options can be improved going into the future.

Reviewer 2:

According to the reviewer, this project is aligned with EEMS and DOT objectives by understanding how curb usage impacts congestion and energy usage in the transportation sector. The findings from this project will help understand how changing regulations and policies along curbs can impact the transportation system.

Reviewer 3:

Curb space management is a critical element of traffic flow management in congested urban settings. The reviewer said that effective curb space use can have significant impacts on traffic-associated energy use and mobility efficiency.

Reviewer 4:

The reviewer affirmed that, yes, this is relevant and quite interesting as deliveries increase. The reviewer commented it would be nice to see an overall slide on delivery increases.

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

Reviewer 1:

Resources appeared to be sufficient to the reviewer for achieving the stated objectives and milestones of the project. The research team estimates it has completed about 25% of the project to date (June 2021). The remaining budget for FY 2022 and FY 2023 activities will be about 62%.

Reviewer 2:

Based on the presentation, it was not totally clear to the reviewer how the funds have been spent. It looks like about $1 million of the total funds has been spent in FY 2020 and FY 2021. It does appear that the researchers have made good progress for approximately one-third of the budget and should be able to complete the objectives within the scope of work.

Reviewer 3:

This reviewer asserted that the project appears to be sufficiently funded.

Reviewer 4:

The reviewer said that the resources are good to start.

Presentation Number: eems101
Presentation Title: RealSim
Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

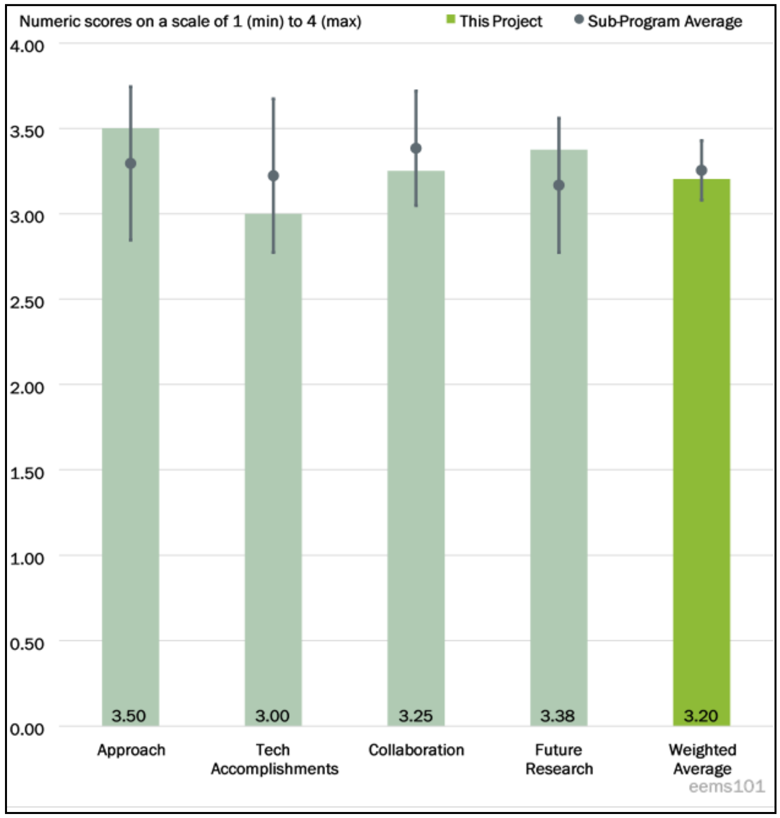


Figure 3-25 - Presentation Number: eems101 Presentation Title: RealSim Principal Investigator: Dean Deter (Oak Ridge National Laboratory)

Presenter

Dean Deter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project aims to create and assemble the building blocks of a system of systems for studying and simulating an ADAS and CAV systems. The approach of progressively building up these features in existing software simulation systems is a sound one, according to the reviewer.

Reviewer 2:

This reviewer asserted that the need identified by the ORNL team is real and successful completion of this project should help provide validation for several other projects involving CAVs and AVs.

Reviewer 3:

The reviewer found that the project approach is sound, and the technical barriers are being addressed. However, as discussed during the presentation, some of the technical barriers will continue to be challenging for the project time, such as working with various beta and prototype software and components and the computational requirements and complexity of the interconnected system of simulated environments.

Reviewer 4:

The reviewer suggested that the researchers might want to reconsider the DSRC environmental data usage in light of the November 2020 FCC decision to reallocate all of DSRC's spectrum for uses other than vehicle transportation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the technical progress is solid. The first deliverable involving the integration of sensor simulation into the perception stack is complete. The second deliverable requiring the demonstration of micro-traffic simulation functionality into Real-Sim is delayed due to COVID-19 (understandable). The third deliverable, which is a prototype platform with vehicle and infrastructure components, is on track.

Reviewer 2:

The project is relatively new, but this reviewer indicated that the team has done a good job of communicating requirements to the IPG Carmaker team and working with them to implement all improvements needed.

Reviewer 3:

Progress has been made despite limited access related to COVD-19 restrictions. The reviewer remarked that two of the three upcoming milestones are still on schedule.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that there is excellent coordination and collaboration between ORNL, ANL, ACM, and IPG CarMaker.

Reviewer 2:

According to the reviewer, a major strength to this project is the coordination with several other EEMS projects, such as EEMS096, EEMS095, EEMS067, EEMS061, and EEMS082.

Reviewer 3:

Good collaboration with the IPG team was noted by this reviewer. Working with ANL should also help provide the ANL teams with validation data in the future to validate the CAV/AV controls. Data collected at ANL on some of the other projects could also provide ORNL with potential test scenarios, etc. The reviewer further suggested that including an OEM as a partner could benefit the project by better defining OEM needs; while the primary purpose is not to meet OEM needs, it could provide valuable insight to the ORNL team.

Reviewer 4:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer praised the future plans as excellent. They involve continued work on sensor simulation and data stream emulation, the ANL prototype demonstration, deployment of field components, construction of the digital twin, and the design of appropriate scenarios for simulation and experimental correlation.

Reviewer 2:

Predictive roadway traffic conditions and environmental data are being adopted in the vehicle routing decision-making process. The reviewer suggested that considering this predictive aspect in addition to the existing setup that is based on real-time data might offer further capabilities.

Reviewer 3:

The proposed project plan looked good to this reviewer, and as previously indicated, perhaps an automotive OEM should be included among the collaborators to understand their perspective.

Reviewer 4:

The reviewer said that future work as described for the remainder of FY 2021 and FY 2022–FY 2023 is appropriate.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer found that this project is very relevant as it is building the test and evaluation environment necessary for assessing the potential energy savings of CAVs in a cost-effective manner.

Reviewer 2:

The coordination of ADAS systems with CAVs will bring increased efficiencies to transportation and yield further reductions in energy use, according to the reviewer.

Reviewer 3:

This reviewer stated that the project can provide validation to a number of other DOE funded projects that are aiming to understand the potential energy efficiency benefits of CAVs/AVs.

Reviewer 4:

Not applicable was indicated 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 commented that the budget of $3.58 million over 3 years is adequate for the planned tool development and experimental correlation.

Reviewer 2:

The resources appeared sufficient to achieve the milestones from this reviewer's perspective. However, given that this project is on the "bleeding edge" of research, there is the potential for unforeseen challenges that could lead to the need for additional funding.

Reviewer 3:

This reviewer remarked that resources are sufficient.

Reviewer 4:

Not applicable was indicated by this reviewer.

Acronyms and Abbreviations

ACEEE	America Council for an Energy-Efficient Economy
ACM	American Center for Mobility
ACT	Applications and Collaboration Tool
ADAS	Advanced driver-assisted system
AI	Artificial intelligence
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
AMBER	Advanced Model Based Engineering Resource
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	Application performance interface
APTA	American Public Transportation Association
ATCS	Adaptive traffic control system
AV	Autonomous vehicle
BEAM CORE	Behavior, Energy, Autonomy, and Mobility Comprehensive Regional Evaluator
BEAM	Behavior, Energy, Autonomy, and Mobility
CARLA	Computer-Assisted Related Language Adaptation
CAV	Connected and automated vehicle
CAVE	Connected and Automated Vehicle Environment
CDOT	Chicago Department of Transportation
CMU	Carnegie Mellon University
CO_2	Carbon dioxide
CORE	Comprehensive Regional Evaluator
COVID-19	Coronavirus disease 2019
CTA	Chicago Transit Authority
CV	Connected vehicle
C-V2X	Cellular vehicle-to-anything
DCRNN	Diffusion Convolutional Recurrent Neural Network
DOE	U.S. Department of Energy
DOT	[state or city] Department of Transportation
DOT	U.S. Department of Transportation
DSRC	Dedicated short-range communication

EcoCAR	EcoCAR Mobility Challenge Advanced Vehicle Technology Competition
EEMS	Energy Efficient Mobility Systems program
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FD	Fundamental diagram
FIF	Fundamental Influencing Factor
FMLM	First-mile and last-mile
FY	Fiscal Year
GM	General Motors
HDV	Heavy-duty vehicle
HPC	High-performance computing
HQ	Headquarters
INEXUS	Individual Experienced Utility-based Synthesis
INL	Idaho National Laboratory
IRB	Institutional Review Board
ITS	Intelligent Transportation Systems
kW	Kilowatt
kWh/lb	Kilowatt-hour/pound
LBNL	Lawrence Berkeley National Laboratory
LDV	Light-duty vehicle
LIDAR	Light detection and ranging
LoOP	Local outlier probability
MDV	Medium-duty vehicle
MEP	Mobility Energy Productivity
MFA	Multi-factor authentication
MIB	Management Information Base
MIT	Massachusetts Institute of Technology
ML	Machine learning
mph	Miles per hour
MPO	Metropolitan planning organization

NDA	Non-disclosure agreement
NGO	Non-governmental organization
NHTSA	National Highway Traffic Safety Administration
NREL	National Renewable Energy Laboratory
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
NVBL	National Virtual Biotechnology Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PATH	Partners for Advanced Transportation Technology
PF	Proportionally fair
Ph.D.	Doctor of Philosophy
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
Q	Quarter
Q&A	Question and answer
QDTA	Quasi-dynamic traffic assignment
R&D	Research and development
RDD&D	Research, development, deployment, and demonstration
RL	Reinforcement learning
RyThMiCCS	Real-Time Mobility Communications and Control System
SAE	Society of Automotive Engineers
SIL	Software-in-the-loop
SMART	Systems and Modeling for Accelerated Research in Transportation
SOF	System optimal fuel use
SOT	System optimal travel time
STA	Static traffic assignment
SUMO	Simulation of Urban Mobility
SVTRIP	Stochastic vehicle trip prediction
SwRI	Southwest Research Institute
TCF	Technology Commercialization Fund

TDOT	Tennessee Department of Transportation
TI	Technology Integration program
TNC	Transportation network companies
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UET	User equilibrium travel time
UIC	University of Illinois at Chicago
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-anything
VAN	Vehicle Analysis program
VIL	Vehicle-in-the-loop
VPPG	Virtual physical proving ground
VTO	Vehicle Technologies Office
XIL	Anything-in-the-loop

4. Electrification

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Electrification Technologies subprogram supports the decarbonization of transportation across all modes, serves to increase American advancement/manufacturing of battery technology, and creates good paying jobs with the free and fair chance to join a union and bargain collectively. The subprogram supports research with partners in academia, national laboratories, and industry covered under the Energy Storage Grand Challenge key priority and distinct crosscuts. The Energy Storage Grand Challenge encompasses R&D across electrification including electric vehicle charging infrastructure. The Critical Minerals crosscut aims to realize electric drive motor innovations through high energy product magnet R&D to reduce or eliminate heavy rare earth magnet materials. Grid Modernization continues to develop Smart Charge Management technologies for fleets, including medium and heavy vehicles to provide more advanced grid services such as resilience of the charging network and continuity of grid and emergency services operations during disruptive events.

The Electric Drive R&D activity supports early-stage R&D for extreme high-power density motors that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability. Reduce the cost of electric traction drive through core research of motors, high-density integration technologies, leveraging high performance computing for modeling and optimization, and utilizing new materials for high-density electric motors. Approaches will include novel circuit topologies and new materials for high-density electric motors. Electric traction drive system integration based on electric motor innovations will also be a priority.

The Electrification R&D activity supports early-stage R&D to understand the potential impacts on, and benefits of, PEV charging to the Nation's electric grid. This research will inform the development of communication and cybersecurity protocols; enable industry to enhance the interoperability between charging equipment, the on-board vehicle charger, and charging networks; and foster technology innovations to improve PEV refueling through extreme fast charging. Core research focuses on developing smart charging, extreme fast charging, and wireless charging technologies for reliable and cost-effective charging of light-, medium-, and heavy-duty electric vehicles. This includes the research of technologies related to cybersecurity of electric vehicle charging/supply equipment, and integration with the electric grid.

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
elt094	Development and Demonstration of Medium-and Heavy-Duty Plug-In Hybrid Work Trucks	John Petras (Odyne Systems)	4-7	3.40	3.20	3.00	2.60	**3.15**
elt095	Vehicle-to-Grid Electric School Bus Commercialization Project	Adam Hunnell (Blue Bird Corp.)	4-12	3.50	3.13	3.63	3.13	**3.28**
elt158	Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project	Seungbum Ha (SCAQMD)	4-16	3.13	3.13	3.00	2.88	**3.08**
elt187	Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System)	Sunil Chhaya (EPRI)	4-19	2.75	2.50	3.25	3.00	**2.72**
elt188	Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity	Omer Onar (CALSTART)	4-22	3.50	3.33	3.33	3.33	**3.38**
elt197	High Power and Dynamic Wireless Charging of Electric Vehicles	Veda Galigekere (ORNL)	4-25	3.38	3.50	3.38	2.88	**3.38**
elt198	Cybersecurity: Securing Vehicle Charging Infrastructure	Jay Johnson (SNL)	4-29	3.30	3.30	3.30	3.50	**3.33**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt199	Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure	Richard Carlson (INL)	4-35	3.63	3.63	3.75	3.50	**3.63**
elt201	Charging Infrastructure Technologies: Smart Vehicle-Grid Integration (ANL)	Keith Hardy (ANL)	4-39	3.50	3.67	3.50	3.50	**3.58**
elt202	Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)	Jesse Bennett (NREL)	4-41	3.10	3.40	3.40	3.10	**3.29**
elt204	Charging Infrastructure Technologies: Development of a Multiport, >1 MegaWatt Charging System for Medium- and Heavy-Duty Electric Vehicles	Andrew Meintz (NREL)	4-45	3.13	3.25	3.25	3.38	**3.23**
elt205	Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX)	David Coats (ABB)	4-48	3.17	3.17	3.17	3.17	**3.17**
elt206	Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem	Sunil Chhaya (EPRI)	4-50	3.33	3.50	3.50	3.17	**3.42**
elt207	Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach	Ryan Gerdes (Virginia Tech University)	4-53	3.67	3.17	3.33	3.17	**3.31**
elt208	Highly Integrated Power Module	Emre Gurpinar (ORNL)	4-55	3.25	3.33	3.25	3.17	**3.28**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt209	High-Voltage, High-Power Density Traction-Drive Inverter	Gui-Jia Su (ORNL)	4-59	3.14	3.07	3.14	3.07	**3.10**
elt210	Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain	Andrew Binder (SNL)	4-63	3.30	3.20	3.10	3.00	**3.19**
elt211	Power Electronics Thermal Management	Gilbert Moreno (NREL)	4-67	3.20	3.30	3.10	3.10	**3.23**
elt212	Non-Heavy Rare-Earth High-Speed Motors	Tsarafidy Raminosoa (ORNL)	4-71	2.88	3.25	3.38	3.13	**3.16**
elt214	Electric Motor Thermal Management	Kevin Bennion (NREL)	4-73	3.67	3.67	3.67	3.67	**3.67**
elt215	Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density	Iver Anderson (Ames Laboratory)	4-76	3.50	3.50	3.25	3.13	**3.42**
elt216	Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines	Todd Monson (SNL)	4-80	3.50	3.50	3.33	3.33	**3.46**
elt221	Integrated Electric Drive System	Shajjad Chowdhury (ORNL)	4-83	3.42	3.33	3.17	3.17	**3.31**
elt236	Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture	Watson Collins (EPRI)	4-87	3.50	3.33	3.83	3.17	**3.42**
elt237	Enabling Extreme Fast Charging with Energy Storage	Jonathan Kimball (Missouri S&T)	4-90	2.67	2.67	3.17	2.67	**2.73**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt238	Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection	Srdjan Lukic (North Carolina State University)	4-93	3.33	3.33	3.33	3.17	**3.31**
elt239	High-Power Inductive Charging System Development and Integration for Mobility	Omer Onar (ORNL)	4-96	3.75	3.75	3.25	3.50	**3.66**
elt240	Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)	Mike Masquelier (WAVE)	4-100	3.50	3.33	3.33	3.17	**3.35**
elt241	High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles	Charles Zhu (Delta Electronics)	4-103	3.25	3.33	3.50	3.00	**3.29**
elt257	Directed Electric Charging of Transportation Using eXtreme Fast Charging (XFC) (DIRECT XFC)	Tim Pennington (INL)	4-107	3.00	3.25	3.13	2.88	**3.13**
elt258	Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)	Andrew Meintz (NREL)	4-110	3.25	3.00	2.88	2.75	**3.02**
elt259	Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions	Marcus Malinosky (Daimler Trucks North America)	4-113	3.20	3.60	3.20	3.20	**3.40**
elt260	Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management	Teresa Taylor (Volvo)	4-118	3.42	3.42	3.33	3.17	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt261	High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter	Ben Marquart (Ricardo)	4-123	3.83	3.50	3.33	3.50	**3.56**
elt262	Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging	Brian Lindgren (Kenworth)	4-126	3.40	3.40	3.50	3.50	**3.43**
elt264	Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams	Joe Picarelli (Exelon/ Pepco Holdings Inc.)	4-130	3.25	3.33	3.50	3.25	**3.32**
elt265	A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicle's-At-Scale	Duncan Woodbury (Dream Team LLC)	4-135	3.00	2.70	2.80	2.90	**2.81**
elt266	ANL High Power Charging Charge Profiles	Dan Dobrzynski (ANL)	4-138	3.30	3.20	3.30	3.10	**3.23**
elt267	ORNL Resilient High Power Charging Facility	Madhu Chinthavali (ORNL)	4-142	3.00	3.17	3.00	2.83	**3.06**
elt274	eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management	David Coats (ABB)	4-145	3.10	3.10	3.20	3.00	**3.10**
Overall Average				**3.29**	**3.29**	**3.28**	**3.14**	**3.27**

Presentation Number: elt094
Presentation Title: Development and Demonstration of Medium-and Heavy-Duty Plug-In Hybrid Work Trucks
Principal Investigator: John Petras (Odyne Systems)

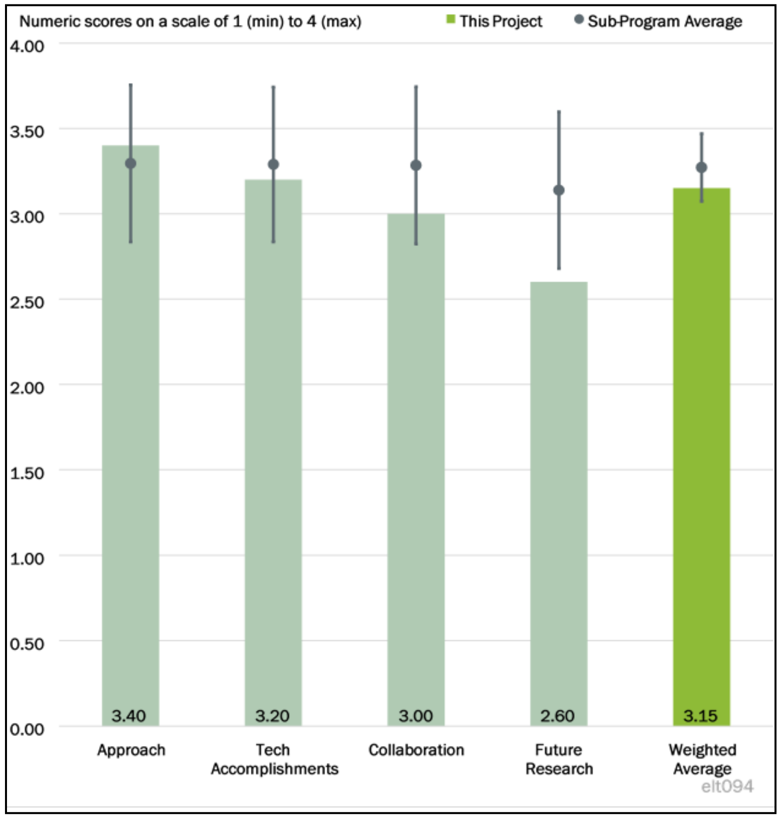


Figure 4-1 - Presentation Number: elt094 Presentation Title: Development and Demonstration of Medium-and Heavy-Duty Plug-In Hybrid Work Trucks Principal Investigator: John Petras (Odyne Systems)

Presenter

John Petras, Odyne Systems

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 60% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that, fundamentally, this is a very strong project. It has a solid, quantified objective to develop and demonstrate an advanced plug-in hybrid electric vehicle (PHEV) medium-duty (MD and heavy-duty (HD) work truck with greater than 50% reduction in fuel consumption compared to a conventional diesel vehicle baseline.

The reviewer stated that the project's approach is excellent by combining a standard hybrid powertrain, a stock transmission, and an electric motor connected through the power take-off (PTO), along with a modular design. This approach is minimally intrusion, requires no changes to the base powertrain, while retaining the powertrain warranty. It provides ample hydraulic/pneumatic power, exportable power, and applies to multiple original equipment manufacturer (OEM) and application platforms. This modularity and flexibility are key. In addition, this project covers largely new ground with regard to improving the fuel economy and emissions of non-traditional stationary, work truck vocational applications.

The overall project is well designed, feasible, and ultimately will be successful as the applications are demonstrated, the return on investment (ROI) steadily improves as the cost of batteries comes down, and further technology, design simplifications, and cost savings opportunities are implemented.

Reviewer 2:

The reviewer indicated that the approach to performing the work is considered to be excellent. This a straightforward application of electrification using standard architecture to apply electrification to the auxiliary systems of the vehicle rather than using a "running" engine. It is intended to utilize existing PTO technology to run a generating motor. It is clear that the approach is intended to minimize the disruption of operator activity.

The reviewer indicated that the approach seems to be directed at geographic markets that will require that vehicles not continuously idle during the stationary activities, thus making cost a lesser factor. What is not clear is what the cost parameters may have been to identify the potential for adoption across all markets. The reviewer suggested that this is a shortcoming that should be studied and reported on in future presentations.

Reviewer 3:

The reviewer liked the approach to performing the work. General goals were established, and then when users commented—for example, that the project team did not need 15 kilowatts (kW) of power, but only 12 kW—the goal for exportable power was re-adjusted.

Reviewer 4:

The reviewer referenced 2018 project presentation Slide 3, which indicates the objective of targeted ROI of less than or equal to 5 years. The reviewer was not sure if any of the results have been shared already. Considering the continuous reduction in battery cost, the reviewer suggested that it might be helpful to revisit the results of such a study on a yearly basis to discuss if such an objective is still within scope or to explain why it is being excluded.

Reviewer 5:

The reviewer noted that the overall approach is comprehensive. However, the biggest gap in the work seems to be the definition of the Stationary Fuel Use profile. The team acknowledges limited work in this area, so the experimental dynamometer data from the National Renewable Energy Laboratory (NREL) related to this is good to see and seems promising. Nonetheless, a clearer approach to how this fuel use profile is determined should be presented because this represents a major fuel consumption use of the vehicle.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has achieved a number of impressive technical accomplishments. This includes the use of Oak Ridge National Laboratory (ORNL) simulation and hardware-in-the-loop (HIL) analyses to refine driving strategies to optimize fuel economy over the driving and stationary cycles of operation. A number of features have been identified to improve fuel economy up to 34%-50% over a baseline diesel vehicle. The design and integration of the test truck has been completed. The test truck has been tested on the dynamometer at the NREL Renewable Fuels and Lubricants Laboratory (ReFUEL), where the mild strategy yielded a 9.5%-23% fuel economy improvement and the aggressive strategy yielded a 69%-75% improvement in fuel economy. In addition, over the stationary work cycle, the test truck yielded an 80%-99% improvement in fuel economy and emissions.

Reviewer 2:

The reviewer observed very good stationary cycle test results. The reviewer expected further definition and validation of this fuel use cycle with real-world scenarios from participating utility companies in the future. Additionally, the comment about TCO is also important for eventual vehicle adoption and should be clarified in future technical updates.

Reviewer 3:

This reviewer referred to 2019 project presentation Slide 5, which reflects a Fleet Data Collection, Analysis, and Summary by November 2020. The reviewer inquired about the outcome of this target, and the new timeline for fleet build and data collection if not already met.

Reviewer 4:

The reviewer remarked that modular configuration of the PTO and main powertrain allows for deployment on different platforms. The goal of acquiring a lower cost battery needs work, and if it is beyond the scope of this effort, it should be so stated.

Reviewer 5:

The reviewer stated that the progress can be considered to be good, and the schedule has generally been met. However, the reviewer pointed out that there is a severe shortcoming in that the report states that there is not a cooperating demonstration partner identified and it seems to be that this may be a reason that the project may not be completed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that this project exhibits outstanding collaboration and coordination through an impressive number of strong project partners covering all bases including modeling and simulation, technology development and integration, testing and validation in the laboratory and fleets, as well as procurement.

Reviewer 2:

The reviewer indicated that the coordination between project team members appears well thought out and executed.

Reviewer 3:

The reviewer stated that the collaborations have been good with the original list of cooperating partners. The exception is the identification and confirmation of the demonstration partner. This is a major shortcoming of the program and places the final outcome in jeopardy. Since no time was allowed for in-depth questioning, the lack of a demonstration partner was not clarified.

Reviewer 4:

The reviewer was extremely disappointed that absolutely no utility fleets, non-utility fleets, or other fleets were identified as partners for demonstrating the developed prototypes. The Principal Investigator (PI) should have at least identified the fleets that the project team had conversations with and the potential fleets that the project team will attempt to contact. The pandemic is no excuse for failure to talk.

Reviewer 5:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the project's intention to complete a full year of simulation of truck fuel savings based on NREL driving and stationary test results, continue to optimize and refine the system to minimize fuel consumption and improve ROI, and perform 1-year real-world demonstrations with utility partners is logical and appropriate.

The reviewer indicated that the presentation indicates the challenge of getting utilities to participate and contribute capital equipment and mentioned revising the program plan to allow a depreciation cost-share rather than full equipment. The reviewer asked some questions about and suggested some ideas for the challenges faced. What other approaches might encourage utility participation? Is it possible to consider reducing the number of demonstration vehicles initially from, for example, 10 total to 6 total while still achieving statistically valid and credible results? In short, this could potentially reduce the utility capital equipment burden upfront with additional demonstration vehicles added in the future as they become available. Additionally, is it possible to explore bulk battery purchases in collaboration with other entities or applications to drive down battery costs initially? The presentation mentioned Ricardo as the lead for procurement.

Reviewer 2:

The reviewer commented that the future work is considered to be on a sensible path regarding the function of the system being built. There was a high degree of confidence that it will work. The reviewer wanted to know the cost in comparison to legacy systems and identified finding and confirming a demonstration partner(s) as a critical element.

Reviewer 3:

The reviewer indicated that Slide 9 appears to be missing timelines for identified Budget Periods (BP) 2 and 3.

Reviewer 4:

The reviewer suggested that further clarification on the type of utility partners being considered and their relevance in terms of meeting the fuel use goal demonstrations was needed. The presenter mentioned there are many candidate partners, but limited information on their specific use cases and relevance to the project goals was given.

Reviewer 5:

The reviewer commented that there was no slide identifying proposed or suggested additional research needed or items for consideration for future research.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer confirmed the support of overall U.S. Department of Energy (DOE) objectives by saying the stationary fuel use scenario is a critical use case that should be considered to significantly further energy independence and greenhouse gas reduction (GHG). This project is perfectly in line with those goals.

Reviewer 2:

The reviewer stated that this project clearly supports DOE objectives to reduce petroleum consumption and emissions, as results already indicate the feasibility of achieving greater than 50% improvement in full duty-cycle fuel economy and more than an 80% reduction in stationary emissions. Given the modular nature of the project's technology approach, successful development will enable many pathways to expand implementation throughout MD and HD vehicle vocational applications.

Reviewer 3:

The reviewer attested and affirmed the substantial need for improving the fuel efficiency of MD trucks and work trucks (used for PTO).

Reviewer 4:

The reviewer confirmed this project does support DOE objectives of reducing GHCs and local air pollution through elimination of running engines during stationary activities of vehicle use. The reviewer raised the concern that it is not clear at what cost this may be achieved.

Reviewer 5:

Not applicable was indicated 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 stated that the resources appear sufficient to achieve the project goals.

Reviewer 2:

The reviewer commented that sufficient resources have been provided to achieve project objectives to date, and this project has a strong contractor cost-share percentage of 58%.

Reviewer 3:

The reviewer stated that the resources not adequate. The project needs a demonstration partner.

Reviewer 4:

The reviewer thought the amounts of funds designated for Federally Funded Research and Development Centers (FFRDC) (NREL and ORNL) were excessive.

Reviewer 5:

Not applicable was indicated by this reviewer.

Presentation Number: elt095
Presentation Title: Vehicle-to-Grid Electric School Bus Commercialization Project
Principal Investigator: Adam Hunnell (Blue Bird Corp.)

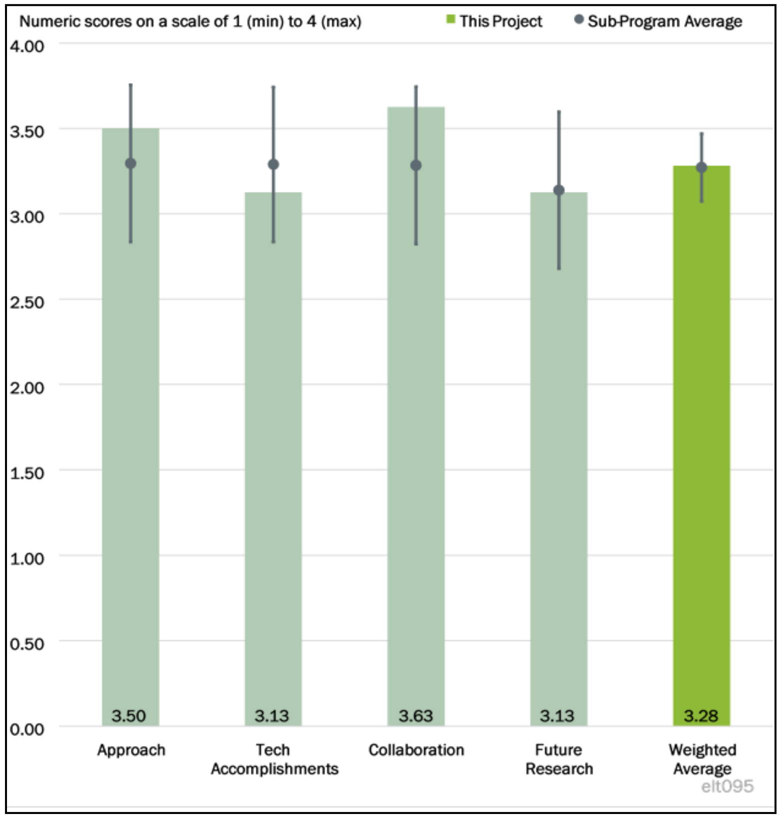


Figure 4-2 - Presentation Number: elt095 Presentation Title: Vehicle-to-Grid Electric School Bus Commercialization Project Principal Investigator: Adam Hunnell (Blue Bird Corp.)

Presenter

Adam Hunnell, Blue Bird Corp.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that this project was well thought out and happens to be a niche solution that fits a niche problem at the right time and place. The partners and collaborators were also a perfect fit.

Reviewer 2:

The reviewer stated the fundamental assumption that a competitive TCO for an electric school bus can be achieved through optimization of three parameters (bus capital cost, bus operating cost, and revenue generation from grid integration) appears sound. The broad approach targeting technical (at the vehicle and electric vehicle supply equipment [EVSE] level), regulatory, and metering challenges is appropriate as progress in all three areas is mandatory to achieve viability for MD and HD EV vehicle-to-grid (V2G) applications.

The reviewer further commented that this project is working to address a broad range of barriers to V2G integration including technical and non-technical barriers including vehicle and EVSE level improvements, regulatory (interconnection and tariffs), and metering. Specific objectives for this period include specification and procurement of high-power bidirectional EVSEs, interconnection contracting for EV-based distributed energy resources (DERs), and metering and tariffs to support service provision on utility and recovery time objective (RTO) networks.

Reviewer 3:

The reviewer observed that the goals appear to be appropriately targeted.

Reviewer 4:

The reviewer remarked that was good to see the change of direction from alternating current (AC) to direct current (DC) bi-directional charging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that there have been broad, strong project accomplishments across the technical, regulatory, standards certification, and metering spaces in the last 2 years. The primary technical accomplishments the last 2 years have concerned charging and grid integration including modeling of the revenue generation opportunity from grid services; building the high-power bidirectional charging and communications chain; and developing protocols for a school bus DER to function as a node on a utility distribution circuit. Fiscal Year (FY) 2021 and FY 2022 milestones appear on track including the build and test of on-board circuits to allow high-power charging and discharging and prototype 3 (P3) prototype build and commissioning.

The reviewer observed that steady progress has been made including improving fuel efficiency by 9% (but still short of the target of 1.32 kilowatt-hours [kWh] per mile) through lower rolling resistance tires, more aggressive regenerative braking, and lightweighting.

The reviewer noted that modeling of potential revenue generation through provision of V2G services leverages several earlier projects to inform its approach and results. Superficially, the revenue generating potential looks promising; however, key assumptions such as the potential reduction of monthly demand charges and tariff levels are not clearly defined, lending doubt to the credibility of the total cost of ownership (TCO) analyses at this time.

The reviewer acknowledged that progress has been made with ground-breaking efforts on the regulatory front including interconnection, metering, and tariff proposal for presentation to the California Public Utilities Commission (CPUC).

Reviewer 2:

The technical accomplishments and progress are what the reviewer had expected as measured against performance indicators.

Reviewer 3:

The reviewer observed that TCO results represents a $55,755 advantage over 15 years considering a $246,062 credit for electric vehicle (EV) grid services. It would be helpful to have the breakdown for the grid services credit to assess the business case strength.

Reviewer 4:

The reviewer acknowledged that it is a hard problem to solve and bumps on the road are expected. The reviewer also wondered about risk mitigation strategies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project maintains strong, diverse project collaborators across its technical, regulatory, and procurement elements. This activity also benefits from cross-fertilization leveraging other projects including Southern California Edison (SCE)'s V2G Integration Project (2021-2023) funded by the California Energy Commission (CEC), and the "Make-Ready" elements of the Rialto Unified School District

(USD) charging infrastructure through SCE. These collaborations permit leveraging of technology, knowledge, and resources—always a good thing to see.

Reviewer 2:

The reviewer remarked that it seems like all parties are engaged.

Reviewer 3:

The reviewer suggested that perhaps a more urban school district than Rialto (a very exurban or suburban school district) would have been a better partner because it would have imposed a less rigorous requirement on the school buses (for example, less range and thus less battery capacity for energy storage and thus lower battery weight). The reviewer added that all the other partners are excellent.

Reviewer 4:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the project identifies the remaining challenges and barriers as achieving energy efficiency objectives and completing arrangements for Rialto USD's electric school bus fleet to function as a DER including an interconnection agreement and establishing terms of DER participation within SCE's distribution grid.

The reviewer commented that a definitive conclusion about the project's potential V2G economic contributions cannot be made until contract and regulatory arrangements have been established. It would be very beneficial to comprehensively frame the value proposition of this V2G application from a best case to worst case TCO perspective regarding regulatory and tariff scenarios. In this way, a truly objective assessment could be established, and specific target parameters (regarding demand charge reduction and tariffs) could be established mitigating any potential ambiguity as to the value proposition of electric school bus V2G applications.

The reviewer asked if it would it be beneficial to explore the opportunity to potentially reduce battery costs through volume purchases? In addition, the reviewer wanted to know about the potential of conducting an analysis of the steady progression in battery cost reduction in recent years and where battery costs are likely to be in the near future and subsequently using this information to inform estimates of future ROI.

Reviewer 2:

The reviewer highlighted that the listed future research "DER term negotiation" is an essential step for validation commercialization options.

Reviewer 3:

The reviewer suggested that there is more work needed to reduce weight of the school buses and to improve energy-storage density of the electric batteries. Also, the reviewer indicated that more work is needed on the cost modeling for electric school buses to serve as DERs during peak periods. The reviewer suggested replacing or comparing gasoline-powered school buses instead of diesel-powered school buses. Also, the reviewer did not think it is fair to compare the 15-year lifespan to a 15-year diesel or gasoline-powered school bus. The lifespan of diesel and gasoline vehicles is over 20-30 years (for example, look at dump trucks).

Reviewer 4:

The reviewer indicated that there is lots to clean up. The reviewer wondered about the grid services $250,000 benefit, and how that one was calculated.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that having this deployment project is essential to test the technology readiness level.

Reviewer 2:

The reviewer liked the idea of using electric school buses to serve as DERs during peak periods of electric energy use and re-charging the school buses during non-peak periods of electric energy use. The time of use of school buses and the range of school bus routes fit nicely for "peak-shaving."

Reviewer 3:

The reviewer noted that the project addresses a core Vehicle Technologies Office (VTO) objective to reduce the cost of plug-in electric vehicles (PEVs) and understand the potential impacts of EV charging on the nation's electric grid by pioneering V2G technology in MD and HD vehicles.

Reviewer 4:

Not applicable was indicated 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 remarked that the project appears to be on track.

Reviewer 2:

The reviewer stated that sufficient resources have been provided to achieve targeted objectives to date and the project has a strong 50% contractor cost share.

Reviewer 3:

The reviewer had no comments.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: elt158
Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project
Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

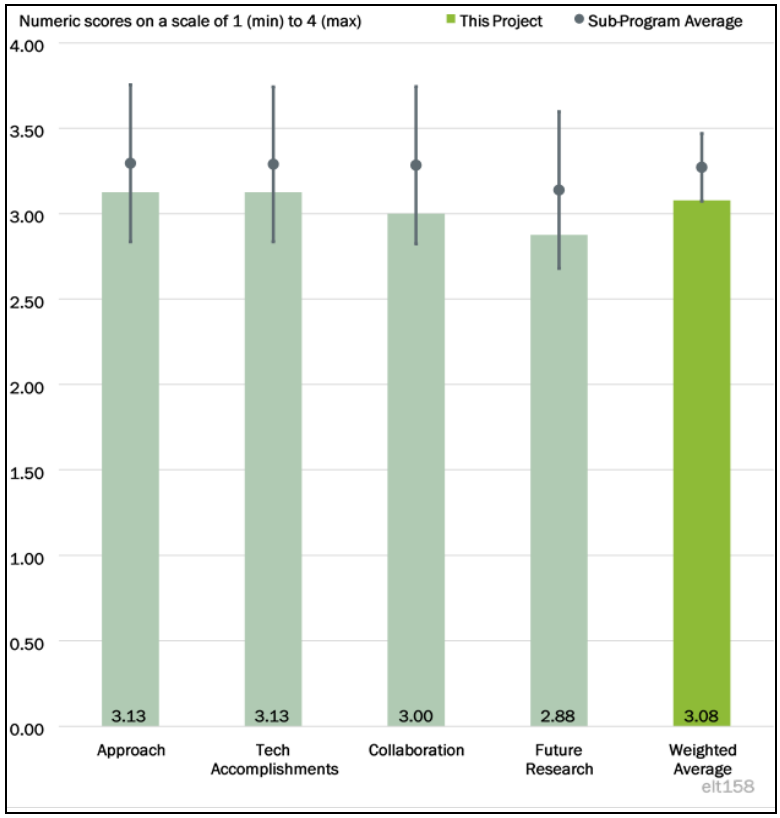


Figure 4-3 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Seungbum Ha (South Coast Air Quality Management District)

Presenter

Seungbum Ha, South Coast Air Quality Management District

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project is well planned and, given that it is near the end, expects that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 2:

The reviewer expressed the belief that the U.S. Government has to be a main resource of funds for research and development (R&D) of a high-risk, high-cost technology such as hydrogen fuel-cell HD trucks. The reviewer indicated that it was not necessary to fund the effort on compressed natural gas (CNG) or hybrids since such technology was mature 4-5 years ago. Even the speaker admitted that the partners wanted the PI to shift focus from data collection and analysis to more intensive deployment. Additionally, the reviewer highlighted that this project has profound implications for improving the air quality of the low-income, minority neighborhoods surrounding the Ports of Los Angeles and Long Beach in California.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project provided good metrics against plans, and it is a long program comparing differing solutions. The reviewer called it a good job.

Reviewer 2:

The reviewer remarked that the overall progress was good when measured against performance indicators and goals. There definitely could have been much more average daily use of the hydrogen fuel-cell demonstration trucks. It was not clear to the reviewer what the “hold-up” was. The reviewer suggested that the PI should have listed the components in the hydrogen fuel-cell power train and electronics that need standardization so that a standards committee with DOE support could work on them.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although there always could be more, the reviewer observed a good job in sharing results with key stakeholders.

Reviewer 2:

The reviewer emphatically remarked that it was disappointing not to see the Port of Los Angeles and Port of Long Beach listed as formal partners on the project team. U.S. DOT had worked with the Ports and secured their cooperation for the safety of alternative fuel trucks (both hydrogen and natural gas) operating in their jurisdictions. The U.S. Department of Transportation (DOT) even provided training on hydrogen fuel safety for the Total Transportation Services Inc. (TTSI) truck drivers.

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 state project ended.

Reviewer 1:

The reviewer observed that the standardization of hydrogen components and electronics is definitely needed. Also, research is needed to determine what can be done to bring down the cost and to commercialize hydrogen-fuel-cell engines and powertrains.

Reviewer 2:

The reviewer remarked that the program is basically done.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that, yes, this project is needed to attain zero-emissions in an area classified as a non-attainment zone. In addition, the reviewer commented that there is a social or environmental justice issue.

Reviewer 2:

The reviewer said that, yes, this project did support 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:

The reviewer said that, yes, resources are sufficient.

Reviewer 2:

The reviewer remarked that the funds for the CNG-hybrid part of this project should be moved over to the hydrogen and fuel cell part of this project to address studies on standardization and commercialization of hydrogen fuel-cell engine and electronic components as described above. The CNG-hybrid work is not necessary as described above.

Presentation Number: elt187
Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System)
Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

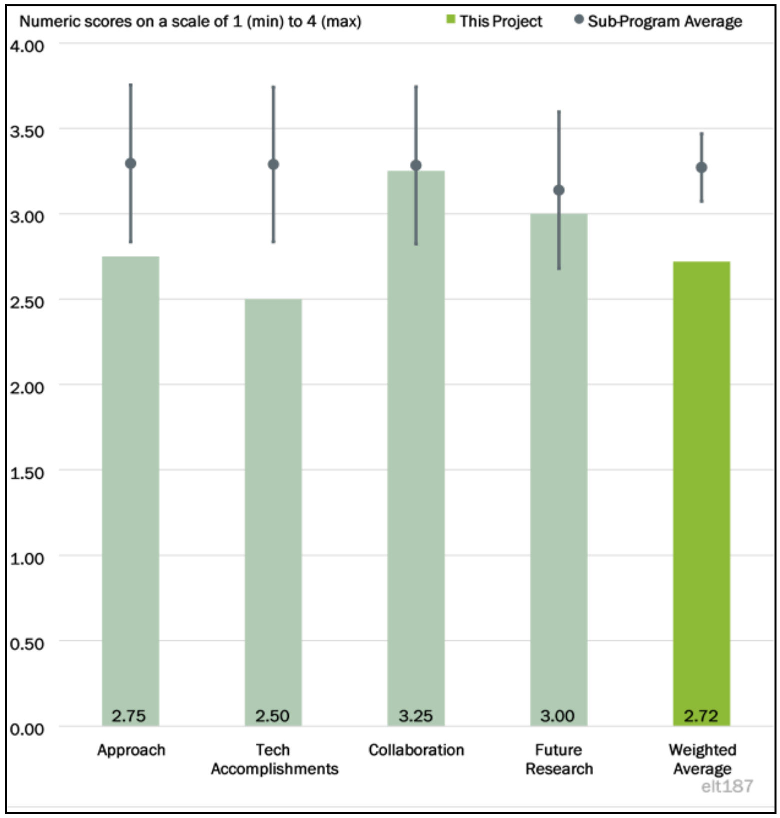


Figure 4-4 - Presentation Number: elt187 Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid (SPIN System) Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the approach is relatively basic. It is interesting that the idea was to work on a unit targeted toward multi-unit dwellings. The project also focused on both AC and DC charging, while many programs have tended to ignore AC for V2G. The project also looked outside of just EV batteries for input. Overall, the approach seems reasoned and appropriate.

Reviewer 2:

The reviewer commented that the project Relevance is presented as “Viability of V2G as DER resource and cost/benefit to consumer and utilities. Technical progress (viability) has been made even with the impact of coronavirus disease 2019 (COVID-19). However, no progress is apparent on the benefit of V2G, and only battery life is being examined as a cost of V2G. Several barriers are listed corresponding to cost-benefit that would have been apparent at the beginning of the project. The reviewer asserted that without a clear cost-benefit, it is difficult to see a future for the technical achievements of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that it appears that all planned activities have been completed, while pointing to a direction for future efforts. Testing and validation were completed over the past several months, as was integration of the Smart Power Integrated Node (SPIN) unit. It should be noted that this project has been extended from June 2020 to June 2021, at least partially due to delays due to COVID-19. In particular, these delays impacted DC testing.

Reviewer 2:

The reviewer asserted that as earlier discussed, no progress has been made on the cost benefit of V2G, nor the power and energy requirements for DER applications. Without a cost benefit to V2G, the standards and hardware developed in this project are of little use.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the team was led by the Electric Power Research Institute (EPRI) and also included an EVSE manufacturer, an integrator, and an EV manufacturer. The project also collaborated with NREL, ORNL, and the Society of Automotive Engineers (SAE). The team appears to have made good use of its partners for the specific capabilities, as well as the labs (for testing and technical input) and SAE for technical outreach and coordination. The reviewer observed that it was a bit surprising there was not a utility on the team, though (upon questioning) the PI did indicate that might be an element of future work. It was good to see that the AC work led to a collaboration by several of the team members for SCE to define interconnection requirements for OEMs and EVSE manufacturers to include in the permitting process.

Reviewer 2:

The reviewer commented that it is a bit confusing why barriers include insufficient data on DER applications and insufficient value of V2G integration as a DER asset when EPRI is the prime. The reviewer thought there would be excellent access within EPRI to past utility data as well as thoughts on the value of V2G as a DER asset.

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 state project ended.

Reviewer 1:

The reviewer noted that the current project is nearly complete, though there are some key elements still to complete. The project team appeared to indicate that there will be continuing work on application and integration work, including potentially more testing work from Fiat Chrysler Automobiles (FCA) and NREL. It also appears there is also additional work needed focused on certifications, integration with solar and utility operation, and more in-use verification.

Reviewer 2:

The reviewer said that the project has reached scheduled end data and is wrapping up current work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project is focused upon evaluation of V2G systems, both for AC and DC charging. A greater understanding of the technical requirements and impacts of V2G is needed for future EV penetration scenarios, as there may be opportunities for improved financial performance through V2G.

Reviewer 2:

The reviewer indicated that understanding the value of V2G as a DER asset is important to overall DOE objectives. However, the greatest challenges to making V2G valuable are not technical. Developing application-specific costs, commercial issues (including warranties), pricing, and availability/reliability are issues that must be solved. Future projects should be much more commercially focused than technically focused.

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 sufficient to achieve the originally planned work, which is nearly complete.

Reviewer 2:

The reviewer stated that the resources were not sufficient to resolve barriers concerning insufficient data on DER applications and the value of V2G integration as a DER asset.

Presentation Number: elt188
Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity
Principal Investigator: Omer Onar (CALSTART)

Presenter

Omer Onar, CALSTART

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers felt that the project was relevant to current DOE objectives, 33% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

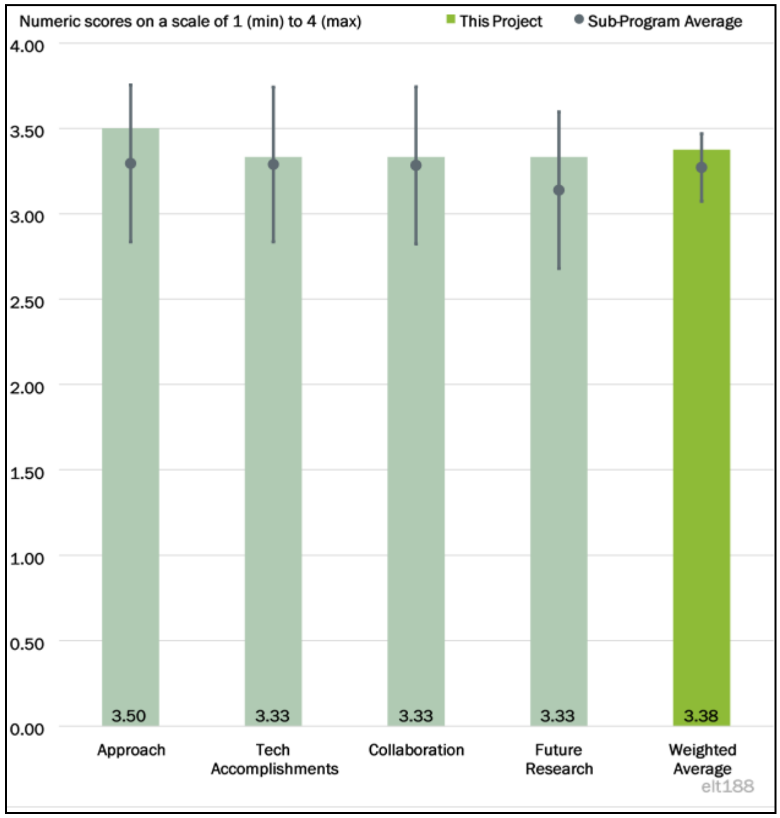


Figure 4-5 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty, Vehicle-to-Grid Connectivity Principal Investigator: Omer Onar (CALSTART)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the approach is good and systematic. It involves simulation, building and testing components, and finally integrating and testing the full system.

Reviewer 2:

The reviewer observed an outstanding approach and also raised some technical questions for the project team. Why was an inductor–capacitor–capacitor (LCC) compensation network selected? What are other options? Should the project team go for LCC for all wireless charging applications?

The reviewer remarked that it seems like the DC link capacitors look different as some of them are black, some of them are silver. They are also placed in an interleaved way. Is the project team using two different types of DC link capacitors? Is there any consideration the project team should be made aware of?

The reviewer noted that the 20-kW charger will make people think it is a single-phase charger, but in this project, three-phase is used, which can go to much higher power. Why was 20 kW picked for this project?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the work the team has carried out so far is tremendous, and the reviewer highly recognized the great efforts and achievements the team had made. However, it seems the majority of the work presented in this year's review had already been completed before February 2020. The reviewer highly appreciated the nice revisit of the previous content but also expected to see some updated slides as compared to the 2020 review to highlight the hard work that the team has done between February 2020 and June 2021. If the reviewer were to rate the whole project, the reviewer would go for outstanding.

Reviewer 2:

The reviewer commented that the progress made is good, but the pending testing of the full system will provide a better verification of the performance.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there has been good collaboration across the project team, and this will become more evident when the system is tested in the actual vehicle.

Reviewer 2:

The reviewer commented that the collaboration and coordination between ORNL, United Parcel Service (UPS), and Workhorse is great. The only reason that it is not "outstanding" is because the reviewer did not see much involvement from the project lead CALSTART. Maybe CALSTART will be involved more in the next budget period, so this could be outstanding next time.

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 state project ended.

Reviewer 1:

The reviewer commented that the proposed future research is outstanding. The final deployment and 6-month data collection in real-life applications would be the most interesting part. The reviewer asked what type of data are being collected? Will efficiency, vehicle battery usage, charging and discharging power be collected?

In addition, the business case of this bidirectional wireless charging system is the key. Bidirectional wireless charging has always been a question for the reviewer. If the reviewer understood it correctly, the presenter mentioned the application being the UPS vehicles coming back to the depot with about 30%-40% state of charge (SOC) leftover after the day of the work and can output power to compensate for the other vehicles' charging loads that added on to the building loads. This is equivalent to peak shaving or demand charge mitigation. This sounds like the vehicle battery pack could be further optimized, and a stationary battery pack could be placed at the building to offer more help with higher efficiency and may be lower cost. The reviewer agreed that the bidirectional wireless technology should be looked into, but if the business case could be justified, this would definitely be outstanding.

This reviewer expressed interest in seeing how convenient the wireless charger is versus the conductive in this bidirectional case. It would be fantastic if it could be quantified—how much additional loss/cost versus how much time it can save the driver to plug in. How much economic benefit could the fleet gain by participating into the ancillary services market, as compared to putting less margin on the vehicle? How much economic benefit could the fleet gain by moving the unused 30% battery capacity to stationary energy storage (more efficient being conductive and less weight on the fleet vehicle, and less expensive being that battery is stationary rather than automotive qualified)?

Reviewer 2:

The reviewer commented that the testing of the full system that was simulated in the actual system is a logical step for verification.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that the project is relevant to DOE objectives.

Reviewer 2:

The reviewer remarked that the maturing wireless charging technology, especially for MD and HD vehicles, supports the DOE objectives. It would have been helpful if the performance targets and more details about the targeted application had been provided.

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 resources are sufficient.

Reviewer 2:

The reviewer thought that the resources are sufficient. Every organization has unique expertise and great collaboration. The reviewer is looking forward to seeing CALSTART contributing to the business case and economic analysis.

Presentation Number: elt197
Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles
Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

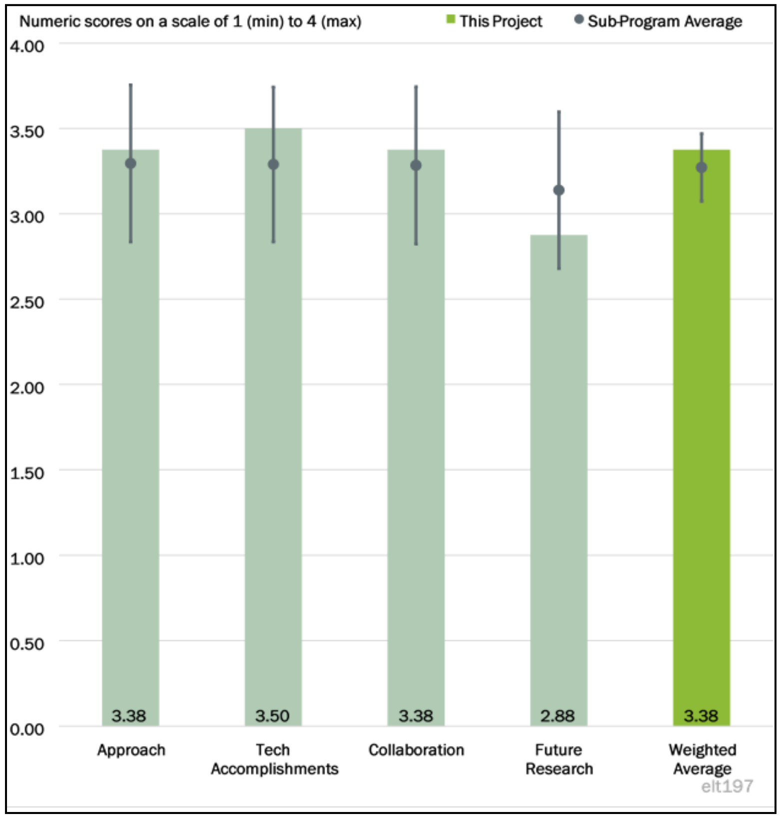


Figure 4-6 - Presentation Number: elt197 Presentation Title: High Power and Dynamic Wireless Charging of Electric Vehicles Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Presenter

Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the work is very well planned and executed projected. All milestones are very clearly defined and explained.

Reviewer 2:

The reviewer commented that this project sought to address efficiency (90% or better), power density, and controllability barriers related to dynamic wireless charging. This team’s approach included studies and analysis, followed by laboratory validation and finally real-world validation of an integrated system. Thus far, the approach appears to be working well as the team successfully completed their go/no-go decision point last year.

Reviewer 3:

The reviewer remarked that the project team presented a good and systematic approach. It would have been helpful to compare the proposed approach to the state of the art.

Reviewer 4:

While the overall efficiency target of 90% has not yet been demonstrated in a moving vehicle, this reviewer observed simulation results that appear to indicate the project is moving in the right direction. Regarding identifying Class 8 EV models, the reviewer agreed that perhaps the biggest benefit of dynamic wireless power transmission (DWPT) may be derived by Class 8 trucks, if the on-board battery size can be sufficiently reduced. Because this reviewer did not believe there are any Class 8 EVs in production, is there a process to quantify the benefit derived from DWPT in a real-world scenario, without relying exclusively on simulation?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that there appear to be a significant number of accomplishments on this project made by each of the project partners. From benchtop characterization of couplers to validation of power electronics, the team has made good progress. The real-world conditions site was identified, which drives the team closer to the validation of an integrated system under real-world conditions.

Reviewer 2:

The reviewer stated that the team has demonstrated a working lab prototype, which demonstrates the potential of this work as well as prepared this team well for a field test.

Reviewer 3:

This reviewer reported that all 2021 milestones have been met so far, and the other milestones are on target to be met.

Reviewer 4:

The reviewer indicated that the project team showed good progress but verifying the dynamic performance is very critical.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project is well coordinated among ORNL, NREL, and Idaho National Laboratory (INL).

Reviewer 2:

The reviewer remarked that this project brought to bear three different national laboratories to address the challenge, as well as an OEM, a test facility, and a university institute. Each of laboratories had clear tasks and contributions to the project.

Reviewer 3:

The reviewer indicated that there is good collaboration across project team. Verification in actual vehicles is critical.

Reviewer 4:

The reviewer noted collaboration with an OEM (Hyundai) to integrate the DWPT system in a real vehicle, and with ACM for DWPT demonstration. This is a good way to go because the knowledge of these organizations will allow faster project completion and improve the chances of success.

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 state project ended.

Reviewer 1:

The reviewer stated that the future work proposed looks logical, testing out the piece parts in controlled environments before testing of the integrated systems on a test course.

Reviewer 2:

The reviewer asserted that the proposed research is logical. Verifying the dynamic performance and real- life verification are critical milestones.

Reviewer 3:

The reviewer commented that the project's next steps are field demonstration, which is logical; however, the project team may not have enough time to execute this fully.

Reviewer 4:

One critical question identified by this reviewer that has to be answered is the impact on infrastructure and the grid. If a large number of vehicles that are on the road in Atlanta are going to be driving in a charge-sustaining manner, what kind of power requirements does it impose on the overall DWPT system and the power grid? What would it take for the grid to be capable of supporting this level of wireless charging? Is there a trade-off between the percentage of roadway that is electrified and the overall system cost?

The reviewer also inquired about what happens with the freeze-thaw cycles that occur during the winter and pot holes that show up on the roads. Perhaps this is not as much of a problem in Atlanta as it may be further up north.

Lastly, this reviewer referenced mention of optimizing the geometry to remove thermal hot spots. Would the extreme temperatures that are being faced across the western United States present a challenge for the cooling requirements?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project is relevant because it is working on drivetrain technology that will reduce GHGs and perhaps make vehicle batteries smaller for commercial trucks.

Reviewer 2:

The reviewer said, yes, this project supports the DOE objectives for climate goals and full electric transportation.

Reviewer 3:

The reviewer observed that the project is relevant because the dynamic wireless power transfer can help reduce the on-board battery requirement as well as potentially reducing range anxiety.

Reviewer 4:

This reviewer remarked that successful implementation of DWPT should improve acceptance of EVs and make a large number of them more efficient because of smaller battery packs.

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:

Sufficient resources were observed by this reviewer.

Reviewer 3:

The reviewer stated that the project funding is sufficient for the project tasks.

Reviewer 4:

The reviewer commented that the project has a short time left to completion compared to its deliverables.

Presentation Number: elt198
Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure
Principal Investigator: Jay Johnson (Sandia National Laboratories)

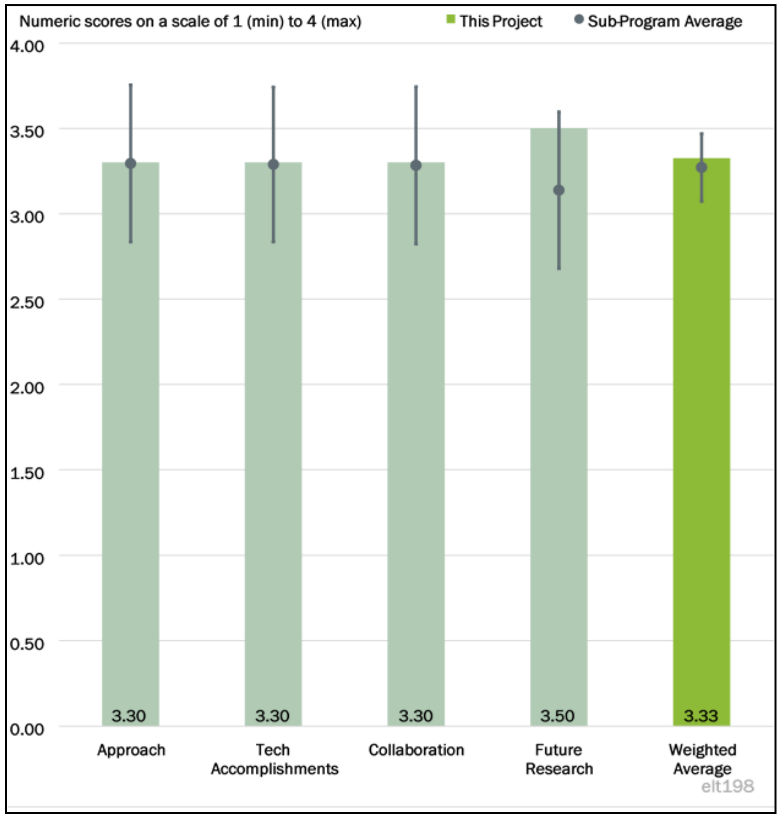


Figure 4-7 - Presentation Number: elt198 Presentation Title: Cybersecurity: Securing Vehicle Charging Infrastructure Principal Investigator: Jay Johnson (Sandia National Laboratories)

Presenter

Jay Johnson, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that, overall, the project has identified and implemented a very strong approach with a logical sequence of goals, milestones, and project deliverables. In short, the project approach has been to develop comprehensive EV/EVSE vulnerability assessments/threat models, investigate and quantify potential grid consequences of cybersecurity breeches, and subsequently develop a risk matrix and prioritize mitigation strategies. In addition, the project approach has been to develop a hardening guide to mitigate threats and work with standards development organizations to develop a new public key infrastructure (PKI) standard and testing system for use in EVSE ecosystems. The reviewer stated that the project presented overall, a very solid approach at this stage of the game.

The reviewer offered that the project approach has largely been a bottoms-up effort looking at vulnerabilities and threats to specific EVSE and their backend systems and how this could radiate throughout the EV ecosystem. At this point, it may be good to start considering top-down cybersecurity elements. For example, where breeches may occur at the cloud, grid, or other level and how EV/EVSE systems could be used as pathways to widely propagate these breeches and their impacts. At this point, what is the right cybersecurity strategy moving forward—a bottoms up approach, or a combination of bottoms-up and top-down approaches and how and where do they intersect both technically and temporally to maximize the overall effectiveness of cybersecurity protection throughout the EV ecosystem?

Reviewer 2:

The reviewer commented that, unfortunately, audio was lost on this presentation for quite some time. Some of the reviewer's comments come only from slide review and not the from presentation because of these audio outages.

The reviewer noted the overall approach of focusing on a portion of the National Institute of Standards and Technology (NIST) Cybersecurity Framework (labeled Risk Assessment under Identify) is sound. Actually, it is the same basic path an adversary seeking compromise would take, which is like walking in an attacker's footsteps to understand their likely methods, discoveries, and eventual exploitation.

However, the reviewer questioned accepting Pacific Northwest National Laboratory's (PNNL's) assertion that the major and severe risks are not actionable, and the reviewer urged that DOE does not accept this argument. Difficult breaches happen all the time and the percentage of national state-backed attacks are into the double digits now and increasing. The reviewer suggested that the project team have a follow-on task to focus on the "big ticket items" in the severe category.

Reviewer 3:

The reviewer remarked that the overall objectives are solid and addressing cybersecurity for greater deployment for EVs is critical, particularly given the increased opportunities for attacks and impacts due to involvement of EVSE and the grid. The approach is a bit complex, though the project team is addressing a complex set of issues. However, the approach may be a bit more complex than desirable for a smooth project, and this may have contributed to how much is left to be accomplished at this time with only 3 months left in the project.

Reviewer 4:

The reviewer stated that the work plan addresses the somewhat open-ended task in a comprehensive manner by methodically assessing all possible attack paths and investigating these in detail. The reviewer indicated that mitigation/avoidance plans are desired outcomes for the work.

Reviewer 5:

The reviewer remarked that it appears that the approach is mixing up physical layer, design-performance evaluation with the original objective of cybersecurity evaluation. It is not clear how the physical layer and crosstalk evaluation fits the cybersecurity evaluation. The reviewer also noted that the reference on Slide 6 for the report titled, "Threat consequence report published 9/2020," appears to be missing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project has made excellent progress on the Red Team assessments of EVSE vulnerabilities, the development of attack graphs and demonstration of particular elements of those graphs, and the Best Practices Guide to securing systems and Risk Matrix/remediation.

Reviewer 2:

The reviewer noted that this project has achieved a number of significant technical accomplishments including the following:

- The project has conducted a first of its kind EV charging infrastructure threat analysis. This includes building of attack graphs that illustrate the various ways an adversary can attack a system and identify key components or vulnerabilities that can be exploited by an adversary. The EV charging attack graphs illustrate attacker access points, staging areas, and consequences of concern and illustrate the steps an attacker must take to move from system/network access to consequences of concern. Central nodes have been identified and prioritized for mitigation efforts. A key finding has been identified—the energy sector cannot mitigate cross-site scripting attacks (XSS) alone and the "ecosystem parties need strong coordinated cyber practices."

- Extensive Red Team assessments have been conducted, which are ideal for complex systems, dynamic adversaries, and security trade-offs. Red Team assessments included, eight DC fast charging (DCFC) and four Level 2 (L2) chargers, two backend networks, and Open Charge Point Protocol (OCPP) 1.6 and International Organization for Standardization (ISO) 15118-2 PKI requirements.
- The project has developed a Best Practices Guide covering all the critical areas of the EVSE ecosystem that provides a high-level view of the entire ecosystem ensuring critical security aspects are not overlooked.
- An updated analysis of power systems consequences has been developed that indicates inter-area oscillations put the grid in an elevated state of risk during system events but does not indicate significant adverse effects caused by the events and scenarios studied.

Reviewer 3:

The reviewer asserted that the project has seemed to accomplish a great deal, including a number of important elements, such as PNNL's grid impacts modeling that showed that major and severe power system impacts are unlikely. The reviewer expressed the concern that there appears to be a lot of work that is still left to be done and the project has only 3 months left. The project team is trying to speed things up, though it may be tough.

Reviewer 4:

The reviewer asked the project team, when considering the smaller sampling rate of evaluated products and assuming that similar identified cybersecurity exist in other non-sampled products, what is the mechanism to enable other manufacturers in the market gain the knowledge and avoid similar pitfalls?

Reviewer 5:

The reviewer commented that, unfortunately, audio was lost on this presentation for quite some time. Some of the reviewer's comments come only from slide review and not from the presentation because of these audio outages.

The reviewer assumed that Slides 6-14 represent the technical accomplishments (though there were not marked as such), again the loss of audio impairs the reviewer's ability to competently comment on the actual remarks. These slides represent an exceptional body of work (with the exception of what the reviewer interpreted is a disavowal of the major and severe consequences on the risk matrix, which the reviewer thought is a position of false hope). The reviewer noted that the attack graphs and the power system consequences update are of particular interest. Additionally, the reviewer thought that the graphic information will go a long way to help educate the general user and power company and aggregator community and help secure the "last leg" better than it has been. This is an important consequence, even if not the most technically sophisticated outcome.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed many key members on the team, including three national laboratories, the Volpe National Transportation Systems Center, four vendors, a utility, EPRI, SAE, and others. These are exactly the organizations that are necessary for addressing this issue. In addition, the project team is coordinating with a number of external agencies, including Department of Homeland Security (DHS), DOT, Army, Navy, and two other DOE programs.

Reviewer 2:

The reviewer noted that the project team included a wide array of relevant organizations. It would be good to have a leading cybersecurity company onboard, and the reviewer did not see one in the list of partnerships and collaborations.

Reviewer 3:

The reviewer stated that the project encompasses a strong group of partners and collaborators across the government, private sector, a utility, and academia. However, the presentation does not indicate the roles or current contributions of many of these partners and collaborators, so it is difficult to assess their true integration and impact on the project.

Reviewer 4:

The reviewer commented that, unfortunately, audio was lost on this presentation for quite some time. Some of the reviewer's comments come only from slide review and not from the presentation because of these audio outages.

While the reviewer was sure this was excellent, the loss of audio hurt the reviewer's ability to comment. Only PNNL was specified as a performer (others were mentioned at the front as teammates, but not given a dedicated slide or bullet comment showcasing their contribution), and there were no graphics or statements showing how coordination and collaboration happened, etc. So, while this is an excellent project and must have had input from the performer community, the loss of audio only allowed the reviewer to see what was on the slides, and the slides did not tell this story.

Reviewer 5:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the breadth of potential future research that was identified is both extremely important and well conceived. The researchers have a clear understanding of how to leverage this initial task under the Identify function and extend it to future R&D programs and their ability to produce informative, industry-facing material (e.g., the Info Graphic) shows that the project team can also bridge concepts into the user community.

Reviewer 2:

The reviewer remarked that the next steps are an appropriate extension of the work done so far.

Reviewer 3:

The reviewer commented that the project team has appeared to identify a number of important future areas for proposed research, indicating that this project has been only a beginning in this critical area. The high level of collaboration has clearly benefited this project in the identification of future needs.

Reviewer 4:

The reviewer stated that the presentation provides merely an adequate discussion of future proposed research by identifying areas requiring additional research, including standardized policies, perimeter defenses, situational awareness and intrusion detection and prevention systems, response mechanisms, and contingency operating modes.

The reviewer expressed concern that the proposed future research appears to be lacking a high-level, overall strategic approach to cybersecurity for the EV ecosystem, which is an ideal role for government. A number of relevant issues and questions to possibly consider include the following:

- What is the process to achieve cross-sector cybersecurity coordination across the EV/EVSE/grid ecosystem? As mentioned earlier, the project has conducted a first of its kind EV charging infrastructure threat analysis with a key finding being that the energy sector cannot mitigate eXtreme Fast Charging (XFC) alone and the "ecosystem parties need strong coordinated cyber practices." As a result, what specific steps need to be taken to address this need for coordination and how do you incentivize and achieve it?
- To date, as it should be, most of the effort has looked at cybersecurity vulnerabilities from the perspective of a specific EVSE and its associated network and subsequent potential grid impacts. In the future, it may be good to examine cybersecurity vulnerabilities from a "system of systems" context. For example, what new and unique cybersecurity vulnerabilities does a full XFC facility or microgrid present where multiple chargers (from different manufacturers) are integrated with battery energy storage and renewable energy generation? How does this scenario present new cybersecurity vulnerabilities and challenges that must be identified and mitigated?
- Overall, what is the "right" high-level cybersecurity strategy? Does a bottoms-up approach, top-down approach, or a combination of the two make the most sense? How does the reality of staggered industry and utility implementation of cybersecurity measures throughout the EV ecosystem affect the effectiveness of the high-level strategy and its implementation?

The reviewer suggested that the project has successfully provided a number of recommendations on how to enhance cybersecurity. The reviewer added some additional suggestions to the project team. A question is how do you further encourage EV ecosystem entities to implement these recommendations? In addition, in the future, it would be good to work with EVSE and grid entities to determine which mitigation strategies and recommendations are truly feasible to implement from a technical and economic standpoint. When not feasible, consideration should be given to going back to drawing board to identify alternate mitigation solutions.

Reviewer 5:

Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project shows an outstanding alignment with DOE's emerging mission as the power source for surface transportation over the next decade and securing the common generation and distribution system that will continue to power our homes and businesses.

The "contingency operating modes" sound closely aligned with an automotive industry current imperative for resilience, and there would likely be strong and very relevant future work on that, too.

Reviewer 2:

The reviewer stated that this project is very relevant as cybersecurity threats to critical U.S. infrastructure will become increasingly pronounced as the transition to EVs at scale and integration with the grid accelerates.

Reviewer 3:

The reviewer said that the quantifying cybersecurity risk to EV grid integration supports the overall DOE objectives.

Reviewer 4:

The reviewer remarked that the EVSEs are a key infrastructure element to enable the DOE goal of widespread EV adoption. Protecting that infrastructure from cyberattack is critical, especially if vulnerabilities can expose the electric grid to risk of failure.

Reviewer 5:

The reviewer noted that the project is addressing cybersecurity for EV charging systems, from the vehicle to the EVSE to the grid. Addressing this concern is critical to greater deployment of EVs while maintaining safety, security, and privacy.

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 is progressing well with the resources provided.

Reviewer 2:

The reviewer remarked that while there were no specific logistical slides, it is clear the project was well managed and produced excellent output. It seems resources were appropriate and well used.

Reviewer 3:

The reviewer stated that the resources provided to date have been sufficient to meet project objectives.

Reviewer 4:

The reviewer indicated that the there was no indication that additional resources are required. The PI did indicate that this is just the beginning of work in this area, so future projects are anticipated.

Reviewer 5:

Not applicable was indicated by this reviewer.

Presentation Number: elt199
Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure
Principal Investigator: Richard Carlson (Idaho National Laboratory)

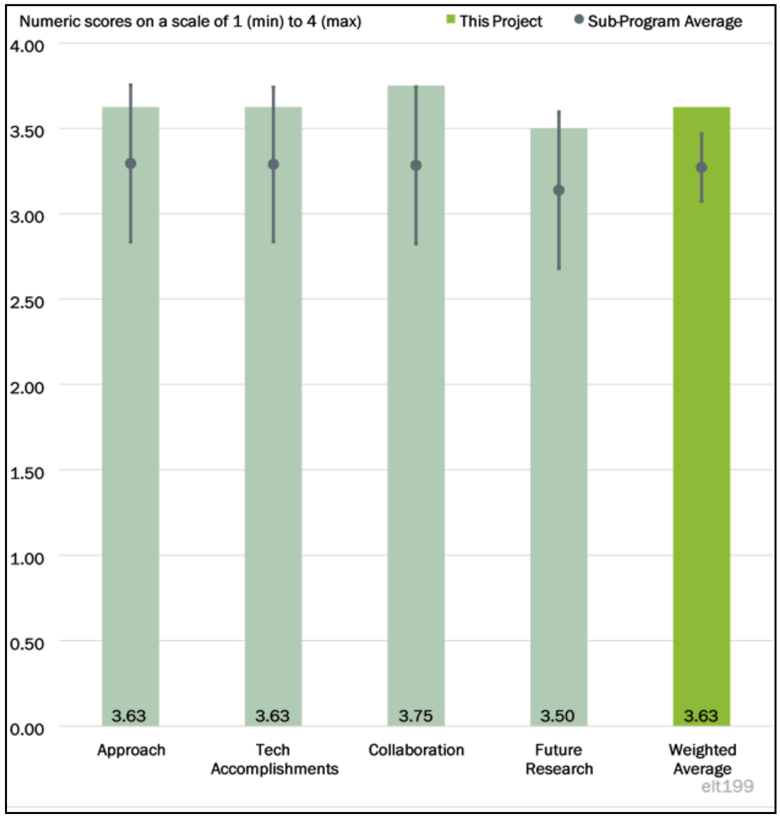


Figure 4-8 - Presentation Number: elt199 Presentation Title: Cybersecurity: Consequence-Driven Cybersecurity for High-Power Charging Infrastructure Principal Investigator: Richard Carlson (Idaho National Laboratory)

Presenter

Richard Carlson, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the project team presented an excellent approach on high consequence events (HCEs).

Reviewer 2:

The reviewer said that the project has a reasoned and straightforward approach for addressing cybersecurity issues, focused on identification, scoring, and developing mitigation strategies for high consequence events (HCEs). The approach included not only established scoring but then using laboratory evaluations for verification.

Reviewer 3:

The reviewer stated that the project team presented an excellent overall approach. The threat matrix application appropriate and allowed reducing the field of interest to less than half of potential study targets allowed focus on what was most relevant. The reviewer added that the use of consequential scoring also highlighted broad areas for study.

Spending time here near project completion to recommend set of mitigating strategies is a great way to end the project (and disseminate that knowledge and set of recommendations). To the point about mitigating strategies, the reviewer posed two questions to the project team. Firstly, and with regard to chipset features, has the project team looked at (or is there a plan to look at this in some future project) the integrity of manufacturer code and reducing risk of foreign sourced components to provide supply-chain assurance and is there a plan in place to sample and validate imported hardware? Secondly, and with respect to micro-patching, has the project team interacted with the Defense Advanced Research Projects Agency's (DARPA) Assured Micropatching Program (AMP) program (this could be additional future work)?

Reviewer 4:

The reviewer stated that the approach identifies an effective means to evaluate the criteria and leads to scoring the impact. This allows utilities, vehicle, EVSE suppliers, and others to focus on their concerns and on actions to reduce security effects.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project team has created an impressive, broad, and actionably body of work. Creating mitigation examples reinforces this.

The project team has also ensured, through broad study and accomplishments, that different aspects of risk are covered such as safety, grid impacts, and even the economic health of corporations. There is clearly "red meat" in the project team's work for many audiences.

While the reviewer is not a strong proponent of intrusion detection system (IDS) type solutions, the reviewer understood why the project team has included these solutions. The project team's work with additional gate driver logic, the safety instrumented system (SIS) concept, and the buffering solution is very interesting, as is (of course) improved communications integrity.

Reviewer 2:

The reviewer noted that the project appears to have identified and scored a number of very specific HCEs, including some that may have not been anticipated initially (like cooling systems). In particular, the project team identified multiple attack pathways, then identified vulnerabilities and attempted system compromise approaches. The project team is now completing development of mitigation approaches. Overall, the project team appears to have accomplished most of what it set out to do in the approach, with the remainder scheduled soon. The reviewer wanted to know if the project team acknowledges that the project may run long by a few weeks or even a month, due to COVID-19-related delays.

Reviewer 3:

The reviewer commented that the project is at the stage to offer several solutions that can be included to reduce security issues.

Reviewer 4:

The reviewer acknowledged that this group understands the high impact HCEs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project is primarily collaborating among three national laboratories, two charger equipment manufacturers, and a charge site owner-operator. In addition, the project team is also collaborating externally with Volpe, the National Motor Freight Traffic Association (NMFTA), the 21st Century Truck Partnership, a bus manufacturer, a wireless charger manufacturer, a university, and four other DOE cybersecurity projects. Together, this provides a very strong approach to collaboration.

Reviewer 2:

The reviewer said that the partners and collaborators included have the background and experience to lead to positive results. This project varies from others as it focuses on consequences, impact severity, and safety aspects.

Reviewer 3:

The reviewer noted that there has been good outreach thus far. The project team still needs to go to grid operators as they put in XFCs.

Reviewer 4:

The reviewer commented that while both ORNL and NREL had a special slide dedicated to them, the other performers did not have any special call-outs, so it was difficult to evaluate collaboration for this task. It is obvious that a lot of great work was performed, and the audience can infer coordination, but that content was not built into the slides, so the reviewer cannot really see 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that, as noted in the slides, the work is nearly complete, and the project is at its scheduled end. With that said, there are clear potentials for work with industry and also excellent potential for future government research programs that may not be limited to DOE. Supply chain matters and micro-patching are examples of work applicable to DOE and other government research programs, and things like buffering and developing new circuit logic could be DOE only.

The reviewer added that mitigating the set of problems described in the objectives is a big issue with big potential impacts, and this research points a clear direction for future work build upon this solid platform.

Reviewer 2:

The reviewer stated that the presentation identified the research remaining under the existing project but did not really identify any future research under potential next projects. Upon questioning, the PI did identify a few ideas for future projects. There is an on-going project for resilient charging (ELT267) that focuses on a near-term need. The PI also indicated that there is related work underway at the site level or multi-site level.

Reviewer 3:

The reviewer said that the future work is expected to include implementing these solutions on future product to validate these claims.

Reviewer 4:

The reviewer noted that there is going to be continued research on this project. The devil, however, is in the details of Mitigation & Improved Planning across the Grid. The reviewer asked where that future research is noted.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that this absolutely is relevant to DOE. Larger vehicles (over-the-road trucks) will need to have XFC to be relevant. Automobiles will need to have XFC to be able to mimic the time “for fueling” of internal combustion engine (ICE) vehicles. The reviewer strongly emphasized that this is a very relevant project.

Reviewer 2:

The reviewer remarked that the project is focused on preventing system compromises for higher-power EV charging, a key cybersecurity area necessary for increased penetration of electric vehicles. This protection is necessary to ensure safe, reliable, and private charging of EVs, while also protecting the grid.

Reviewer 3:

The reviewer stated that this project deals with public safety, the economic health of the electrical suppliers and aggregators, etc., by understanding potential economic impacts, the overall health of the grid, personally identifiable information (PII) issues, and operational stability of local and regional electrical systems. The reviewer was not sure how any project could have more areas of interest to DOE, or how any other single project could have such wide applicability to support the nation's steady progress toward electrified transportation infrastructure.

Reviewer 4:

The reviewer commented that the results from this ranking and scoring of high-consequence events will help the industry and focus the effort into proper categories of impact severity and cyber manipulation. Generally, targets are focused on higher impact areas; however, even lower levels still need attention. Lab results will provide continuous improvement in security approaches.

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 there is critical work still required to be completed, there was no indication that funds were not sufficient. At the same time, as with all the cybersecurity projects, this project likely has formed a basis for future work.

Reviewer 2:

The reviewer commented that funding is "sufficient" for how this project is currently scaled and detailed.

Reviewer 3:

The reviewer remarked that the reviewer had no opportunity to observe the milestones, but it was a great project, so the project team clearly used whatever it was given to great effect.

Reviewer 4:

The reviewer said that the collaboration with other labs, equipment manufacturers, and charge point providers provided a good balance of focus on the goals of this project and is expected to lead to positive results.

Presentation Number: elt201
Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration (ANL)
Principal Investigator: Keith Hardy (Argonne National Laboratory)

Presenter

Keith Hardy, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

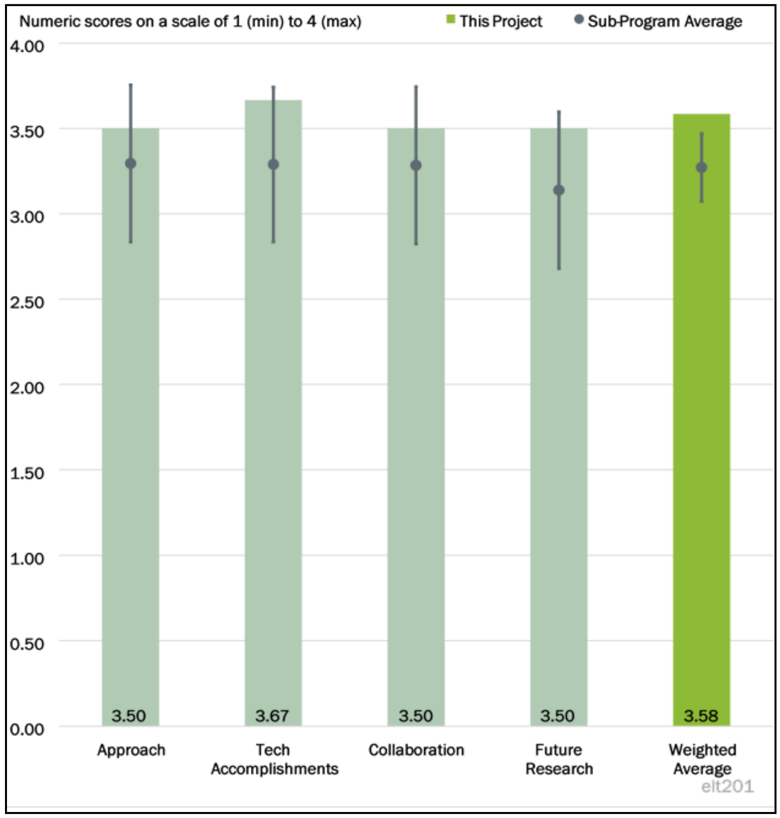


Figure 4-9 - Presentation Number: elt201 Presentation Title: Charging Infrastructure Technologies: Smart Vehicle-Grid Integration (ANL) Principal Investigator: Keith Hardy (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer applauded the excellent ground-up approach considering that many of the technologies are not well developed. The creation of "reduction to practice" hardware for the vehicle-grid integration (VGI) vision is a valuable contribution.

Reviewer 2:

The reviewer remarked that the updates to the Smartgrid EV Communication (SpEC) II communication controller with diagnostics and a phone app provide alternative tools to capture information and establish analysis on charging sessions. SpEC is an excellent tool to aid in VGI, diagnostics, and other items for the charging session.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project accomplished great progress considering COVID-19 interruptions. Use of simulated real-time transmission system and distribution grid linked between ANL and INL was a great alternative to actual systems. Development of the ISO 15118 ecosystem was another great accomplishment that can be leveraged by industry.

Reviewer 2:

The reviewer commented that progress was made with the ISO 15118 EVSE and the capability to capture power line communication (PLC) data. The dashboard that includes digital and graphical information is a good tool for the customer and OEMs to use.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that ANL has led the collaboration and coordination and ensured that the teams in other regions are included in this effort. Information exchange of the approach and progress at ANL, INL, and the Joint Research Center (JRC) labs are used to mature and validate the standards for energy management communication and controls.

Reviewer 2:

The reviewer noted that a wide array of collaborations occurred to get the work done, and all relevant parties appear to be participating.

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 state project ended.

Reviewer 1:

The reviewer remarked that ANL has an outstanding future research position because charging systems are still evolving, and energy plaza capabilities will be able to validate updates to the standards and identify issues that need to be resolved for further updates to improve charging system interoperability. The monitoring and diagnostic tools being developed will continue to aid in the development of existing and new features.

Reviewer 2:

The reviewer said that the next steps are appropriate extensions of the work done to date.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that the project supports the DOE vision of making EV technologies more widely available by providing hardware and software implementation examples that industry can leverage in products deployed in the field.

Reviewer 2:

The reviewer stated that this project supports DOE objectives by providing a national laboratory approach for development and validation to improve and expand the communication and equipment standards. The project contributed by developing diagnostics and metering equipment and complements this by providing solutions for the 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 stated that ANL has sufficient resources for this project and is able to balance OEM and EVSE supplier needs.

Reviewer 2:

The reviewer emphasized that the team is doing a good job with resources provided.

Presentation Number: elt202
Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE)
Principal Investigator: Jesse Bennett (National Renewable Energy Laboratory)

Presenter

Jesse Bennett, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

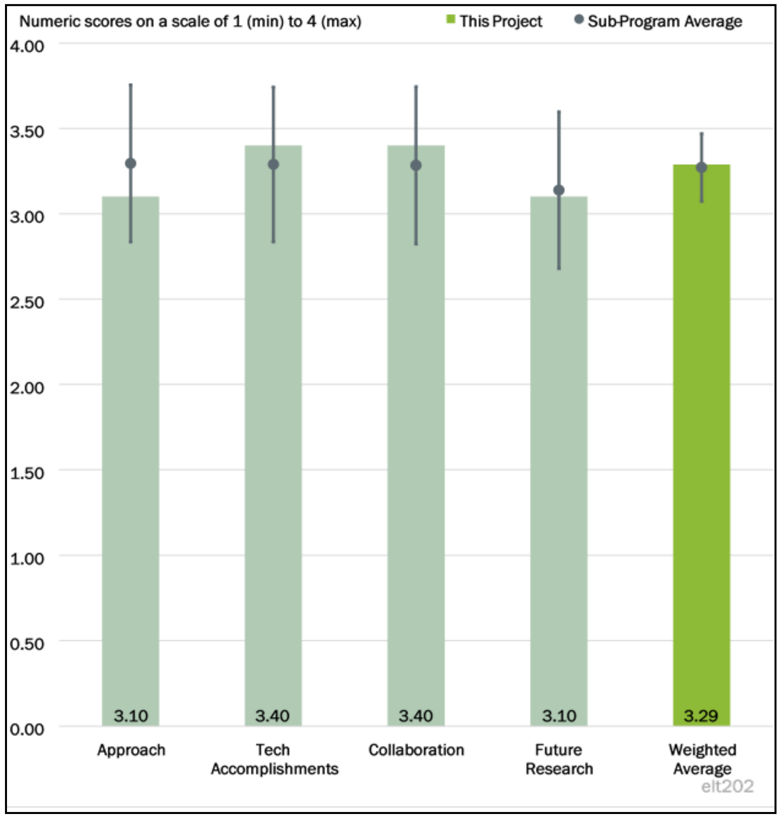


Figure 4-10 - Presentation Number: elt202 Presentation Title: Charging Infrastructure Technologies: Smart Electric Vehicle Charging for a Reliable and Resilient Grid (RECHARGE) Principal Investigator: Jesse Bennett (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this project has an excellent approach for optimized use of the grid for balancing the grid and meeting vehicle charging requirements. This project provides the background for a variety of loads and management scenarios.

Reviewer 2:

The reviewer observed an impressive project approach because the project seems very comprehensive. Would like the final Annual Merit Review (AMR) to provide more detail on how lessons learned from this work will be transferred to industry. The reviewer asserted that this work is so important, it should be transferred to utilities other than just those involved with the project.

Reviewer 3:

The reviewer observed that the model development appears to be very good, and it is apparent that much effort and thought went into it. The reviewer was less clear about how the various assumptions and strategies relate to real-world behavior. As an example, how would a random time-of-use (TOU) strategy actually be implemented?

The reviewer also mentioned that scenarios also assume everyone behaves exactly the same way and asked what percentage of EV owners today can and do take advantage of time-of-day pricing. Does EDF Renewables or the utility partners not have those data?

Reviewer 4:

The reviewer noted that several changes are needed to the work approach. A straight, across-the-board percentage cut of conventional cars cannot be assumed to adopt EVs. DOT has found that socioeconomic class (i.e., affluence) affects vehicle purchase because EVs are discretionary purchases—not purchases out of necessity. Because socioeconomic class also affects geographic distribution of residences, power distribution for EV recharging will also be affected, which has to be taken into account.

Additionally, this reviewer indicated that commercial vehicles (i.e., trucks and buses) need to be taken into account. Resiliency was only considered for hurricanes in the Atlanta area; no such consideration for resiliency was made for Minneapolis. The reviewer also remarked that changes in home-work travel patterns have occurred, and more work-at-home is expected after the pandemic. This needs to be taken into account.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project appears to be well managed and is on track to meet the stated schedule.

Reviewer 2:

The reviewer commented that the milestone chart in the AMR presentation slides was very helpful in evaluating this dimension. The reviewer was very interested in seeing the final project review, which will hopefully be able to go into more depth on all phases of the project and not just the final year of work. One concern expressed by the reviewer is that it looks like very many of the difficult tasks need to be completed in the final 6 months of the project.

Reviewer 3:

The reviewer suggested that using charging history as input is needed to predict future needs. This balances the planning for additional and changing needs to include vehicle charging in infrastructure plans. Considerations that have included climate effects to grid loads have demonstrated a full approach for aggregators and planners to establish the optimal control and user benefits for balancing vehicle charging needs.

Reviewer 4:

The reviewer commented that the technical accomplishments for passenger EVs are satisfactory as measured against performance indicators. However, the geographic distribution of EVs as affected by socioeconomic class and thus the recharging and distribution of power for recharging were not taken into account.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the overall coordination appeared very good except with respect to actual, real-world data that this reviewer believed some of the partners could be providing.

Reviewer 2:

The reviewer said that this project has demonstrated close coordination with other national laboratories and includes assignment of resources to optimize the effort of all participants.

Reviewer 3:

The reviewer was very glad that the project is working with three separate cities and their representative power companies. This collaboration should help make certain that project results are transferable to any utility in the

United States. However, because the project plans to "Develop and evaluate the effectiveness of smart charging control strategies," it would be helpful to increase vehicle OEM participation in this project.

Reviewer 4:

The reviewer stated that no real challenges were faced—the only external stakeholders were the few who supplied data.

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 state project ended.

Reviewer 1:

The reviewer noted that this year will integrate the approaches previously developed and then be able to validate the approaches. More effort can be applied to DER combined with optimized energy usage.

Reviewer 2:

The reviewer commented that the proposed Future Research was not fully explained in the AMR presentation. Time was short for the question and answer (Q&A) period, but this reviewer was interested in more detail on the "publication development" bullet point on the Proposed Future Work slide. Again, this is a very good project, and the team should work to make certain that it and the results are appropriately transferred to industry.

Reviewer 3:

The reviewer remarked that the project team seems to have identified a potential risk in the TOU immediate scenario. It is not likely that every EV owner behaves the same way, but even if 25% or 30% do respond to TOU, there appear to be risks to the infrastructure. The reviewer asked the project team why that is not addressed.

Reviewer 4:

The reviewer referenced prior comments and explained that the only research seen as needed is addressing the four approach shortcomings previously pointed out.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project very directly supports several of the DOE's goals but is primarily aimed at efficient use of the grid to charge EVs.

Reviewer 2:

The reviewer stated that this is relevant as major metropolitan areas are where EV adoption is highest and where the need is greatest.

Reviewer 3:

The reviewer affirmed that this project supports DOE objectives by including planning functions for grid stability. This planning and approach are expandable as the quantity of vehicles increases and the management approach is expanded to other locations.

Reviewer 4:

The reviewer said that this research is premature, that is, ahead of its time. It is not possible to have any idea of what the adoption rates for EVs will 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 noted that the resources appear to be sufficient to meet the goals by the end of the project.

Reviewer 2:

The reviewer commented that this project sufficiently steps through the actions needed to meet current needs while planning for additional growth of the electrification market. This project demonstrates the ability to dynamically adjust and adapt as conditions change due to climate and vehicle availability and usage varies while matching the grid stability functions. National laboratory resources are imperative to establish the foundation for this analysis, and tools that can be then used by aggregators and planners. No single or combined entities in the private sector can accomplish this task.

Reviewer 3:

The reviewer said that there are no issues noted in this area.

Reviewer 4:

The reviewer stated that the $6 million is excessive for this kind of modeling work.

Presentation Number: elt204
Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MegaWatt Charging System for Medium- and Heavy-Duty Electric Vehicles
Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

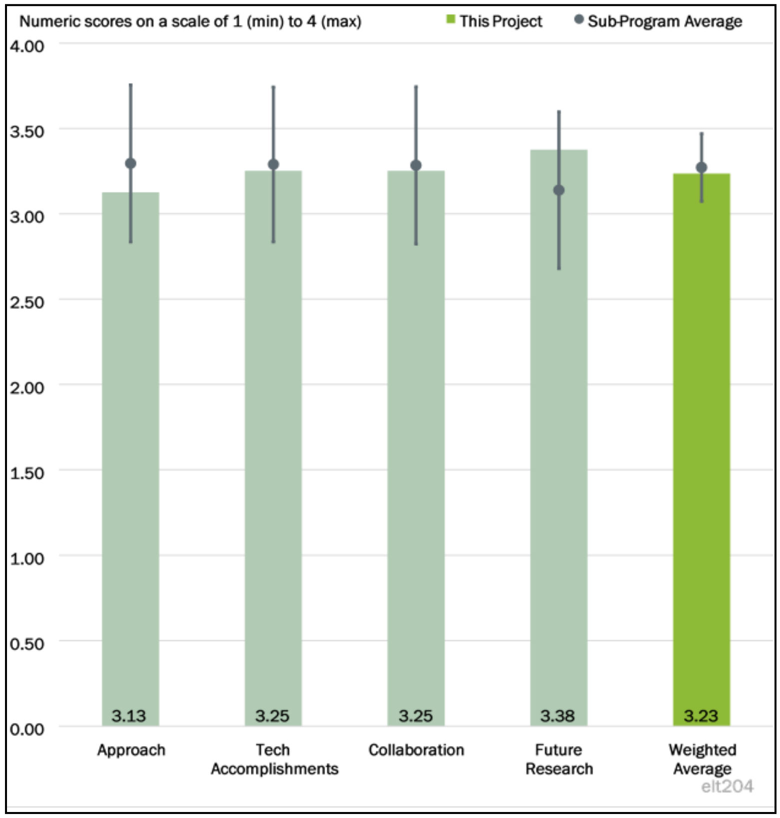


Figure 4-11 - Presentation Number: elt204 Presentation Title: Charging Infrastructure Technologies: Development of a Multiport, >1 MegaWatt Charging System for Medium- and Heavy-Duty Electric Vehicles Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the approach to the technical work and engagement with standards bodies looks very good, but there are still three points that could be clarified better:

- A lack of end-user industry project partners. Many industry engagement partners are listed, but it is not clear to what extent any have contributed information or data for this particular project.
- The end product is a journal article and a prototype of one portion rather than a physical demonstration of the entire system. Many technical issues can crop up when taking a design to actual real-world usable hardware.
- The reviewer questioned whether end-users actually want a physically connected 1+ megawatt (MW) charger when there are wireless chargers in development with similar power and 92% target efficiencies (mentioned in Project ELT240), though this is a small portion of the overall objectives.

Reviewer 2:

The reviewer commented that the project is well planned and, given that it is near the end, expected that it will be completed. However, the reviewer stated that there is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 3:

The reviewer observed good tool use and development and an approach that accounts for all the right key elements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the milestones indicate the team is on track to complete the project. It would be helpful to the evaluators if the project team would make the quarterly reports available because they are referenced in the milestones.

Reviewer 2:

The reviewer stated that the project team has accomplished a lot from site analysis, power engineering (PE) design, battery options, and connector design.

Reviewer 3:

In the past few years, the reviewer has seen a decrease in evidence presented in these AMR reviews to confidently share that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the freight efficiency improvements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that there is a clear connection to industry partners for inputs.

Reviewer 2:

The reviewer noted that the presentation does not specify which partner is responsible for which part of the project. However, since technical progress appears to be proceeding to plan, is the reviewer assumed that collaboration among named partners is good.

Reviewer 3:

The reviewer remarked that there seems to be little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed there should be more effort on fleet and other engagements in these programs.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed next steps are in line with the stated objectives.

Reviewer 2:

The reviewer observed a good program and there is a need within industry for help.

Reviewer 3:

It was not completely clear to the reviewer how the remaining challenge of “Definition and refinement of 1+ MW charging site scenario (distribution feeder and charger utilization) that will drive understanding and

R&D" is different from the challenge that was addressed in the project. The reviewer asked for clarification by asking the project team whether this has already been done by this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that this project supports DOE objectives to reduce fuel use in commercial vehicles by helping to understand if the charging infrastructure is possible to support electrified commercial vehicles.

Reviewer 2:

The reviewer briefly stated that the project is very relevant to the overall DOE objectives.

Reviewer 3:

The reviewer stated that the project furthers the DOE objective of advancing electrification in transportation, although the reviewer believed it would be much more effective with an industry partner, resulting in demonstration hardware for a whole 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 stated that the project team did not indicate that they were short of any resources.

Reviewer 2:

The reviewer commented that the funding seems to be sufficient.

Reviewer 3:

The reviewer remarked that a lot was achieved, and it was a lot of money. It appears that the labs brought enough resources to make the work happen as good results were achieved in all areas. Considering the value to the commercial vehicle charging industry, it would seem that some industry cost share could be expected.

Presentation Number: elt205
Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX)
Principal Investigator: David Coats (ABB)

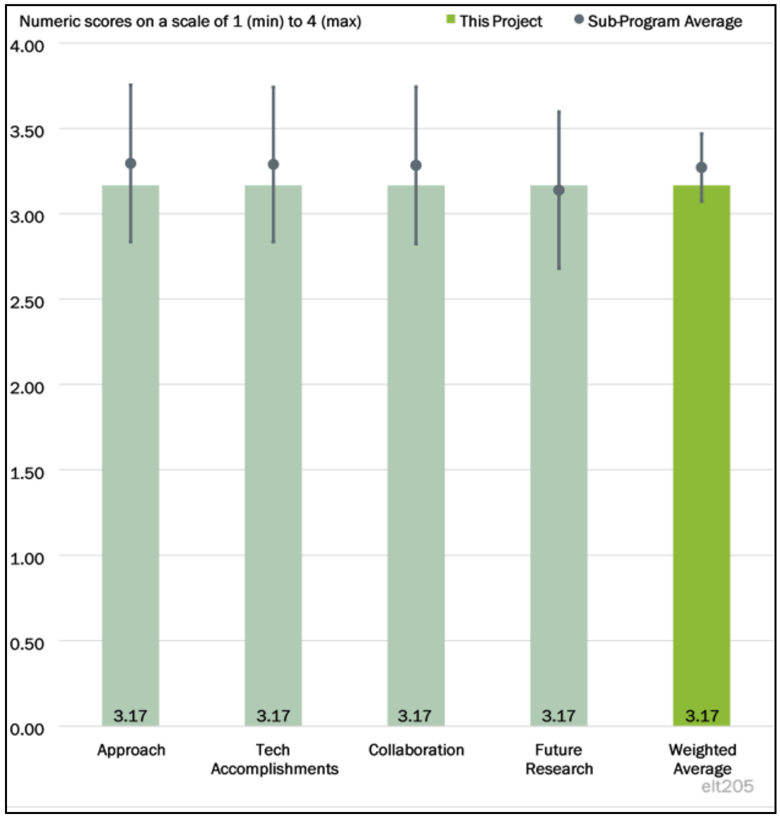


Figure 4-12 - Presentation Number: elt205 Presentation Title: Cybersecurity for Grid-Connected Extreme Fast Charging Station (CyberX) Principal Investigator: David Coats (ABB)

Presenter

David Coats, ABB

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 33% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this is a good approach with modeling, simulation, then HIL testbed.

Reviewer 2:

The reviewer remarked that this approach appears to train the system to address a fairly limited range of operating conditions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the schedule milestone completion listing indicates that good progress has been made. However, the AMR contains limited technical data evidence to support the summary status listings.

Reviewer 2:

The reviewer commented that the Milestone 5 was marked completed since last year's AMR. It would have been good to see some more details and data regarding the results of this effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the progression of the work from the ABB lab to INL indicates strong collaboration and coordination across the project team.

Reviewer 2:

The reviewer commented that it was good to see utilization of both ABB and INL testing capabilities. It looked to the reviewer like all partners are contributing.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed future research indicates that future work would appropriately focus on previous gaps.

Reviewer 2:

The reviewer noted that it looks like the right work to close out the project with high power testing at INL.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project supports the overall DOE objectives to advance the state of the art of cybersecurity for high-power EV charging systems.

Reviewer 2:

The reviewer stated that it is not completely clear how high a priority this work is. Certainly, charging is needed to meet DOE goals, and secure charging needs to be part of that. It was just not clear to the reviewer how big a problem secure charging is and whether it is at the level where DOE-funded research is needed to enable it.

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, in light of the COVID-19 induced delays, this project likely needs more resources.

Reviewer 2:

The reviewer commented that the project has sufficient resources. COVID-19 hurt, but that was unavoidable.

Presentation Number: elt206
Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem
Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Presenter

Sunil Chhaya, Electric Power Research Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

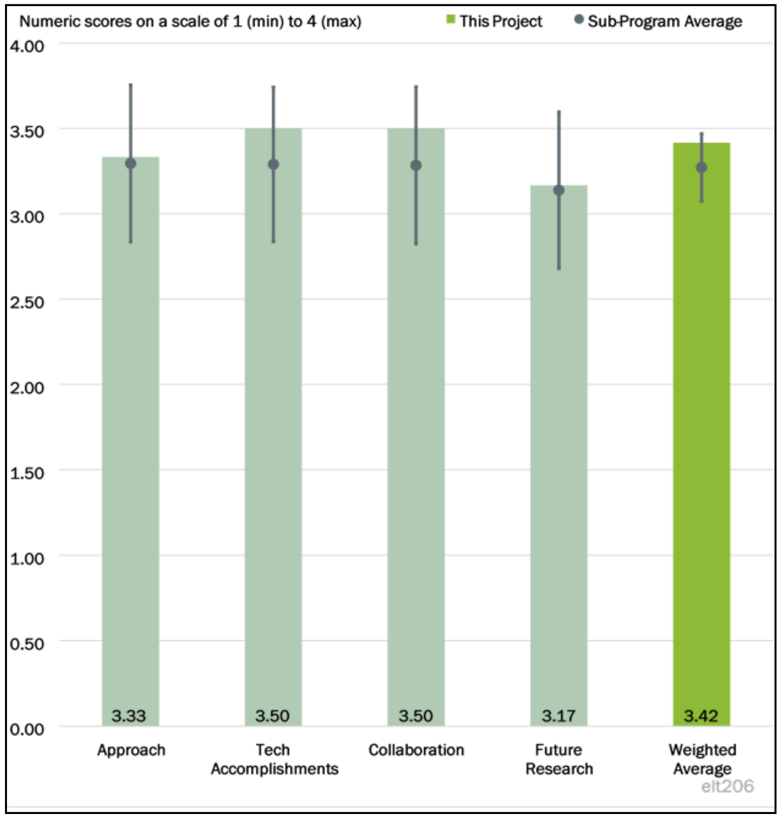


Figure 4-13 - Presentation Number: elt206 Presentation Title: Cybersecurity Platform and Certification Framework Development for Extreme Fast Charging, Integrated Charging, Infrastructure Ecosystem Principal Investigator: Sunil Chhaya (Electric Power Research Institute)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the work has an excellent division of effort at CSRL, ANL, and NREL. Each work group has the ability to work both independently but also toward common approaches and solutions to improving security.

Reviewer 2:

The reviewer stated that the overall approach appears straightforward for addressing cybersecurity concerns, with a focus on a specific solution—the secure network interface card (S-NIC). The approach includes clear elements on assessment, define and design, build, test and validation, and outreach and coordination.

Reviewer 3:

The reviewer remarked that it is good to be looking at the whole ecosystem. Open-source NIC would seem like a good starting point, but the reviewer asked if the industry would use an open-source device.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the common approaches are tested at multiple sites to validate the approach and results. Each lab also includes specific functions that add to the completion of the project.

Reviewer 2:

The reviewer stated that the project appears to have largely accomplished what it set out to do, with the key accomplishment being the design and development of the S-NIC. During 2020-2021, there were three primary areas of focus—testing to verify results, developing an integrated grid tool, and then working to get the word out on developments including through the Working Group. The project did hit some COVID-19-related delays and will therefore be ending a bit later than originally anticipated, although all project objectives are expected to be met.

Reviewer 3:

The reviewer said that the EV Communications and Cybersecurity Management (EVC2M) tool seems to be a significant accomplishment to help the industry, but it does not seem to have been released yet per the schedule in the presentation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project looks like excellent collaboration between labs and industry on defining the reference architecture and understanding the ecosystem.

Reviewer 2:

The reviewer noted that the core team is led by EPRI and includes two national laboratories, a system integrator, a charge system network provider, and an EVSE manufacturer. The project team appears to be clearly taking advantage of the unique capabilities of each research organization. In addition, the project team externally engaged an EV Infrastructure Cybersecurity Working Group, as well as a utility, three EV manufacturers, and a site operator-owner.

Reviewer 3:

The reviewer said that each participant complements the other in working toward the goals of the project. Validating this at the various labs provides the support to ensure improved security approaches.

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 state project ended.

Reviewer 1:

The reviewer said that the project is essentially complete. The stated future goal of incorporating project knowledge into standards seems like a good approach.

Reviewer 2:

The reviewer stated that this effort is applicable to the continued effort required for new security threats. Continued evaluation is needed as threats and solutions continue to evolve.

Reviewer 3:

The reviewer stated that the project team has identified several areas for future research, particularly in the areas of scale-up, field testing and verification, and aligning results and recommendations with national-level industry approaches. In effect, the PI was recommending a continuation of the path this project has established, although perhaps without providing too many specifics on individual research activities.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project is focused on approaches to ensure secure high-power charging of EVs, which is critical to the expansion of use of EVs.

Reviewer 2:

The reviewer stated that EV charging is needed and some standards on secure charging are needed to move this forward.

Reviewer 3:

The reviewer commented that this project allows the analysis of existing standards to be evaluated and improved. While each of the team's approaches this from different angles or aspects, more solutions can be realized than from a project with less diverse and smaller teams.

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 was no indication by the PI that the resources were insufficient. As with all cybersecurity projects reviewed, there was an indication that this project formed the basis for future work.

Reviewer 2:

The reviewer commented that the resources seem fine.

Reviewer 3:

The reviewer remarked that these labs have the equipment and resources to accomplish this task. Additional vehicles and chargers are always harder to include, but as production and diversity continues, this will be more sufficient in future projects.

Presentation Number: elt207
Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach
Principal Investigator: Ryan Gerdes (Virginia Tech University)

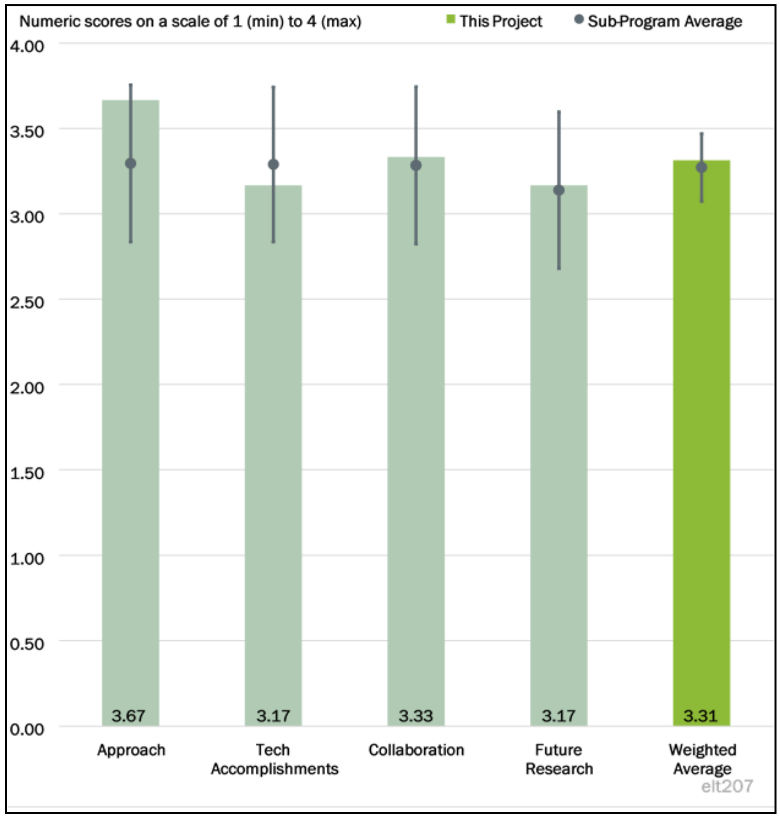


Figure 4-14 - Presentation Number: elt207 Presentation Title: Enabling Secure and Resilient Extreme Fast Charging: A Software/Hardware Security Co-Design Approach Principal Investigator: Ryan Gerdes (Virginia Tech University)

Presenter

Ryan Gerdes, Virginia Tech University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach should be able to identify failures in implementing communication standards and lead to more robust systems.

Reviewer 2:

The reviewer commented that the software-hardware co-design approach is good. The cost optimization thinking is a good approach. The reviewer liked that the moving target defense does not have to have a known model of the system. It makes it more generic and useful, but the reviewer asked if it can be shown to be as effective as having a model of the system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the task assignments of effort for lead and support is well defined and will help to show positive results in each category.

Reviewer 2:

The reviewer commented that it looks like good progress across a range of milestones in hardware and software. Milestones 10 and 11 list functional testing of the hardening features as outcomes and as complete, but the material does not clearly show results of those tests. In fact, the details for Milestone 11 say "waiting for printed circuit boards (PCBs)" so it appears that the "complete" status in the initial table is inaccurate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that each team has a clear focus on each task and what it is expected to contribute to the overall progress.

Reviewer 2:

The reviewer stated that it is good to see the lead on different milestones being spread around to different 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that it is good to see a number of areas covered.

Reviewer 2:

The reviewer remarked that the expanding the approach to other communities and products now in the market will validate the approach used in this project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer commented that secure charging is needed to help EV's meet DOE objectives.

Reviewer 2:

The reviewer stated that more vehicles and EVSEs continue to enter the market and additional updates to standards are also being implemented. These need to be continually analyzed for security aspects. This is an ongoing effort and needs to expand as the market grows.

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 fine.

Reviewer 2:

The reviewer stated that the resources are sufficient for the start of this approach. Expansion to other suppliers and charge point operators along with additional utilities are key to maximizing input for a robust solution and need to expand to include more of these variations.

Presentation Number: elt208
Presentation Title: Highly Integrated Power Module
Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

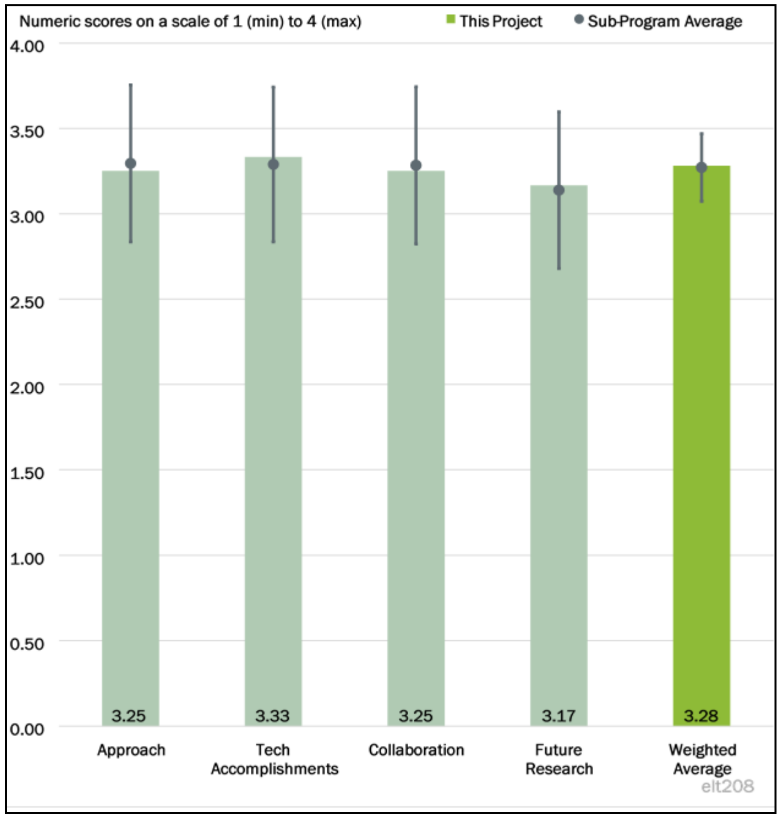


Figure 4-15 - Presentation Number: elt208 Presentation Title: Highly Integrated Power Module Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

Presenter

Emre Gurpinar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the presentation seems to be logically organized, which may reflect the project status.

Reviewer 2:

The reviewer stated that it looks like accumulated experience and know-how from the past ORNL projects are nicely utilized to move further forward.

Reviewer 3:

The reviewer said that the presentation included many good data slides and information reviewed. It would help to show a summary slide that describes the purpose of each tested component. There is a good comparison to DOE technical goals, but it would also be good to see a comparison to the current state of the art.

Reviewer 4:

The reviewer remarked that the proposed technical approach is sound and addresses many critical issues associated with power module reliability. This area of focus is a key enabler for increasing power density and efficiency to achieve the 2025 DOE ELT technical targets. The team would benefit from expanding the rigorous multi-objective optimization approach to other aspects of the design, including thermals.

Reviewer 5:

The reviewer commented that, overall, the approach is reasonable. Not all technical barriers have been addressed. For example, there is no discussion of activities relating to reliability of the device and system under severe NVH conditions. This is important since this power electronics device is aimed at traction vehicles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the progress that has been reported thus far is quite good.

Reviewer 2:

The reviewer noted that very nice progress can be observed. In particular, a prototype of the optimized heat-sink is good. Also, good is that switching transient waveforms is much cleaner than those presented last year. The reviewer emphasized that it is very important to fully utilize wide band gap (WBG) power semiconductor capability without electromagnetic interference (EMI) problems.

Reviewer 3:

The reviewer stated that it looks like good progress was made and the project is on track.

Reviewer 4:

The reviewer remarked that the details of the testing and design are shared, but a high-level overview of accomplishments compared to the plan would be beneficial.

Reviewer 5:

The reviewer said that the team has shown significant progress toward technical goals and objectives early in FY 2021. However, the reviewer added that the primary deliverables and milestones for FY 2021 are not hardware oriented. Upcoming milestones of hardware testing will be critical for benchmarking recent team progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the national laboratories, universities, and industry coming together demonstrates excellent collaboration.

Reviewer 2:

The reviewer stated that the partnership among different participating entities is excellent, and distribution of work is very good.

Reviewer 3:

The reviewer stated that it looks like the workload is well divided.

Reviewer 4:

The reviewer remarked that the presentation did not note where the project team mentioned how partners were involved with the work.

Reviewer 5:

The reviewer remarked that collaborations are claimed in the slides, but partner organization specific contributions are not highlighted in the detailed technical slides. Also, the deliverables (publications, etc.) appear biased toward ORNL team members. The project looks very ORNL-centric, and the reviewer wondered to what extent the other team members are being engaged and contributing. Team members should be more clearly highlighted, and their contributions specifically identified.

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 state project ended.

Reviewer 1:

The project has identified hardware-oriented go/no-go decisions to guide future project outcomes. This is a strength. One opportunity for improvement would be enhanced quantitative metrics surrounding decision points and criteria.

Reviewer 2:

The reviewer said that the future challenges are documented.

Reviewer 3:

The reviewer said that the future research is well documented.

Reviewer 4:

The reviewer stated that the project team presented a very good and reasonable step-by-step plan for the continuing work. It would be even better if a cost reduction requirements estimation could be done for the piezoelectric (PZLT) capacitors and other possibly expensive components in order to meet the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Electrical and Electronics Technical Team Roadmap (EETT) cost target of $2.70/kW.

Reviewer 5:

The reviewer noted that, in Future Research, there is no discussion of activities relating to how reliable the device and the system will be under severe NVH conditions. This is important since this power electronics device is aimed at traction vehicles.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that for the high-power density power electronics of the DOE objectives, this line of highly integrated power modules is one of the key factors. The relevance of this project to the overall Electric Drive Technology (EDT) Consortium is very high.

Reviewer 2:

The reviewer stated that it is very relevant and expressed interest in seeing some industry engagement.

Reviewer 3:

The reviewer remarked that the power electronics devices are vital to various energy systems and more electrification of various systems, including vehicles. All of these are within the scope of DOE objectives.

Reviewer 4:

The reviewer said that, yes, the project is well aligned.

Reviewer 5:

The reviewer commented that the expected impact on traction power would be good to know. How does the DOE goal influence this?

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, for the defined scope of work, the resources should be sufficient.

Reviewer 2:

The reviewer observed sufficient, available resources based on Slide 2 of the AMR presentation.

Reviewer 3:

The reviewer stated that the resources appear sufficient, but it is unclear what the resource breakdown is between partner organizations. So, more optimal distribution may be possible with detailed analysis.

Reviewer 4:

The reviewer remarked that the sufficiency of the resources was the assumption.

Reviewer 5:

The reviewer did not see the overall budget number in the AMR presentation.

Presentation Number: elt209
Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter
Principal Investigator: Gui-Jia Su (Oak Ridge National Laboratory)

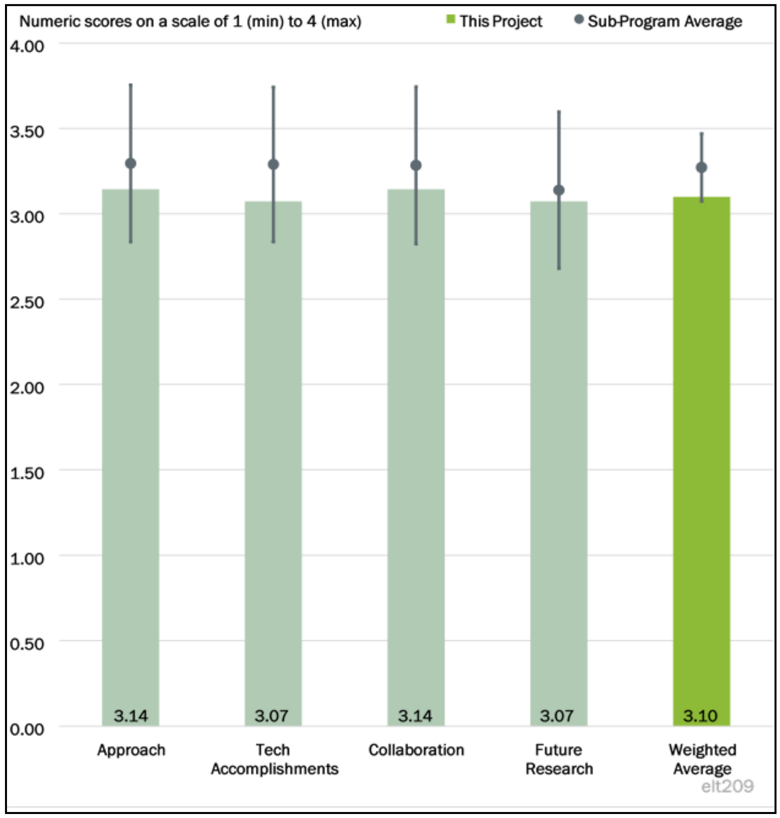


Figure 4-16 - Presentation Number: elt209 Presentation Title: High-Voltage, High-Power Density Traction-Drive Inverter Principal Investigator: Gui-Jia Su (Oak Ridge National Laboratory)

Presenter

Gui-Jia Su, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the very thorough design work and step-by-step problem solving to getting a minimum capacitor in an inverter DC bus is an excellent approach.

Reviewer 2:

The reviewer stated that it seems to be one of the “group” projects, which is very good.

Reviewer 3:

The reviewer commented that the project is a nicely thought through approach, including comparative evaluation with the open-end winding three-phase six-leg inverter.

Reviewer 4:

The reviewer remarked that the team seeks to explore various inverter architectures, increase bus voltage, and optimize bus bar designs to maximize power density and reduce the size of passives. This is an important objective, and the team pulls from strategic partners for critical inputs (Virginia Polytechnic Institute and State University [Virginia Tech], power modules, University of Arkansas, sensors, NREL, and thermals).

Reviewer 5:

The reviewer stated that the approach used is in line with the project objectives.

Reviewer 6:

The reviewer commented that the project is very well addressed to a high degree and is feasible. Overall, the approach is reasonable. Not all technical barriers have been addressed. For example, there is no discussion on activities relating to how reliable the device, and the system will be under severe NVH conditions. This is important since this power electronics device is aimed at traction vehicles. On cost issues, it has not been noted if these are for volume quantities. Another thing is about the 300,000-mile reliability and lifetime definition—it is important to mention for what kind of vehicles and under what kind of terrain and drive cycle are these numbers valid.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the technical accomplishments are promising and demonstrate good achievements.

Reviewer 2:

Great progress has been made since the 2020 AMR according to this reviewer.

Reviewer 3:

The reviewer said that the progress made is compatible with the timeline.

Reviewer 4:

This reviewer noted good technical accomplishments including 100 kW inverter design completion. The motivation for "metal–oxide–semiconductor field-effect transistor (MOSFET) only," "MOSFET with Body-Diode," and "Diode" comparison for the third quadrant operation on Slide 10 was not crystal clear to this reviewer because it is going to be "MOSFET with Body-Diode" anyway in the inverter operation.

Reviewer 5:

The reviewer remarked that the accomplishments should be clearly highlighted and not just work done stated.

Reviewer 6:

The technical accomplishments of the project appear acceptable, but focus primarily on simulations, designs, and down selections. There is a lack of clear metrics identified for performance targets, and so it is difficult to fully assess progress relative to expectations. More clear benchmarking can occur once the hardware prototypes are fabricated and tested in upcoming quarters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the collaboration seems to be good, and it is vital for success.

Reviewer 2:

The reviewer said that the group is very capable, and the participating entities got the correct assignments for each.

Reviewer 3:

This reviewer observed good teamwork by the ONRL team led by Gui-Jia Su, which is collaborating with NREL, Virginia Tech, and the University of Arkansas.

Reviewer 4:

The reviewer stated that the national laboratories and university collaboration is good. It would be even better if there were industry collaborators.

Reviewer 5:

The team has demonstrated collaborations with other partners (Virginia Tech, University of Arkansas, and NREL), although partner contributions could be more clearly identified. This is particularly true for NREL in which it is not clear to what extent it has been engaged in the project to date.

Reviewer 6:

The reviewer commented that the collaboration was reviewed fairly quickly and did not provide much detail.

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 state project ended.

Reviewer 1:

The reviewer stated that the planning is excellent.

Reviewer 2:

The reviewer indicated that the proposed future work focuses on hardware prototypes, benchmarking, validation, and iteration. This is the appropriate next phase in the work, given the current status of the program. The reviewer looks forward to seeing the full hardware prototype testing results.

Reviewer 3:

It was logical to this reviewer that once the power stage of power-dense inverter is designed, it is time to complete the control board. The team is following logical steps in designing a power-dense SiC inverter.

Reviewer 4:

The reviewer observed a good plan for continuing work. The reviewer is enthusiastically looking forward to hearing about the hardware prototype built and its test results. Also, it would be great if cost reduction requirements estimation would be carried out for some of the possibly expensive components, such as TDK Ceralink capacitors and silicon carbide (silicon carbide [SiC]) MOSFETs, in order to meet the U.S. DRIVE EETT cost target of $2.70/kW.

Reviewer 5:

The reviewer stated that the plan outline for future work is consistent with the scope of the project timing.

Reviewer 6:

The reviewer stated that it is nothing new, just continuing the project. The reviewer would have liked to see some adjustments based on recent findings.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that, yes, high-power density inverters are highly relevant to the EDT Consortium target. This project is tackling the challenging problem of building a very high-power density inverter as one of the keystone items.

Reviewer 2:

The reviewer liked this keystone "bundle" projects and would have liked to see more of them.

Reviewer 3:

The reviewer said that the project supports the DOE objectives and is relevant to transportation and other energy related activities.

Reviewer 4:

The reviewer stated that the inverter architecture trade studies and hardware design and development are critical to meeting technical targets.

Reviewer 5:

The reviewer is looking forward to seeing the final results.

Reviewer 6:

The reviewer remarked that this project fulfills DOE's aspiration to get to a 100-kW inverter. However, the reviewer was not very sure the cost target will get to $2.7/kW. This project is very relevant to industry's need for improved understanding of vehicle power inverters.

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 well aligned with requirements.

Reviewer 2:

This reviewer indicated that the team has enough resources and great support from universities.

Reviewer 3:

The reviewer commented that the project is on track to complete the work.

Reviewer 4:

The reviewer said that the resources are reasonable for the stated milestones.

Reviewer 5:

The reviewer noted that the resources seem to be sufficient.

Reviewer 6:

Based on Slide 2 of the AMR presentation, the reviewer interpreted the resources for the project as sufficient.

Presentation Number: elt210
Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain
Principal Investigator: Andrew Binder (Sandia National Laboratories)

Presenter

Andrew Binder, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

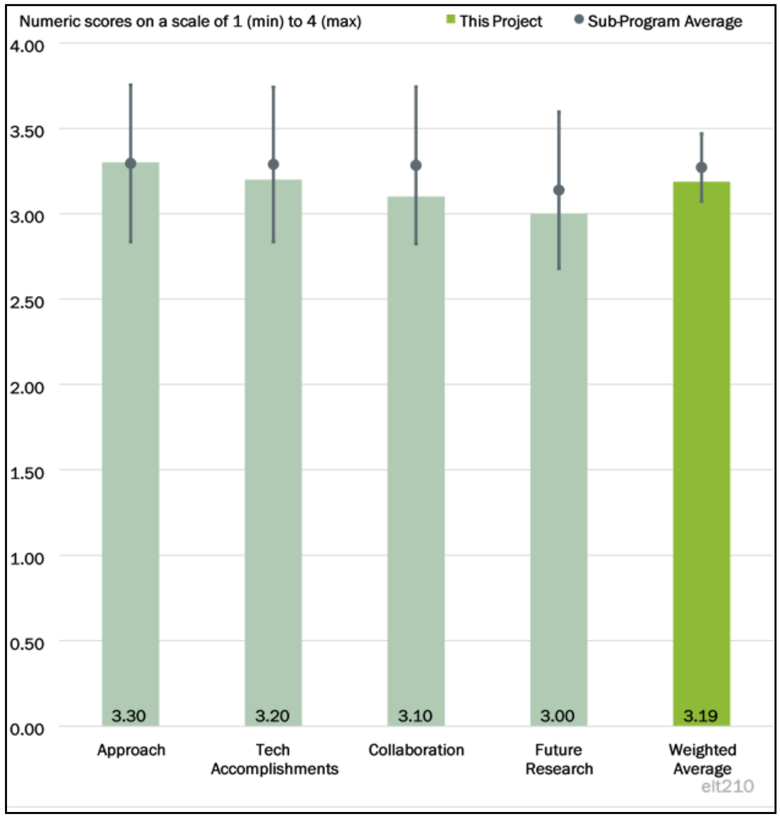


Figure 4-17 - Presentation Number: elt210 Presentation Title: Development of Next-Generation Vertical Gallium-Nitride Devices for High-Power Density Electric Drivetrain Principal Investigator: Andrew Binder (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the proposed work is well developed and has a strong path forward. Exploring gallium nitride (GaN) devices and optimizing, considering system level issues, is an acceptable technical approach.

Reviewer 2:

This reviewer noted that a logical progression to get to GaN MOSFET with GaN Diode seems like a good approach. The PI is applying knowledge from the SiC MOSFET + SiC Diode to SiC MOSFET+GaN Diode to finally having both as GaN-based devices.

Reviewer 3:

The reviewer commented that multiple paths (both SiC and GaN) are taken into account and challenging goals are set (e.g., vertical GaN) with the convincing approach. The step-by-step approach shown on Slide 6 is also convincing—SiC MOSFET + SiC diode, SiC MOSFET + GaN Diode, and then GaN MOSFET and GaN diode. Because MOSFETs are being used as active devices, the reviewer wondered if the external diodes are going to be eliminated eventually for cost reduction.

Reviewer 4:

The reviewer stated that the barriers are very clearly defined in terms of real facts. The reviewer suggested that it would be better if the cost target of $/kW is also correlated with volume involved. Similarly, operational life should also be related to the drive cycle and types of driving profile involved.

Reviewer 5:

The lack of participation from device manufacturers concerned this reviewer about whether the right, most pressing issues are being addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed there are good technical accomplishments on the project. In particular, the first vertical GaN MOSFET demonstration is good. The reviewer was looking forward to hearing about the scaled-up demonstration.

Reviewer 2:

The reviewer commented that quite a bit of device testing, including thermal testing, has been carried out.

Reviewer 3:

The reviewer stated that the technical accomplishments are reasonable as of now.

Reviewer 4:

The reviewer stated that the project team demonstrates strong positive results, particularly given COVID-19 constraints occurring during FY 2020 and FY 2021.

Reviewer 5:

The reviewer observed that the work is being done systematically. Appropriate testing and experimentation are being done and results made available.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the touch points with other projects, both at Sandia National Laboratories (SNL) and with other collaborators (ORNL, NREL, State University of New York [SUNY] Polytechnic Institute Albany Campus, Ohio State University, and Lehigh University) are clear and acknowledged. The team is doing a good job of reaching out for capabilities to supplement in-house expertise.

Reviewer 2:

This reviewer observed great teamwork consisting of universities, DOE labs led by SNL, and small industry.

Reviewer 3:

The reviewer stated that the distribution of activities is very well specified.

Reviewer 4:

The reviewer commented that the collaboration of national laboratories and universities is good. It would be even better if there were an industry collaborator.

Reviewer 5:

The reviewer observed that the lack of an industrial partners is a real weakness 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed future work seeks to continue demonstrating and improving upon specifications and technical targets with GaN devices. The proposed future scope is aligned with technical needs and rational.

Reviewer 2:

The reviewer stated that iterative design and testing activities in the project will give good confidence to the project team. Additionally, this reviewer indicated that the device-to-system approach planed for future research seems quite appropriate.

Reviewer 3:

The reviewer remarked that the new device R&D require a lot of time and efforts. The proposed future work looks quite reasonable based from that viewpoint. It might be out of the scope of this particular project and too farfetched, but it would be great if some cost reduction requirements estimation would be carried out for the U.S. DRIVE EETT cost target $2.70/kW.

Reviewer 4:

The reviewer indicated that the future activities are less clear and are noted as dependent on funding level, which will be available in the future on the AMR presentation slides. Also, it seems that the power level and current level of the devices are less than the overall objectives set earlier in the slides. For example, the forward currents noted seem to be less than what will be needed to accomplish the objectives of the overall system power.

Reviewer 5:

The reviewer expressed the concern that the project team needs industry input from manufacturers of devices.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that the DOE objectives and U.S. DRIVE EETT target accomplishments require full utilization of WBG semiconductors. This project is highly relevant from that viewpoint.

Reviewer 2:

The reviewer remarked that the development of GaN devices, if successfully implemented, will support the overall DOE objectives. The technology, although relatively less mature, deserves attention in terms of research efforts.

Reviewer 3:

The reviewer stated that advanced devices will play a critical role as a foundation of next-generation power electronics technologies.

Reviewer 4:

This reviewer remarked that WBG power electronics-related research is quite relevant to industry and DOE labs.

Reviewer 5:

The reviewer answered that, yes, GaN has a value proposition for automotive uses.

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 SNL-led team is well resourced and has great support from universities.

Reviewer 2:

The reviewer stated that the resources seem appropriate.

Reviewer 3:

Based on Slide 2 of the AMR presentation, this reviewer interpreted project resources as sufficient.

Reviewer 4:

The reviewer remarked that the funding level is sufficient at this time. It is not clear at this time if future activities will need additional funding support or not.

Reviewer 5:

The reviewer expressed the concern that until there is direct input from device manufactures, it is difficult to say if the resources are appropriate.

Presentation Number: elt211
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 five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

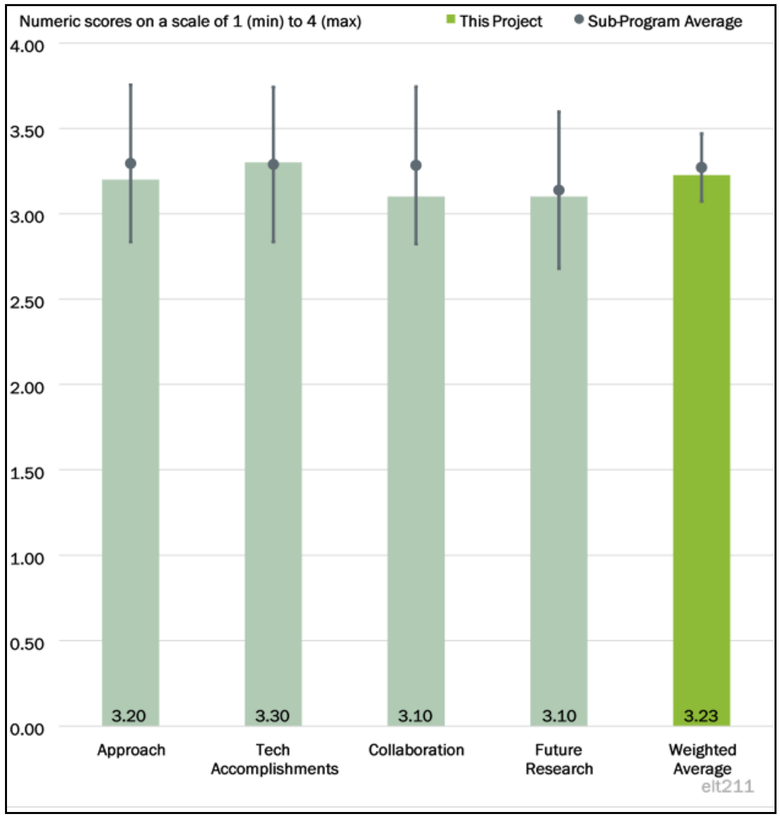


Figure 4-18 - Presentation Number: elt211 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the proposed approach is very strong and leverages strong capabilities in thermal modeling and measurements to explore various thermal management options. The double-sided cooling strategy seems quite effective, and exploration of advanced cooling fluids further adds to the value of the work.

Reviewer 2:

The reviewer stated that dielectric fluid cooling has a great potential for a better cooling scheme. Identifying the most suitable dielectric fluid is a key factor. The approach taken by this project is reasonable and convincing. Also, the comparison of single-sided versus double-sided cooling schemes is good.

Reviewer 3:

The reviewer said that the approach used is in line with the project objectives.

Reviewer 4:

The reviewer stated that better thermal can lead to better matching of application to typical load instead of overbuilding a component based on rare, high-power events. The reviewer expressed interest in seeing work performed that integrated dielectric fluid cooling with other methods to see if a combination of techniques may yield a better result.

Reviewer 5:

This reviewer commented that a systematic thermal design approach is being followed. Also, the NREL team led by Gilbert is applying knowledge from the previous, successfully completed, project year.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent design and simulation work has been carried out since last year, which this reviewer emphatically described as a great job.

Reviewer 2:

The reviewer said that the work is moving along and being done very systematically. The project team has used well thought out experiments.

Reviewer 3:

The reviewer remarked that the various interesting and useful outcomes can be observed here as accomplishments. Identifying AC-100 as one of the best candidates for low pumping power requirement is an important outcome. Also, quantitative comparison between the single-sided scheme and the double-sided scheme is a useful information so that the right trade-off estimation can be done.

Reviewer 4:

The reviewer stated that the technical progress has been acceptable, particularly given COVID-19 constraints in FY 2020 and FY 2021. Several dielectric fluids have been investigated as well as a dual-side cooling approach and various flow configurations. Productivity of the team has been strong throughout this period, including a review article and several invention disclosures.

Reviewer 5:

The reviewer indicated that the accomplishment to date is reasonable and well planned.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed excellent teamwork consisting of a DOE lab, universities, and industry (ROHM).

Reviewer 2:

The reviewer described national laboratories, universities, and industry coming together and collaborating as very good.

Reviewer 3:

The reviewer remarked that the collaborations are effective and well-documented with Georgia Institute of Technology (Georgia Tech), ROHM Semiconductor, and dielectric coolant manufacturers. There is some question regarding the extent to which the ORNL-NREL teams are coordinating on the thermal management solutions effectively, and this should be made clearer and more explicit moving forward. For example, does NREL access the thermal optimization tools being utilized in the ORNL programs and vice versa?

Reviewer 4:

The reviewer expected more details and specifics on the collaboration by the key partners than was provided by the project team.

Reviewer 5:

The reviewer expected to see more collaboration, especially with some others working on thermal solutions.

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 state project ended.

Reviewer 1:

The reviewer explained that device reliability is one of the industry issues faced. A new package and method for thermal management that are not mainstream is an industry non-starter. Therefore, proposed reliability is an excellent idea from this reviewer's perspective.

Reviewer 2:

As part of the long-term reliability, the reviewer was interested in knowing how that is going to be achieved and under what parameters.

Reviewer 3:

The reviewer stated that this is a good future research proposal. Particularly important is an estimation of the long-term reliability of the dielectric fluid through experiments. The reviewer was looking forward to hearing about the outcomes.

Reviewer 4:

The reviewer said that the proposed future directions are acceptable.

Reviewer 5:

The reviewer suggested that the project team broaden future work to include investigating some alternatives beyond jet impingement.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Efficient thermal management is one of the key factors to realize high-power density power electronics. From this viewpoint, this project is highly relevant to the overall DOE objectives and EDT Consortium goal to meet U.S. DRIVE EETT targets.

Reviewer 2:

The reviewer described this project as very relevant to industry needs and also highlighted the 100 kW/L power-density target set by the DOE VTO Tech Team.

Reviewer 3:

The reviewer stated that this project will have an impact on how systems are designed and perform.

Reviewer 4:

The reviewer said that the thermal management is a key requirement to achieve DOE Tech Team targets.

Reviewer 5:

The reviewer indicated that this project has the potential of having a big impact on power electronics that support the 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 remarked that the NREL-led team is well resourced and has support from university and industry.

Reviewer 2:

The reviewer said that the resources are on track to support the project objectives.

Reviewer 3:

Based on Slide 2 of the AMR presentation, the reviewer believed that the resources available are sufficient.

Reviewer 4:

The reviewer observed that the resources seem to align with the current work. If the work scope is increased to broadening the investigation, then additional resources should be provided.

Reviewer 5:

The reviewer said that the project funding seems sufficient for the proposed work.

Presentation Number: elt212
Presentation Title: Non-Heavy Rare-Earth High-Speed Motors
Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

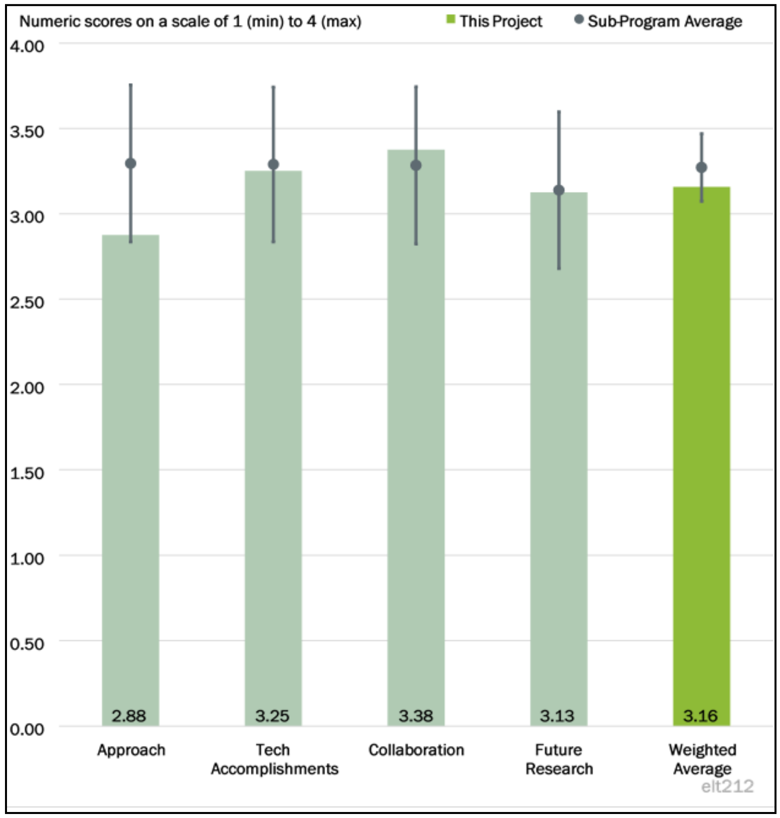


Figure 4-19 - Presentation Number: elt212 Presentation Title: Non-Heavy Rare-Earth High-Speed Motors Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

Presenter

Tsarafidy Raminosoa, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that at a first glance, the approach appears quite exotic. It will however be very interesting to see how this motor will perform with the segmented inverter in ELT209 titled, “High-Voltage, High Power Density Traction Drive Inverter.” The reviewer looked forward to hearing about how this approach will come out through the prototype and test results down the road.

Reviewer 2:

The reviewer remarked that the technical barriers are well recognized. Regarding the cost barrier of $3.30/kW, it is better to also include at what volume quantity this is valid. On the 300,000-mile lifetime barrier, it is important to know what the vehicle drive cycle and drive profile are. Also, the issue of NVH is important, i.e., whether there will be any issues with the survivability of the motor, given that it has the magnets in the outer rotor. On the peak power of 100 kW and the peak torque of 143 Newton-meter (Nm), it is beneficial to know the duration allowed for these peak quantities.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the accomplishments, as of present, are impressive.

Reviewer 2:

The reviewer remarked that completing the design is a good accomplishment. Looking forward to hearing about the prototype build in the future.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the work distribution is clearly indicated between various teams and is clearly defined.

Reviewer 2:

Collaboration among national laboratories is good sharing of the tasks for electromagnetic, thermal, and material. It would be even better if university and industry collaborators would be there 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Prototype building and testing are very important, and the reviewer looked forward to hearing about it. It would also be great if cost reduction requirements estimation could be carried out, particularly as associated with using Litz wire, a high-volume permanent magnet (although no dysprosium [Dy] is used), and reducing the manufacturing complexity, to estimate proximity to the U.S. DRIVE EETT cost target of $2.70/kW.

Reviewer 2:

The reviewer stated that the future research indicated is reasonable. Application of three-dimensional (3-D) (or additive manufacturing) has been indicated regarding electrical connections. Given that this is an outer rotor machine, it may be beneficial to look into 3-D technology for other parts of the system as well.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the high-power density non-heavy rare-earth (HRE) electric motor R&D is highly relevant to the overall DOE objectives and EDT Consortium goals.

Reviewer 2:

The reviewer stated that the project takes a different perspective on the technology and using non-HRE metals and is within 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:

Based on Slide 2 of the AMR presentation, the reviewer considered that the financial resources available are sufficient.

Reviewer 2:

The reviewer said that the funding available is sufficient and is compatible with the work done so far.

Presentation Number: elt214
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 three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

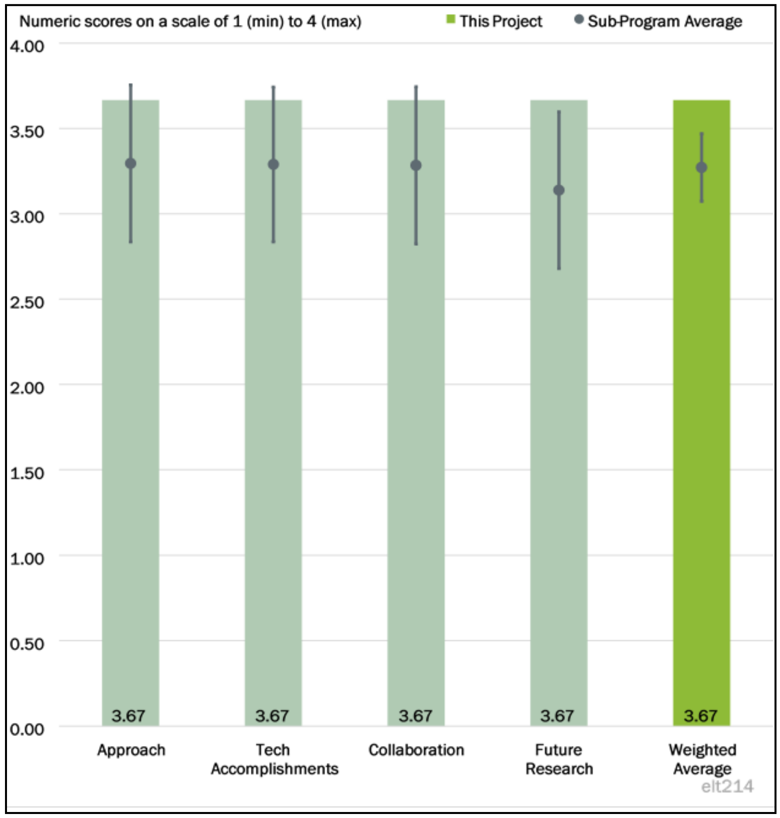


Figure 4-20 - Presentation Number: elt214 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that one of the most critical aspects of the machine design is thermal design. Using innovative materials and techniques plays a crucial role in increasing the power density of the motor. This project is vital for finding better solutions using better materials, methods, and implementation. The project aims to support mechanical and thermal measurements of new motor materials, thermal support analysis of electric machines, and measurement of slot-liner materials. This project has a systematic approach to evaluate new materials and test them. The reviewer found this project to be very important and timely for research on the development of motors that would meet the power density requirements of DOE.

Reviewer 2:

The reviewer indicated that the approach addresses the need for thermal and mechanical properties measurements on engineering materials, as well as the computational analysis of thermal systems. The project was well designed, and the goals were achievable and feasible.

Reviewer 3:

The reviewer stated that the AMR presentation provided a very good explanation and detail of each motor component. It would be good to see an overall estimate of how the combined improvements will, or will not, achieve the overall goal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the team reported that it completed all of the technical milestones for this period. The final report is currently in preparation.

Reviewer 2:

The reviewer stated that it would be good to see a milestone schedule for the status of work.

Reviewer 3:

The reviewer stated that one of the most critical aspects of the machine design is thermal design. Using innovative materials and techniques plays a crucial role in increasing the power density of the motor. This project is vital for finding better solutions using better materials, methods, and implementations. The project aims to support mechanical and thermal measurements of new motor materials, thermal support analysis of electric machines, and measurement of slot-liner materials. This project has a systematic approach to evaluate new materials and test them. The reviewer found this project to be very important and timely for research on the development of motors that meet DOE power density requirements DOE. The reviewer observed excellent lab and personnel with high qualifications on the project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project team displayed excellent communication that described what partners are contributing.

Reviewer 2:

The reviewer stated that the project team has made multiple, effective collaborations with subject matter experts in other national laboratories and in universities. The reviewer suggested that collaboration with industrial partners, both OEM and lower tiers in the supply chain, may be useful.

Reviewer 3:

The reviewer noted that the project collaborates with two universities, ORNL, SNL, and Ames Laboratory. It is evident from the presentation material that the team is successful in providing expertise in mechanical and thermal design to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that the project has robust plans to continue the research. Future research includes improving the certainty in the field-epoxy samples' thermal conductivity measurement and preparing for the mechanical property tests with SNL material samples. In addition, the study will continue to support material characterization efforts, support universities for thermal analysis, modeling, and material selection. Challenges and barriers are well identified, and plans are made to carry out the next step in research.

Reviewer 2:

The reviewer said that the AMR presentation provided an excellent summary of upcoming needed work.

Reviewer 3:

The reviewer stated that, yes, the proposed future research adequately addresses the goals and needs of the EDT Consortium.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said, yes, the project supports the overall DOE objectives by providing needed thermal and mechanical properties data on engineering materials as well as computational analysis of thermal management systems.

Reviewer 2:

The reviewer stated that the project is very relevant because thermal design is extremely critical to increase the power density of the motor and reduce the cost.

Reviewer 3:

The reviewer said that, yes, electric motor efficiency is absolutely required to assist 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 indicated that the resources are sufficient and observed excellent lab and personnel with high qualifications on the project.

Reviewer 2:

The reviewer stated that the resources are sufficient to achieve the stated milestones.

Reviewer 3:

The reviewer assumed that the resources are sufficient.

Presentation Number: elt215
Presentation Title: Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density
Principal Investigator: Iver Anderson (Ames Laboratory)

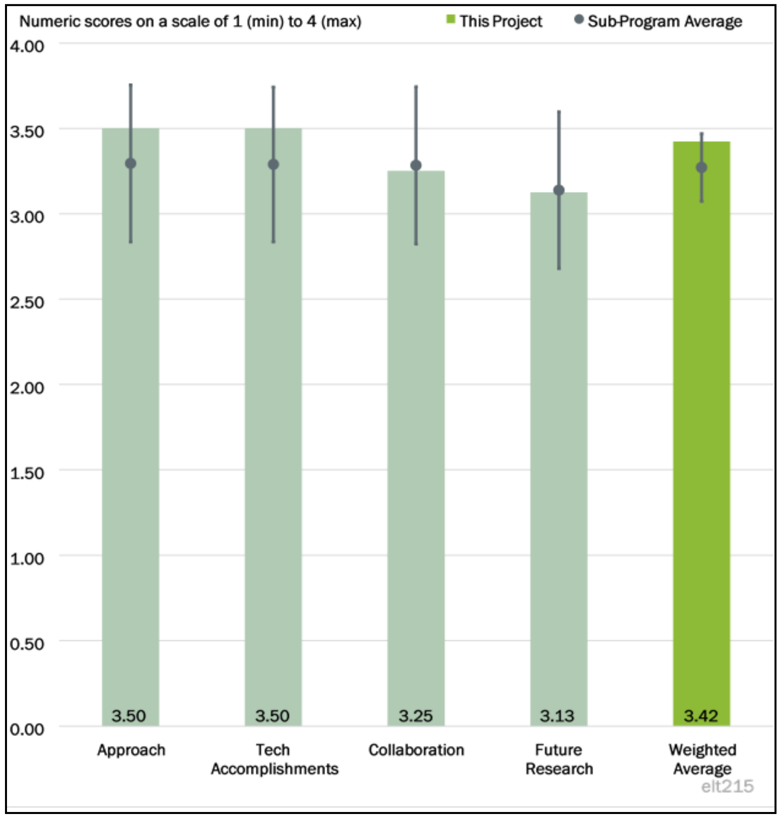


Figure 4-21 - Presentation Number: elt215 Presentation Title: Permanent Magnets Without Critical Rare Earths to Enable Electric Drive Motors with Exceptional Power Density Principal Investigator: Iver Anderson (Ames Laboratory)

Presenter

Iver Anderson, Ames Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the material selection is critical to reduce cost and increase the performance of motors. Better materials allow increased flux density, stronger magnets, avoiding HRE metals, and better thermal cooling. Using innovative materials is extremely important in increasing the power density of the motor. This project aims to develop HRE-free rare-earth permanent magnets (RE-PM) by processing ultra-fine grain size. This project has a systematic approach to develop and evaluate ultra-fine powder using various techniques, including powder passivation technology. The reviewer found this project to be very important and timely for the research for the development of motors that would meet the power density requirements of DOE and reduce the cost and dependency on other countries.

Reviewer 2:

The reviewer said that AMR presentation did well explaining the current work and process involved.

Reviewer 3:

The reviewer stated that the project is pursuing grain size control as a method to increase coercivity in RE magnets instead of using expensive HRE elements, such as Dy. The approach leverages powder processing methods used in other industries and is adapting them for use with reactive RE powders. Where appropriate, surrogate materials, such as Bakelite powder, are used during process development.

Reviewer 4:

The reviewer remarked that the proposed approach seems good but noted that it is important to provide a clear comparison of the expected properties and the properties of commercially available Dy-free neodymium-iron-boron (NeFeB) permanent magnets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project is making acceptable progress despite finding limitations in certain powder processing methods like ball milling. The project is working to address those challenges by using jet milling combined with passivation methods and sintering aids to inhibit grain growth. These approaches are yielding progress toward achieving a magnet microstructure with superfine (1-3 micron) grain sizes.

Reviewer 2:

The reviewer rated the project team on the progress it had made when compared to performance indicators as well done.

Reviewer 3:

The reviewer remarked that the good progress had been made. According to the reviewer, it is important to quantify the expected benefits in terms of motor performance, assuming the magnet development is successful and the predicted material properties are achieved.

Reviewer 4:

The reviewer indicated that the technical accomplishments and progress of the project included collaboration with ORNL, NREL, and SNL for the newly developed magnetic materials' thermal and mechanical properties and evaluation. In addition, the project provides support and expertise on material selection for other universities, including permanent magnet selection.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project is successfully collaborating with other national laboratories engaged in advanced electric motor design and systems developments.

Reviewer 2:

The reviewer stated that the project team collaborates with ORNL, SNL, and Ames Laboratory. It is evident from the presentation material that the project team is successful in providing expertise in material knowledge to these entities.

Reviewer 3:

The reviewer indicated that the project showed reasonable collaboration between Ames Laboratory, NREL, and, to some extent, SNL.

Reviewer 4:

The reviewer indicated that the project team showed reasonable collaboration on the AMR slide provided.

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 state project ended.

Reviewer 1:

The reviewer said that the project has robust plans to continue the research. Future research includes finding access to a multi-milling jet system to achieve ultra-fine powder for the HRE-free RE-PM, allowing the development of mechanical properties and sintering additive composition and developing RE-PM magnets for testing final shaping. In addition, the project plans to continue to support material characterization efforts, support universities for material selection, including permanent magnets. Challenges and barriers are well identified, and plans are made to carry out the next step in research.

Reviewer 2:

The reviewer said that the plan to use a Netszsch Jet mill to produce the ultra-fine grain size powder is appropriate and feasible. However, there seem to be few options beyond the jet mill to enable reaching the targeted superfine grain size.

Reviewer 3:

The reviewer noted that the proposed future research is good, but the future research needs to include a clear comparison of the expected properties and the properties of commercially available Dy-free NdFeB permanent magnets and quantification of the potential project performance in terms of the motor performance.

Reviewer 4:

The reviewer remarked that the AMR presentation provided a very good list of future research that may be needed. However, the plans need to have relevance attached to them. How do the specific future work ideas impact the ability to achieve overall goal?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said eliminating heavy rare-earth material is very relevant to meeting cost targets and developing sustainable electric drivetrains.

Reviewer 2:

The reviewer said that, yes, the project supports the overall DOE objectives of enabling higher performing motors with reduced dependence on critical materials, such as Dy.

Reviewer 3:

The reviewer said that, yes, the project is necessary for future, cost-effective EVs.

Reviewer 4:

The reviewer stated that the project is very relevant because HRE-free RE-PMs have strategic importance because they eliminate HRE metals and reduce the dependency on other countries. They also reduce costs.

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 personnel with high qualifications are working on the project. It appears that the project has sufficient resources. It is noted that the jet-milling challenge was addressed last year, and the team has plans for scaling up the capability.

Reviewer 2:

This reviewer noted sufficient resources based on the proposed scope.

Reviewer 3:

The reviewer stated that the resources available to the project are sufficient to achieve the stated milestones. However, the use of a jet mill at a vendor facility may pose a schedule risk if that equipment becomes unavailable.

Reviewer 4:

The reviewer rated the resources as insufficient since it appears that the project is 30% complete and is behind schedule.

Presentation Number: elt216
Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines
Principal Investigator: Todd Monson (Sandia National Laboratories)

Presenter

Todd Monson, Sandia National Laboratories

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

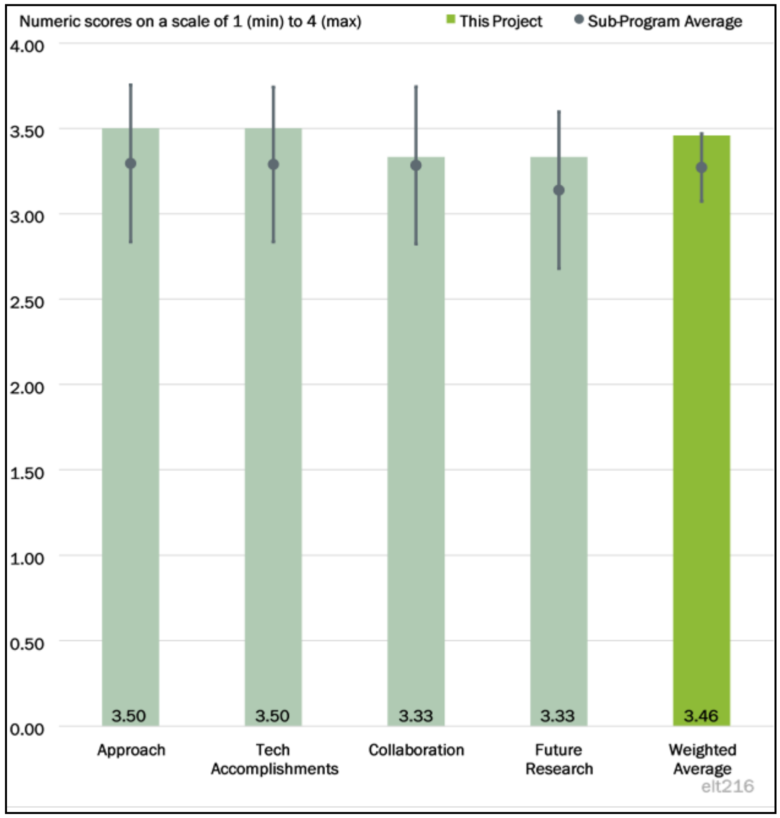


Figure 4-22 - Presentation Number: elt216 Presentation Title: Isotropic, Bottom-Up Soft Magnetic Composites for Rotating Machines Principal Investigator: Todd Monson (Sandia National Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is good, but it is not clear what the expected material properties are and, if successful, how they compare to other commercially available soft magnetic composites.

Reviewer 2:

The reviewer stated that the project is well-designed and has taken a systematic toward the engineering of iron-nitride (Fe_4N)-filled epoxy matrix composites for use as soft magnetic motor components. The major requirements of temperature dependent properties, mechanical strength, and thermal conductivity have been thought through and are being thoroughly tested.

Reviewer 3:

The reviewer remarked that the project is about developing new soft magnetic composites for electrical machines. Better, soft magnetic materials are needed for motor designs to reduce the losses and improve the power density. It is possible to use soft magnetic materials on motor topologies to avoid RE magnets. Using innovative materials for soft magnetic materials is extremely important in increasing the power density of the motor. This project aims to demonstrate a net-shaped, Fe_4N soft magnetic motor component with a vol. % loading of Fe_4N greater than 70% and evaluate its saturation magnetic polarization and eddy-current losses. This project has a systematic approach to develop high magnetization, low-loss Fe_4N-based soft magnetic composites for electrical machines that will lower losses even further and enable efficient operation at rotational speeds up to 20,000 revolutions per minute (rpm). The reviewer found this project interesting for the research to develop motors that would use better soft magnetic materials and avoid RE magnets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has made good progress in developing a process to form highly loaded Fe_4N epoxy composites. This includes the development of the starting powder, epoxy formulation, and diamine catalyst selection. This also includes a hot-pressing method to form coupons with high volume fraction of Fe_4N. The project has met the milestone of making and characterizing a composite with a volume fraction greater than 70%.

Reviewer 2:

The reviewer said that reasonable progress has occurred, but it remains to be seen what material properties can be achieved. In addition, some quantification of potential benefits in terms of motor performance is needed from the project team.

Reviewer 3:

The reviewer remarked that the project collaborates with ORNL, Purdue University, and the Illinois Institute of Technology (IIT) for the newly developed soft magnetic materials' part shapes. It also collaborates with Ames Laboratory and NREL for magnetic material manufacturing, advanced packaging, reliability, prognostics, thermal management, and thermal and mechanical testing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found a reasonable level collaboration but suggested that more collaboration is needed to quantify the benefits of the developed material in terms of the material's effect on motor performance.

Reviewer 2:

The reviewer stated that the project is effectively working with collaborators in other national laboratories and universities engaged in advanced motor R&D.

Reviewer 3:

The reviewer noted that the project collaborates with Purdue University, IIT, ORNL, SNL, and Ames Laboratory. It is evident from the presentation material that the team is successful in coordinating the efforts to use the new soft magnetic material on a motor 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that the project has excellent plans to continue the research. Future research includes evaluating the eddy current losses that will require hot pressed toroids of greater than 70 vol.% Fe_4N/epoxy composites to make additional comparisons to the state-of-the-art materials (e.g., Si electrical steel and soft-magnetic composite [SMC]). Challenges and barriers are well identified, and plans are made to carry out the next step in research, including, in collaboration with NREL, evaluating the mechanical properties of Fe_4N composites.

Reviewer 2:

The reviewer stated that the proposed research plans to measure magnetic properties and eddy currents in toroidal shaped samples. This is critical for understanding the advantage of this material compared to conventional soft magnetic materials, such as SMC and Si electrical steel. If the Fe_4N composites are intended to be used in rotating components, then the mechanical properties of the Fe_4N composites should also be measured.

Reviewer 3:

The reviewer indicated that proposed research is good and will identify what level of material properties can be reached and how motor performance is affected.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the proposed material is relevant in terms of potentially meeting the power density, efficiency, and cost targets, and more specifics about its use and impact on performance of specific motor topologies are needed to support the overall DOE objectives.

Reviewer 2:

The reviewer stated that, yes, this project supports the overall DOE objectives of enabling higher efficiency, high-power density electric machines.

Reviewer 3:

The reviewer remarked that the project is very relevant because using soft magnetic materials without RE permanent magnets has strategic importance because they eliminate HRE metals and RE materials for motor design and reduce dependency on other countries. They also reduce costs of materials for 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 indicated that the personnel with high qualifications are supporting the project. It appears that the project has sufficient resources and partnerships with universities and other national laboratories.

Reviewer 2:

The reviewer said that the resources seem adequate for meeting the milestones on the proposed schedule.

Reviewer 3:

The reviewer stated that the resources are sufficient.

Presentation Number: elt221
Presentation Title: Integrated Electric Drive System
Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

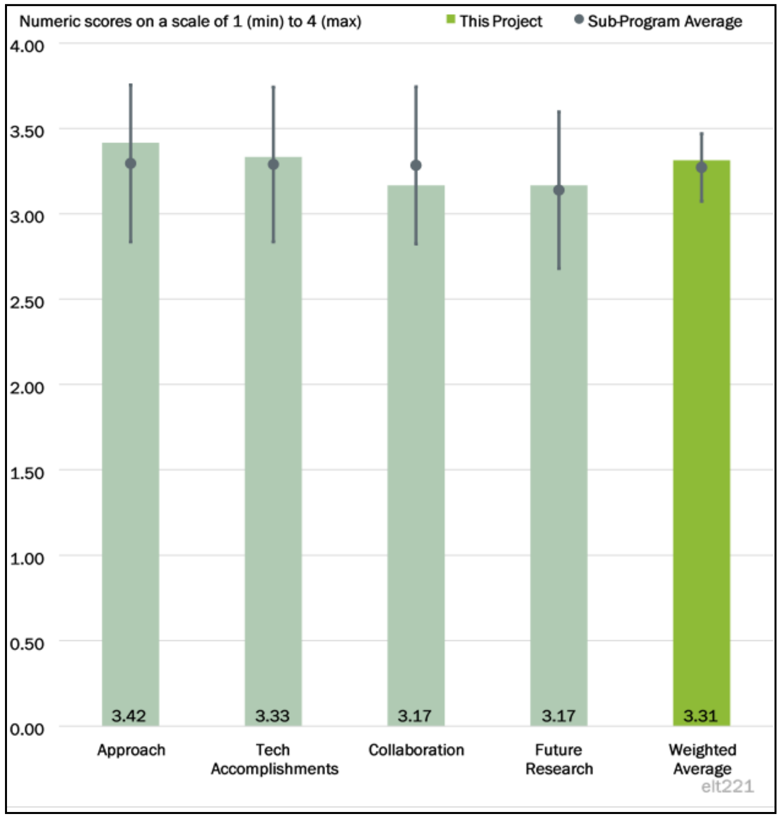


Figure 4-23 - Presentation Number: elt221 Presentation Title: Integrated Electric Drive System Principal Investigator: Shajjad Chowdhury (Oak Ridge National Laboratory)

Presenter

Shajjad Chowdhury, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the approach and outline of the parameters are well understood.

Reviewer 2:

The reviewer stated that this is an important piece of the Keystone project.

Reviewer 3:

The reviewer noted a very interesting approach with putting together each of the unique approaches from ELT209 and ELT212 as one integration project, ELT221.

Reviewer 4:

The reviewer indicated that the approach to performing the work was well done.

Reviewer 5:

The reviewer stated that the proposed technical approach is sound and includes thermal analysis, electrical analysis, reliability, and performance benchmarking of capacitors and includes new packaging approaches.

Reviewer 6:

The reviewer said that the approach is addressing the component variations of this combined system to ensure compliance. The critical attributes are being evaluated and properly addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the capacitor study is very important. The comparative evaluation, characterization, packaging design, and layout design are all very informative. It would be great if capacitor piece-to-piece variation sensitivity estimation would also be carried out, because so many capacitors being put together. A slight characteristics variation could end up with unexpected hot-spot and/or current sharing imbalance.

Reviewer 2:

The reviewer stated that the design and data that were provided were presented clearly in outline format in the AMR presentation. The reviewer is interested in how the final design will perform.

Reviewer 3:

The reviewer said that the team has showed significant progress toward the overall objectives. The number of publications and patents is evidence of progress toward objectives.

Reviewer 4:

The reviewer observed that the packaging and characterization is progressing on schedule with positive results.

Reviewer 5:

The reviewer commented that the project seems to be making good progress and appears to be on track.

Reviewer 6:

The reviewer called the project well done on technical accomplishments and progress but suggested that it would be good to see a summary of the progress versus the plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer really liked this Keystone project where collaboration is essential.

Reviewer 2:

The reviewer stated that the national laboratories collaboration is good. It would be even better if university and industry collaborators would be there.

Reviewer 3:

The reviewer remarked that the information provided demonstrated the collaboration and coordination across project team.

Reviewer 4:

The reviewer stated that the collaboration is clearer in this project than in others presented. The reviewer recommended engaging the Ames Laboratory team more strongly in these efforts moving forward.

Reviewer 5:

The reviewer indicated that the ORNL and NREL have close coordination. There was no detail regarding the effort of SNL and Ames Laboratory for their contributions or status.

Reviewer 6:

The reviewer stated that a high-level overview of the type of collaborations was provided. The reviewer emphatically stated that there is a need to show more specific and details and how they measure against the project objectives.

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 state project ended.

Reviewer 1:

The reviewer remarked that the continuing component level (substrate, capacitor boards, and current sensors) study is certainly important for the integration coming afterward. The reviewer was looking forward to hearing about the three-phase inverter built and integrated into the motor of ELT212 beyond 2022.

Reviewer 2:

The reviewer stated that the project team seems to be managing their focus well.

Reviewer 3:

The reviewer remarked that this is a good list and indicated that it would also be good to see some detail of how the future plans will be accomplished outside of normal plan.

Reviewer 4:

The reviewer stated that the future plans are acceptable as proposed. Thermal management must be a key element of the solution.

Reviewer 5:

The reviewer remarked that the future plan is fine. There is a need to assure that the design is well tested under extreme operating conditions.

Reviewer 6:

The reviewer indicated that there was no information on how to move this project to production products. There is no participation or material from the vehicle OEM or a Tier 1 supplier to the OEM.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The project has promising applications and is consistent with the future outlook for electrification applications to optimize the systems performance.

Reviewer 2:

This is a very important Keystone project, and the reviewer expressed interest in seeing it work.

Reviewer 3:

This project is highly relevant for the challenging high-power density electric drive target of the EDT Consortium and U.S. DRIVE EETT. Hence, this project supports the overall DOE objectives accordingly.

Reviewer 4:

According to the reviewer, this project is required for future EV efficiency.

Reviewer 5:

The integrated drive concept offers substantial potential benefits for overall size, weight, and efficiency. The reviewer noted that this is an attractive project to be pursued for DOE VTO impacts.

Reviewer 6:

The reviewer commented that vehicle modules need to be more integrated and offer more options. This reduces vehicle complexity, weight, and cost of the 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 stated that the project seems to be sufficiently funded.

Reviewer 2:

According to the reviewer, the distribution of effort properly matches the capabilities from each lab.

Reviewer 3:

Based on Slide 2 of the AMR presentation, the reviewer understood that the available resources are sufficient.

Reviewer 4:

The reviewer asserted that the project appears to be following the plan.

Reviewer 5:

The reviewer said that the resources appear sufficient.

Reviewer 6:

The reviewer indicated that the project is consistent with the expected objective.

Presentation Number: elt236
Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture
Principal Investigator: Watson Collins (Electric Power Research Institute)

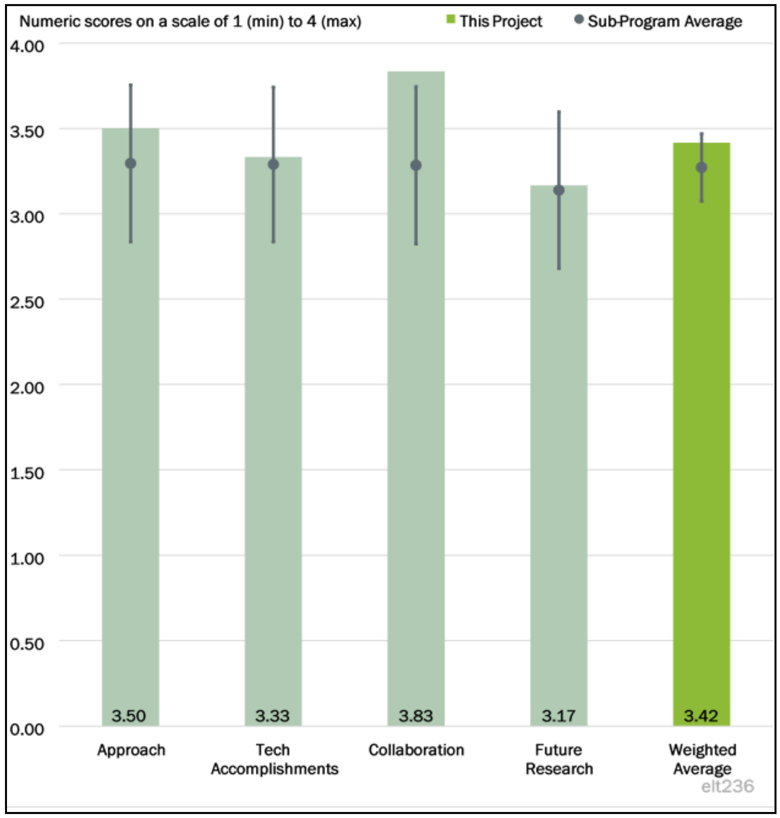


Figure 4-24 - Presentation Number: elt236 Presentation Title: Direct-Current Conversion Equipment Connected to the Medium-Voltage Grid for Extreme Fast Charging Utilizing Modular and Interoperable Architecture Principal Investigator: Watson Collins (Electric Power Research Institute)

Presenter

Watson Collins, Electric Power Research Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is outstanding. The reviewer thought that the highlight of this project is really looking into and optimizing the utility interface and DC load center design. These items are not typically being focused on by other research projects.

Reviewer 2:

The reviewer stated that this seems to be a very logical process to develop the conversion hardware described. A higher rating on Approach could have been earned if there had been more information on the design decisions that were made and why they were made. This knowledge could be more easily transferred to industry after the project concludes.

Reviewer 3:

The reviewer observed an appropriate approach—develop the technology, verify operation, and demonstrate systems at utility partner sites. The approach does not appear to include efforts to estimate the potential cost benefits or increase for the technology nor which entity and/or stakeholder is affected (utility, service provider, equipment manufacturer, etc.).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the technical accomplishments and progress are excellent. Good progress has been made on the utility interface and the DC load center design. The 40-kW cell and the DC-DC head-end unit seem to be ready last year. The reviewer is looking forward to seeing the medium voltage converter rack, with all the 11 cells, installed and tested and the same for the DC-DC head-end unit, with all the 14 units, installed and tested.

Reviewer 2:

The reviewer remarked that the progress has shown completion and operational verification of the prototype power cells and DC-DC modules, but performance metrics are not shown. Did the components and sub-systems meet the anticipated performance and efficiency requirements? The progress of the DC metering, controls of the multiple DC stages, and the integration (control communications) with various DC loads or DER sources is unclear.

Reviewer 3:

The reviewer stated that it is hard to judge this dimension because the project is not complete. The project will have a better evaluation once there are data showing performance of the planned system versus the actual hardware.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaborations among EPRI, Eaton, Tritium, NREL, and ANL are great. Each team member has a very clear deliverable and unique contribution to the final objective.

Reviewer 2:

The reviewer said that the project team brings together the appropriate partners to successfully develop, deploy, and demonstrate this technology.

Reviewer 3:

The reviewer remarked that the team looks very solid and had no issues. Again, it was hard to judge because the reviewer only heard from one of the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer did not know if the project team thinks the “comprehensive system testing at NREL” is part of the proposed future research, but the reviewer gave “outstanding” basically for this proposed testing plan. It looks like the team has a thorough plan and will test and verify Institute of Electrical and Electronics Engineers (IEEE) 1547, IEEE 519, SAE J2894, and IEEE 1668-2017. These are very useful and informative investigations, which are very industrial oriented, and was highly appreciated by this reviewer. Additionally, the reviewer really looked forward to the testing results/waveforms that demonstrate the charger’s performance and prove that it satisfies all standard requirements.

Reviewer 2:

The future research is appropriate for the completion of the development and demonstration of the technology. The reviewer was confused because the "Future Work" slide is labeled as FY 2021, which is 65% completed at the time of presentation; perhaps, the slide is mislabeled and should say FY 2022?

Reviewer 3:

The work that was planned out seems satisfactory. What would be helpful is to plan the future—estimate how industry will use the output of this project when it is completed. The reviewer asked what is the technology transfer plan to get this integrated into industry?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Improving the efficiency, robustness, and cost of high-power EV charging infrastructure is directly aligned with DOE objectives.

Reviewer 2:

This project supports the overall DOE objectives.

Reviewer 3:

The reviewer stated that one goal of DOE is to make that certain battery electric vehicles (BEVs) can be integrated with the electrical grid efficiently. This project will create hardware to support that goal. The only issue that is not clear is what is the main problem being solved? It was unclear to this reviewer whether the project will "just" create hardware, or whether it evaluates the different designs possible to determine the "best" one.

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 appropriate for completion of the development and demonstration of this technology.

Reviewer 2:

The resources are sufficient.

Reviewer 3:

The reviewer heard no issues with the resources.

Presentation Number: elt237
Presentation Title: Enabling Extreme Fast Charging with Energy Storage
Principal Investigator: Jonathan Kimball (Missouri S&T)

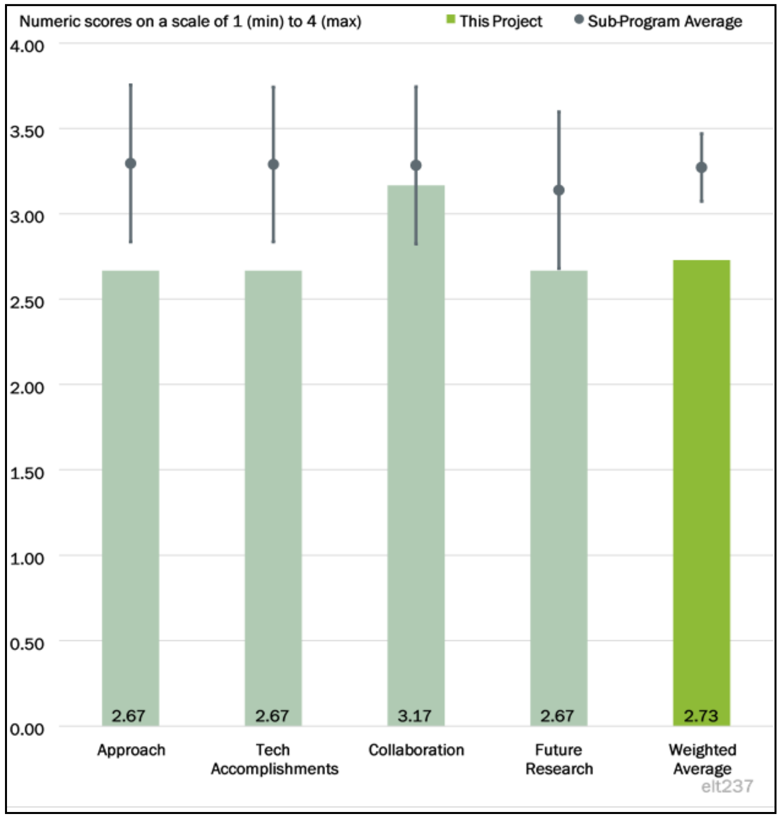


Figure 4-25 - Presentation Number: elt237 Presentation Title: Enabling Extreme Fast Charging with Energy Storage Principal Investigator: Jonathan Kimball (Missouri S&T)

Presenter

Jonathan Kimball, Missouri S&T

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project seems to be on track but would like to see the contributions highlighted.

Reviewer 2:

The reviewer stated that the development work for algorithms based on simulations looks well thought out. A key concern that lowered the reviewer rating for "Approach" is the development plan for the stacked inverter structure. Referencing previous work, the practical "stacking" of inverter modules that alone cannot standoff the voltage applied across the stack is very challenging. The work presented did not seem to address packaging and design issues that will arise with the overall inverter structure. The reviewer was very pleased to see that the project team has a vendor partner, Bitrode, with packaging experience. It was not clear if Bitrode has medium-voltage (15 kilovolt [kV] class) experience. The project appears to have a large volume of work to complete over the next year to meet all milestones—battery design, electrical hardware assembly, and lab validation of the hardware.

Reviewer 3:

The reviewer remarked that it is unclear why the project is developing its own vehicle battery packs. This is the exclusive domain of vehicle OEMs. The fast charger, regardless of whether it has its own energy storage or not, will take commands from the vehicle to control charge. Many other projects are looking specifically at battery operation in XFC duty. The reviewer encouraged the project to focus on the power electronics and do more of the good work performed on uncertainty modeling.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It was noted that COVID-19 had impacted component availability to the project—this may have delayed inverter design and construction testing. As noted previously, the reviewer did not see much supporting work for the inverter construction and module integration. There did appear to be clear packaging plans based on the Bitrode cabinet. It looked like the control algorithm supporting work was well thought out and supported with simulations. A key concern is, again, the MV front-end design and construction.

Reviewer 2:

The reviewer said that it seems that some data on battery aging were collected, though this may be already well researched phenomena.

Reviewer 3:

The reviewer remarked that the project is nearing 60% of the proposed schedule consumed, but is showing only 35% complete (apparently based on expenditures to date). The reviewer would agree with the 35% complete, as the full-scale implementation will be time and resource consuming. The concern is whether there will there be sufficient schedule to complete the project. The footnote on Slide 5, "Any proposed future work is subject to change based on funding levels," adds additional concern.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that it appears that Missouri University of Science and Technology (Missouri S&T) has done an excellent job of working with project partners based on the material presented. The LG Chem battery design looked to be progressing well and is the packaging layout and design with Bitrode for the inverter assemblies.

Reviewer 2:

The reviewer indicated that the greatest collaboration requirements will be with Bitrode and Ameren as a full-scale system is implemented in BP 3. Collaboration with LG Chem seems to be good, with batteries obtained and testing underway.

Reviewer 3:

The reviewer indicated that a high-level workflow breakdown was never presented by the project 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the project plan looks reasonable. The key concern is that the topic area is broad with many elements for the project still in their early design phases. There remain a large number of elements that must be completed for a full-up system test with the full front-end operating from MV with a live battery system.

Reviewer 2:

The reviewer stated that the contribution is somehow questionable.

Reviewer 3:

The reviewer said that the project barriers listed are more the inverse of the project objectives than specific barriers that must be addressed to complete BP 2 and BP 3 scope. The full-scale implementation in BP 3 will be a significant challenge. However, no plans were presented for the scale-up or for the conduct of testing.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the development of lower cost and more reliable approaches to provide for high power charging will be critical to widespread deployment of EVs, especially in applications like fleets of MD and HD vehicles. These are likely to require high power charging where tight integration with the distribution grid will be critical to control cost and make systems reliable. Forward-looking work like that being funded in this project is likely to be very valuable to future EV charging applications.

Reviewer 2:

The reviewer said that the Is not an interesting and very important topic, however given that the project has been running two years already, the reviewer expected some more progress.

Reviewer 3:

The work on uncertainty modeling and power conversion is very supportive of DOE objectives. As the reviewer previously stated, work on vehicle battery charging and pack design is not relevant to DOE objectives outside a vehicle OEM environment (e.g., United States Council for Automotive Research [USCAR]).

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 shown reasonable progress over the first portion of the project, indicating that resources have been sufficient to complete the work.

Reviewer 2:

The reviewer said that the project seems to be well funded.

Reviewer 3:

The reviewer noted that Missouri S&T resources have been sufficient to this point in the project. The Bitrode and Ameren resources will be tested in BP 3.

Presentation Number: elt238
Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection
Principal Investigator: Srdjan Lukic (North Carolina State University)

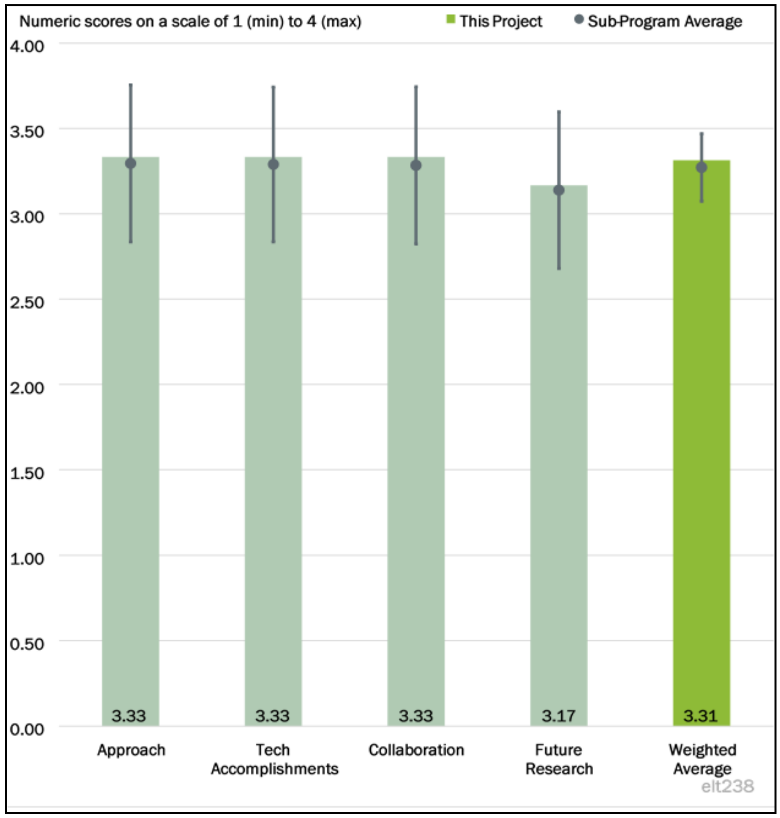


Figure 4-26 - Presentation Number: elt238 Presentation Title: Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection Principal Investigator: Srdjan Lukic (North Carolina State University)

Presenter

Srdjan Lukic, North Carolina State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project approach is outstanding.

Reviewer 2:

The reviewer stated that the approach seems reasonable. It was not perfectly clear in the presentation (but the Q&A did help a bit) about the use of solid-state relays and their origin. The basic approach seems to be to design into this project’s EVSE solid-state relays that were already developed by industry.

Reviewer 3:

The reviewer stated that the barriers are directly addressed through the development, evaluation, and demonstration of MV to DC charging and DC protection. It is unclear if the XFC nodes are being developed in this project or are being sourced, which may be problematic due to availability of XFC designed for the DC source. The potential cost increase or decrease is very important yet does not appear to be within the scope of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the technical accomplishment and progress are outstanding. The solid-state transformer (SST) with a scaled-down version has been designed and built to provide insight for the final full power design. The startup and load change testing done on this scaled-down version also shows that the team is carefully thinking through the possible scenarios that could happen in the field and is timing each individual step effectively, verifying its functionality, and applying protections. The final 1 megavolt-ampere (MVA) SST has been further optimized and is under single module construction and testing. To achieve the final goal within the planned time is very promising.

Additionally, the DC solid-state circuit breaker has been demonstrated with very thorough and detailed testing results. It is a very promising technology that will be commercially available in the near future by ABB.

A site location has been chosen and is under preparation. The reviewer was really looking forward to the final field demonstration and data collection.

Reviewer 2:

The reviewer stated that good technical accomplishments are presented showing the evaluation of prototype MV SST to DC bus. The transient startup operation is detailed. However, it is unclear if the prototype hardware meets the expected efficiency and performance goals.

Reviewer 3:

The reviewer said that the PowerPoint charts on the Representative Tests Passed and System Test Passed were very helpful in evaluating this project in this dimension. What is missing, however, is the linkage back to existing technology—how does the new design compare with non-solid-state devices? What is the interruption speed of the new technology in the tests versus the "benchmark" for mechanical relays? The score provided might improve with a comparison chart for technical performance.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration is outstanding. North Carolina State University (NCSU)utilizes their expertise to push the SST to another level by deploying it to New York Port Authority (NYPA) site. ABB has pushed the DC solid-state circuit breaker to commercialization.

Reviewer 2:

The reviewer said that the team brings together the necessary organizations to design, develop, evaluate, and demonstrate the technology at an approximate 1-MW scale.

Reviewer 3:

Certainly, there is a strong existing team working on this project. Since the goal is to improve EVSE technology, the reviewer suggested that it would be good if there were additional participants in the area of EVSE design and manufacturing. It might also be helpful to include charge point operators on the team to get requirements from that segment of the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

What is left in this project is system integration, deployment, and data collection, and the reviewer agreed with the team's excellent plan.

Reviewer 2:

The reviewer said that the proposed future research of system integration and deployment and demonstration will be very important and beneficial to validate the benefits of this technology and potentially identify any areas of additional refinement and/or improvement.

Reviewer 3:

The reviewer stated that the site preparatory work seems well planned and executed, with the goal of making hardware installation proceed very efficiently. The reviewer would have liked to see what went into the selection criteria because the photo on the slide shows the site to be fairly remote. The Milestones slide only gave limited insight into planned BP 3 work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that reducing the number of conversion stages from the utility distribution feeder to the EV charging infrastructure directly supports DOE objectives.

Reviewer 2:

The reviewer said that this project is relevant to the overall DOE objectives.

Reviewer 3:

The reviewer stated that this project is borderline on relevance, likely because little data were shared on why the planned design is an improvement over existing technology. Perhaps this was discussed in last year's review. It certainly needs to be addressed as part of the final project review. How does this project reduce costs for the final EV driver or improve electrical efficiency? If additional data were provided, this project could definitively be classified as supporting 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 said that the resources are sufficient given the size, capacity, and power level of the technology being developed and demonstrated at full power (approximately 1 MW).

Reviewer 2:

The reviewer said that the project results show that the team has sufficient resources.

Reviewer 3:

The reviewer stated that this project seems to be one of many that have been, and/or continue to be, impacted by COVID-19. Other than by this cause, no resource issues were identified.

Presentation Number: elt239
Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility
Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Presenter

Omer Onar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

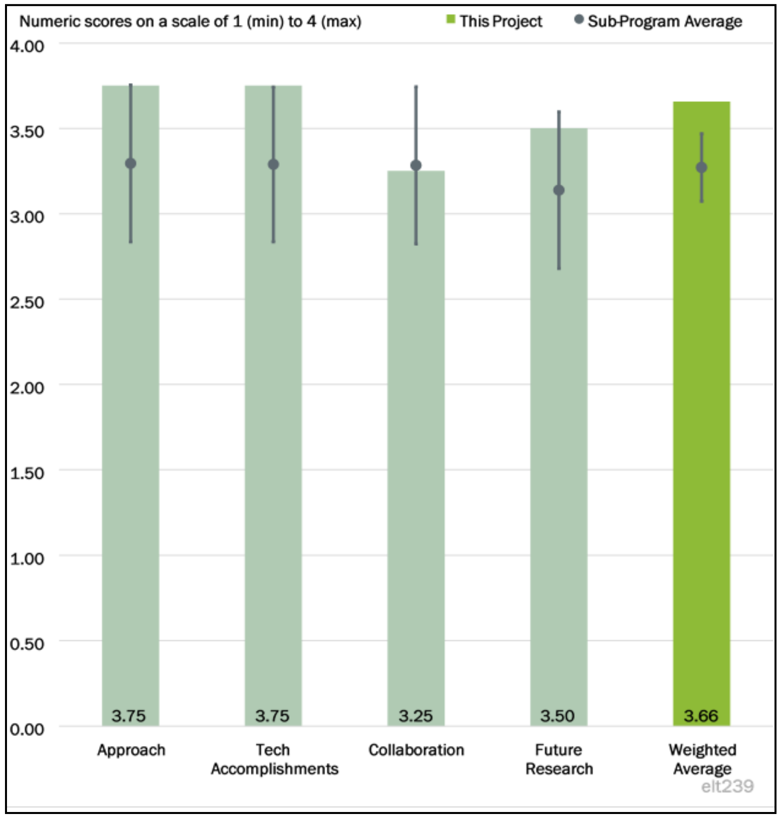


Figure 4-27 - Presentation Number: elt239 Presentation Title: High-Power Inductive Charging System Development and Integration for Mobility Principal Investigator: Omer Onar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer loved it and emphatically stated that this is an excellent project.

Reviewer 2:

The reviewer stated that the approach is outstanding. The system is scalable. The proposed topology and polyphase coupler both are contributing to the optimized design, with minimum DC link capacitance, lower current ripples, and higher power density. The reviewer was curious about whether the project team should use liquid cooled capacitors for the resonant capacitor in all the wireless power transfer applications. Will that be the trend?

Reviewer 3:

The reviewer observed that the project's approach appears very solid, with an appropriately methodical path laid out to accomplish the project's objectives, particularly as related to testing needs. The project focused first on design, modeling, simulation, and analysis, then building the systems, followed by integrating the systems and conducting testing and data collection. This clear approach was then specifically followed to accomplish planned activities, despite the EVSE manufacturer pulling out of the project.

Reviewer 4:

The reviewer stated that this project sought to address the following barriers—operating efficiencies over 90% and charge rates of 100 kW and 270 kW. The project approach was an iterative process of design, analysis, modeling, simulation, testing, validation, and integration. The approach seems to be working as the project is achieving overall efficiencies greater than 90%.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted a tremendous amount of accomplishment and would love to see the results of the testing. The reviewer asked the project team to please include cybersecurity as the project team design this, including the micro components.

Reviewer 2:

The reviewer stated that the project has accomplished a great deal, basically exactly what it said it would at the beginning and then some. Efficiencies so far appear to be over 95% (compared to original objective of over 90%). It will be interesting to see if the efficiency holds once the systems are integrated into vehicles and tested. The project, if fully successful when completed, will demonstrate a significant increase in surface power density. It has also developed key knowledge in a number of inductive charging areas that will be of significant use to other projects. The accomplishments of the project are even more impressive given that the original EVSE manufacturer pulled out of the project. Due to COVID-19-related delays, it appears the project will require about a 6-month extension from the original schedule.

Reviewer 3:

The reviewer stated that the progress and accomplishments of this project are tremendous. A great amount of work has been carried out, and the proposed topology and winding structure seem very attractive.

Reviewer 4:

The reviewer said that the PI presented several accomplishments and provided the case for how those accomplishments were moving the project closer to the end goal. At the time of the presentation, the project was in the process of completing bench top tests and appears to be on track for performing vehicle integrations and preparing demonstrations at the two power levels.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration among the partners seems to be less than in the other projects, but that is understandable, so the reviewer rated collaboration as excellent. Different projects will have different weights on each collaborator. This project is mainly relying on ORNL to develop and demonstrate this high-power wireless charging system technology to the OEMs.

Reviewer 2:

The reviewer remarked that the project is led by ORNL and includes two vehicle manufacturers. The vehicle OEMs appear to be fully on board with the project. It was a bit surprising that there is not an EV charger company on-board, but the PI indicated the original EVSE partner pulled out of the project after it started. It would be good for further projects to include charger manufacturing input. The PI indicated the team is looking for a manufacturer partner for future efforts.

Reviewer 3:

The reviewer remarked that the laboratory included on its team two OEMs to ensure that the system was interoperable. The team however seemed to be lacking an industrial partner that would be able to scale the solution. The PI candidly explained that while ChargePoint was originally a partner, the company has not been able to participate due to COVID-19-related financial reasons. This type of challenge could not have been foreseen, but it would have been good to hear more about how the team was mitigating the risk associated with the missing partner's participation.

Reviewer 4:

The reviewer said that the once the project team gets into test mode with the OEMs, it will see how the collaboration actually worked. The reviewer expressed concern about EMC shielding on the vehicle, on the charger, and on the user.

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 state project ended.

Reviewer 1:

The reviewer stated that the PI indicated the project team is looking to next move toward 600-kW and 1-MW systems, which would match with the needs of MD and HD EVs. This is highly appropriate as there is currently more interest in inductive charging for HD vehicles, particularly transit buses.

Reviewer 2:

The reviewer stated that the future research proposed by the team is to integrate the design in the two vehicles provided by the two OEMs. That is definitely an important step toward demonstrating the effectiveness of the design.

Reviewer 3:

The reviewer stated that the proposed future work is the vehicle validation at the two power levels. That is the logical step needed to confirm that the design is capable of operating on a road vehicle and outside a laboratory environment.

Reviewer 4:

The reviewer emphatically stated a desire to see the outcome and testing of this, as noted previously. The reviewer expressed concern about "cybersecurity" being designed in, as well as EMC concerns all around. The reviewer thought that more future needs will be seen once the project team tests, and encouraged the team to have a Red Team hack.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer enthusiastically said, yes, and was excited about XFC from an EV charging standpoint. However, the reviewer cautioned that many concerns need to be addressed to "hit production."

Reviewer 2:

The reviewer said that the project is focused on high-power inductive charging for EVs, an area that may be critical for certain EV applications as market penetrations increase.

Reviewer 3:

According to the reviewer, the project is definitely relevant to the DOE objectives.

Reviewer 4:

Wireless charging technology provides more options for EVs by making them accessible to other categories of consumers. The reviewer indicated that this project improves EV accessibility by enabling XFC.

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 resources were adequate for the development of a wireless charging system.

Reviewer 2:

The reviewer indicated that the resources appear sufficient to complete the originally planned activities, though it appears there will be a 6-month, no-cost time extension required.

Reviewer 3:

It seems like the project team is making good progress. Again, the reviewer expressed concern as the project team goes to “test.”

Reviewer 4:

The reviewer remarked that the resources are sufficient, but the team could include a charging operator or a charging equipment manufacturer in this project.

Presentation Number: elt240
Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks)
Principal Investigator: Mike Masquelier (WAVE)

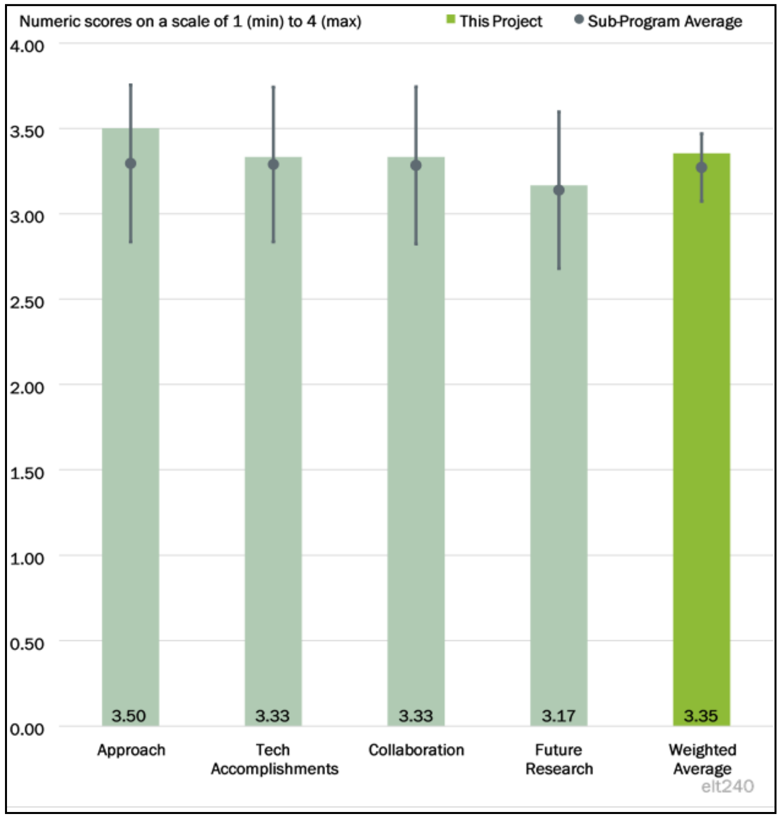


Figure 4-28 - Presentation Number: elt240 Presentation Title: Wireless Extreme Fast Charging for Electric Trucks (WXFC-Trucks) Principal Investigator: Mike Masquelier (WAVE)

Presenter

Mike Masquelier, WAVE

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project is very well designed and integrates multiple advances into the project systems. It increases the performance envelope of wireless charging systems, applies an advanced HD truck powertrain, and MV grid power supply technology to enable HD vehicle electrification.

Reviewer 2:

The reviewer observed that the approach to the work is well underway, and the right players are involved to make the project a success. Good progress is being made relative to objectives. The reviewer would have liked to see some more details on the feasibility versus the project goals, specifically on a breakdown of anticipated hardware costs versus targets for both charging pad and the vehicle-based hardware. Perhaps these could be presented in way that would not reveal proprietary information.

Reviewer 3:

The reviewer stated that the team seems to have had several technical challenges but has managed to find solutions that should meet the TTSI targets for the truck. The reviewer questioned the project team with respect to the design approach, particularly the use of passive battery cooling. This team has the luxury of knowing the exact duty cycle in which the truck will operate and was able to make the decision to use passive cooling because their analysis shows it is sufficient for this duty cycle. Given time and budget constraints and the project goal, this is a logical decision, but it may not be the same one the project team would reach if the project team had to design a more general drayage truck. This may be a trivial point because it is possible that adding active cooling is not a large step, but it left the reviewer wondering what other similar decisions were made elsewhere in the system design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the design surpasses the target performance objectives in terms of vehicle range and duty cycle.

Reviewer 2:

The reviewer said that the rework of the power supply to compensate for not having MV input available obviously was a setback and the project team has a good workaround. It seems the feasibility of getting MV input to many trucking facilities could be a very big challenge to implementing this technology. Also, the reviewer was unclear about where the project team stands relative to the 92% efficiency goal from MV supply to vehicle battery pack—this seems like an admirable but very aggressive goal.

Reviewer 3:

The reviewer remarked that the team appears to have made good progress in the past year and has truck validation underway. However, it does appear the team is behind, and it is unclear how much system validation can be accomplished relative to what may have been planned at the beginning of the project.

The reviewer expressed a concern with respect to grid-to-battery efficiency. A 92% target feels ambitious—some DC-to-DC efficiency data were presented, but not much else. Modeling results and data from the 250-kW system would have been helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that, from the presentation and discussion, it seems there is a good project team, and the collaboration and coordination are working well.

Reviewer 2:

The reviewer stated that the integration of the design progress reflects significant collaboration and coordination by the various partners.

Reviewer 3:

The reviewer stated that the presentation showed that the team is making good progress on many fronts, indicating that partners are now actively engaged though the site relocation indicates that this may not have been the case for the entire 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future work makes sense for addressing the remaining barriers, according to the reviewer.

Reviewer 2:

The reviewer stated that it is not clear whether the proposed future research is intended to address remaining goals of this project or for other potential projects. The evaluation criteria are how the proposed work achieves the remaining objectives of this project.

Reviewer 3:

The reviewer remarked that the plan for future work looks good, although the discussion was not clear on overcoming some of the known barriers. As mentioned above, it is not clear where the project team is relative to the 92% efficiency goal. In addition, no plans to measure and address EMI concerns while charging and what that will take to address those concerns were provided by the project team. Another barrier mentioned was the land-based equipment footprint compared to the real estate necessary for the actual charging pads and parking area for the vehicle.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project paves the way for wireless MW charging in many other heavy-truck applications and is therefore very relevant.

Reviewer 2:

The reviewer stated that this project directly addresses DOE's objective to advance transportation electrification of HD vehicles.

Reviewer 3:

The reviewer observed that this project is totally in line with DOE objectives and is a critical part of implementing electrified vehicles in the larger commercial vehicle industry. The ability to minimize "fueling times" is critical to making BEVs of this size feasible to that particular population of 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 stated that the resources appear to be sufficient at this time to meet the schedule milestones.

Reviewer 2:

The reviewer stated that the main resource that appears to be strained is the schedule timeline due to unanticipated delays in establishing the MV grid power supply.

Reviewer 3:

The reviewer stated that the team is making good progress on hardware design and the prototype builds. There is no detail with respect to actual spending versus planned spending at this point in the project, which is usually a good indicator of progress as well as whether sufficient resources remain. More details in this area would have been appreciated.

Presentation Number: elt241
Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles
Principal Investigator: Charles Zhu (Delta Electronics)

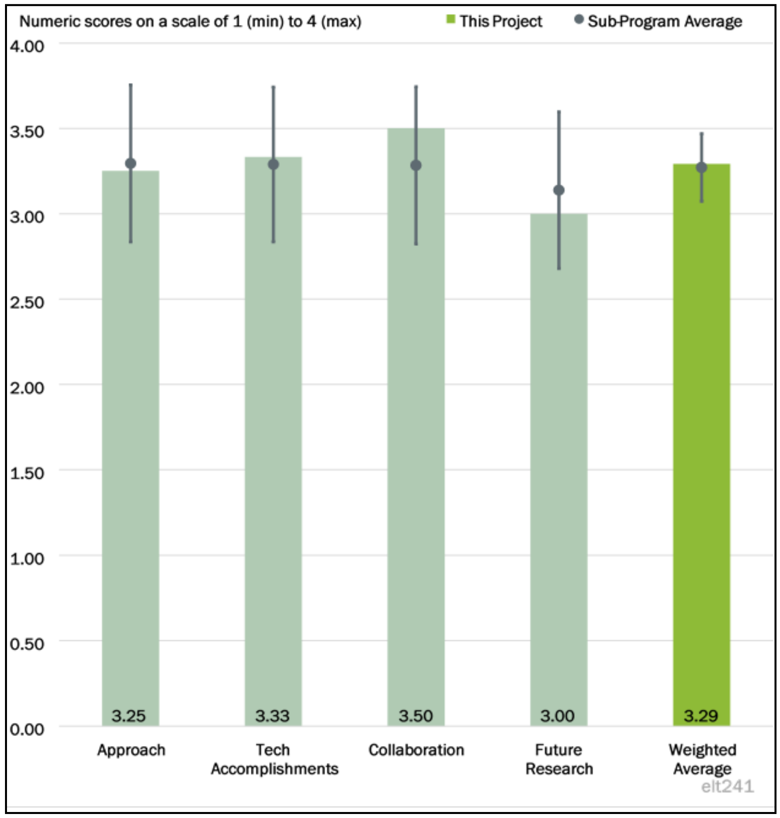


Figure 4-29 - Presentation Number: elt241 Presentation Title: High-Efficiency, Medium-Voltage Input, Solid-State, Transformer-Based 400-kW/1000-V/400-A Extreme Fast Charger for Electric Vehicles Principal Investigator: Charles Zhu (Delta Electronics)

Presenter

Charles Zhu, Delta Electronics

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this is a fascinating project that is explained well.

Reviewer 2:

The reviewer stated that the project's approach has sequentially validated major elements at lower power levels while developing the higher power level system. The project team has successfully demonstrated at the 13.2-kV/400-kW level at end of 2020, beyond the original goal of 4.8 kV at that time. The project is on target to meet or exceed performance goals of 96% energy conversion efficiency. The project could be improved by also evaluating the efficiency of total energy use, including cooling systems and other loads.

Reviewer 3:

The reviewer commented that work on developing the SST has been well planned and executed. The SST barriers are well defined and being addressed, and Delta's experience is clearly coming into play here. No barriers were presented for the rechargeable energy storage system (RESS). It appeared to this reviewer that some very high temperatures are being experienced—positive contactor at 96.4˚ Celsius (C), MSD (1,2)/MSD Fuse (3,4) at 81.15˚C. These temperatures should be addressed if it intended that the pack configuration has some future value to partner General Motors (GM).

Reviewer 4:

The approach was clearly focused on accomplishing the objectives of the project—developing an efficient, smaller footprint and a lower cost, high-power EV charger system—although the PI admitted that the cost element will be left to future research. In order to prove successful operation, the project focused not only on the charger itself but also on ensuring that the test vehicle was adequately improved to handle the higher power.

Reviewer 5:

The reviewer suggested that the early charge rate (C) work selected (3C) (but no capability of the vehicle to charge at that rate) seems like more than a little oversight. Some additional partnership development would have gone a long way in the preparation for this work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Based on what was explained, the reviewer asserted that this is an excellent technical accomplishment. Of course, the devil is in the details and how well it works.

Reviewer 2:

The reviewer stated that the hardware, analysis, and testing have been on or ahead of schedule with respect to the stated plan. The project team has successfully demonstrated at 13.13.2-kV/400-kW level at the end of 2020, beyond the original goal of 4.8 kV at that time. The project is on target to meet or exceed performance goals of 96% energy conversion efficiency. The project could be improved by also evaluating the efficiency of total energy use, including cooling systems and other loads. Progress toward technical targets has not been impacted significantly by COVID-19 supply chain or work issues. A gap analysis of existing standards would benefit this project to clarify where current standards are insufficient for supporting this technology.

Reviewer 3:

The reviewer stated that the project team has appeared to accomplish a great deal, having demonstrated extremely high efficiency (greater than 95%) in the lab at very high power. A key element of this testing was the thermal testing, which was extremely detailed and thorough. The project team still has the final test and demonstration site work to complete and thus expects to complete the project perhaps a bit later than originally anticipated.

Reviewer 4:

Although sure that there were delays due to the pandemic, this reviewer indicated that the American Center for Mobility (ACM) development seemed to be a little behind schedule. This will impact and significantly reduce the amount of testing on the correct vehicle, which will be capable of accepting the higher charge rate. Are there plans for a no-cost time extension? There are good results provided on the power systems control and RESS build.

Reviewer 5:

The reviewer stated that the design and testing work on the 13.2-kV/ 400-kW solid-state system is excellent. RESS thermal has been completed in parallel with transformer testing. Planning for the final test is in place. However, the original project schedule end date is in jeopardy.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer emphatically stated that the project showed good collaboration to get this up and running thus far and to get to a test facility. The project team made it look easy.

Reviewer 2:

The reviewer said that all partners appear to be engaged, allowing transformer and vehicle work to proceed in parallel and planning for the demonstration site to proceed.

Reviewer 3:

The reviewer said that the project has demonstrated effective team participation, tapping a wide base of expertise that includes academia, test facilities, regional groups, suppliers, and a major OEM.

Reviewer 4:

The reviewer stated that the project team, led by Delta Electronics, includes a vehicle manufacturer, utility, university, energy office, and a city, and is providing an interesting breadth for the team. This does seem to include most of the necessary parties, though it would be good to have an organization on the team dedicated to technology transfer. The project team appears to have made very good use of its team members—GM to modify a vehicle and battery pack combination, a utility to conduct the testing, etc.

Reviewer 5:

The reviewer stated that again, with the exception of the early vehicle selection, there is a good group of partners capable of completing the research, though the timing will be difficult with the schedule of the test site.

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 state project ended.

Reviewer 1:

The reviewer stated that the project is well positioned to conduct its demonstration test.

Reviewer 2:

The reviewer stated that the path to target for future work is appropriate. The project stated in the Q&A session that certification requirements would be a focus of the "next project. This project has had to work with existing standards framework. So, a gap analysis of existing standards would benefit this project to clarify where current standards are insufficient for supporting this technology and to help to scope the need for future projects. An example is the use of Combined Charging System (CCS1) connectors, which are not necessarily rated for higher power levels above 350 kW.

Reviewer 3:

The reviewer stated that this work could be relevant to standards creation, and this aspect should be explored.

Reviewer 4:

The reviewer stated that with COVID-19, there have been some delays, which mean there are several important activities still to complete. As for a next project, the PI indicated that the critical element is to drive down cost—the current unit is expensive. Not much future research was indicated beyond that, other than perhaps additional testing.

Reviewer 5:

The reviewer remarked that the project team just sort of stopped here in terms of getting a facility up and going and suggested there needs to be more thought here. What is the goal for testing? What are the concerns? At what point does the project team consider the project a "success"? Does a Red Team hack the project team from a cyber standpoint, all the way down to the board level?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer emphatically stated, absolutely, XFC needs to happen to make that EV recharge "fast." The project is very relevant to the overall DOE objectives.

Reviewer 2:

The reviewer said that this project directly supports DOE and the administrations goals of accelerating zero-emission vehicle adoption by demonstrating high energy conversion efficiencies with solid-state XFC equipment. Commercially viable technology must also be cost effective, but requires a proof of viability, which this project is accomplishing. This technology is applicable to light duty, MD, and HD commercial implementation of BEV charging infrastructure.

Reviewer 3:

The reviewer stated that this project is focused on high-power charging units, which are necessary to speed charging times. This will be important for greater deployment of EVs as drivers begin to expect charging times closer to refueling times for conventional vehicles.

Reviewer 4:

The reviewer stated that reducing losses in charging infrastructure and reducing the packaging footprint, eventual cost, and system complexity are all in alignment with VTO goals.

Reviewer 5:

The reviewer stated that the work on the SST is excellent and has clear future value for XFC. Little was said about the value of expending resources to modify a Bolt to accept XFC. The reviewer suggested that there be more discussion on the strategy of configuring Volt cells for XFC in a Bolt. It is not clear whether this has future value to partner GM.

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

Reviewer 1:

The reviewer emphatically stated good resources. The project team has made a lot of progress and explained this difficult technology quite well.

Reviewer 2:

The reviewer said that the project has effectively tapped the 50-50 cost-share with participants. The project is on track for completion in November 2021 within the original budget.

Reviewer 3:

The reviewer said that the project appears to be moving smoothly with the resources assigned. Additional (and different) resources will be required to construct the demonstration site. It appears these resources are available from partners DTE and NextEnergy.

Reviewer 4:

The reviewer said that the resources were sufficient as demonstrated by the eventual completion of the test site and vehicle modifications. Lack of testing results is a more time-based delay than a funding issue.

Reviewer 5:

The reviewer said that the resources appear sufficient to complete the originally planned work, although the PI did identify future work to build off of this project (including work on reducing system cost).

Presentation Number: elt257
Presentation Title: Directed Electric Charging of Transportation Using eXtreme Fast Charging (XFC) (DIRECT XFC)
Principal Investigator: Tim Pennington (Idaho National Laboratory)

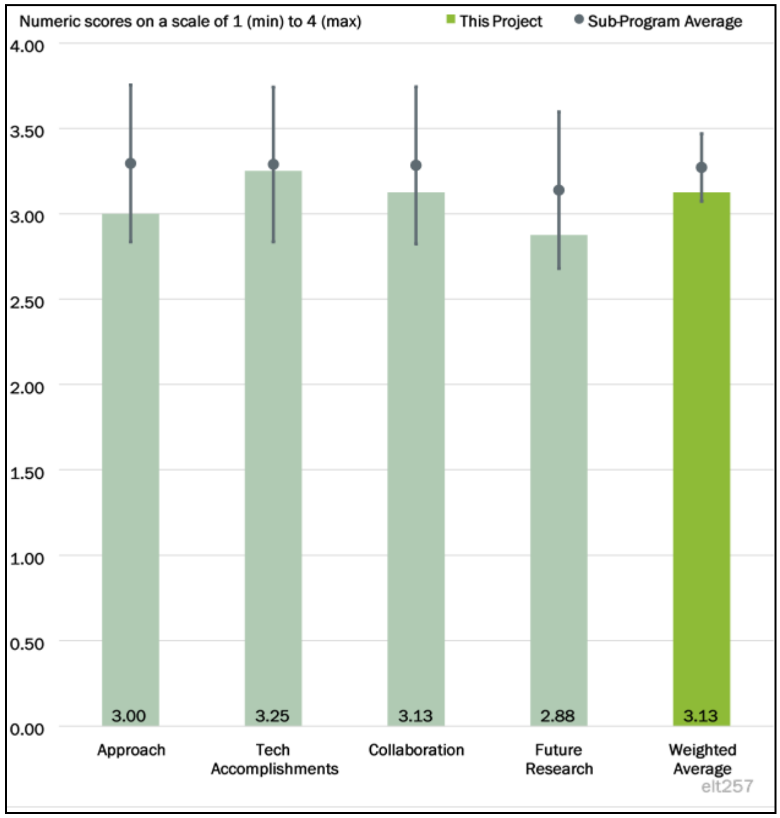


Figure 4-30 - Presentation Number: elt257 Presentation Title: Directed Electric Charging of Transportation Using eXtreme Fast Charging (XFC) (DIRECT XFC) Principal Investigator: Tim Pennington (Idaho National Laboratory)

Presenter

Tim Pennington, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the general approach is useful for simulation. There are no vehicle OEM, XFC charger companies, or city planners involved in this phase of the work. Validation of this methodology could be improved by incorporating some of their business processes and policy planning assumptions.

Reviewer 2:

The reviewer stated that this approach is good since it considers the baseline with no controls in the system and sequentially adds stationary storage, communication, and reservations for evaluation of result combinations. This also includes both AC and DC charging and fleet and private EVs. It however needs to identify how reservation may be used to reroute customers to less utilized locations as options to balance the energy supply and demand.

Reviewer 3:

The reviewer stated that it was not clear how the extra cost for XFC (over and above that for regular or overnight home recharging) was estimated. Even the need or want for XFC was unclear, and whether this is for a certain percentage of EVs. The assumptions should have been elucidated on a separate slide for everyone to see.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the PI met the technical accomplishments and satisfactorily progressed as measured by the performance indicators.

Reviewer 2:

The reviewer stated that the team has made substantial progress to objectives, given the challenges of 2020.

Reviewer 3:

The reviewer stated that the initial operation and approach are clear and seem to be on target. Expanding the reservation function and being able to broadcast that to customers seem to be the next steps.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the labs have variations to their expertise and their contribution is a good match to success of this project.

Reviewer 2:

The reviewer said that there were no real challenges in team partner coordination and collaboration, and further commented that all partners were DOE national laboratories.

Reviewer 3:

The reviewer said that the DOE partners seem to be very well coordinated on the technical aspects of this project. It is less clear how the coordination with non-DOE partners is functioning. More regular interaction could provide significant benefit to validation of the methodology. In addition, adding collaboration with vehicle OEMs and city planners in later phases could enhance the project outcome.

Reviewer 4:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that no future research is needed on this topic.

Reviewer 2:

The reviewer stated that the data are expected to provide results to guide planning of grid usage and benefits of balancing stationary storage needs with communication and reservation requirements to meet EV charging needs. This needs to be balanced to either expand capacity at various sites or reroute customers to less used locations that still meet their travel needs.

Reviewer 3:

The reviewer said that the one key aspect that is not being addressed is in determining how this tool could be adopted into the marketplace, should it prove to address the major XFC adoption barriers.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project supports DOE objectives for adoption of low carbon transportation.

Reviewer 2:

The reviewer stated that the project is very relevant since it provides information on how and where to add resources and communication at charging locations to meet customer travel needs.

Reviewer 3:

The reviewer stated that the need for XFC has not clearly been established. Even if it were, the cost justification was not presented.

Reviewer 4:

Not applicable was indicated 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:

Resources to execute this project seem to be appropriate to deliver the objectives.

Reviewer 2:

These labs have the resources to accomplish this project goals and provide guidance on how to balance the grid and vehicle charging needs.

Reviewer 3:

The reviewer remarked that the expenditure of $3 million on a modeling project that benefits those who can afford the luxury of XFC is excessive and akin to building “Lexus Lanes” for those drivers who can afford to pay extravagant $40-50 tolls. The reviewer explained that this is the expression that state highway administrations are accused of.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: elt258
Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC)
Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

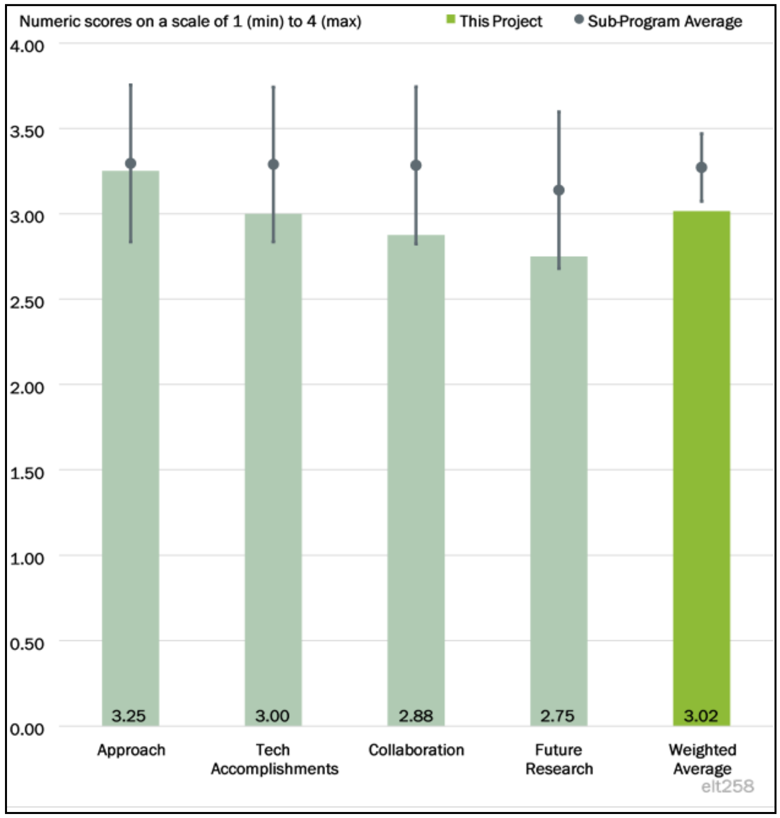


Figure 4-31 - Presentation Number: elt258 Presentation Title: Grid-Enhanced, Mobility-Integrated Network Infrastructures for Extreme Fast Charging (GEMINI-XFC) Principal Investigator: Andrew Meintz (National Renewable Energy Laboratory)

Presenter

Andrew Meintz, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project focus is on densely populated areas. This project also needs data from cities that have more space and options for other slower charge systems.

Reviewer 2:

This is a very wide-scale project with a very complex approach, making it difficult to explain in a short AMR presentation. The reviewer was glad the project will “leverage existing capabilities,” but the slides did not give a clear picture of where existing resources end and where new capability will be developed. Time permitting, it would have been helpful if the investigators could have elaborated on a couple key points, like “EV route scheduling” or “Minutes for driving dynamics.

Reviewer 3:

The reviewer suggested that the approach could be improved as follows:

- Show that the TEMPO, BEAM, HELICS, and PyDSS models have been validated and/or verified. The reviewer had no assurance or confidence that these are valid models. If the project team has, please include that information in backup slides.
- Include commercial vehicles (trucks and buses) in the overall travel pattern.

- Establish the need/want for XFC and the cost justification for XFC. Certainly, there are, or will be, some that will need it. But what percentage of all the EVs, and what percentage of the time?
- Locating XFC stations will be affected by socioeconomic status (affluence). Thus, certain neighborhoods will be much more affected than others and, subsequently, power distribution will be much more affected in certain neighborhoods than others. Just owning an EV is discretionary—not a necessity. Even more so, both owning an EV and affording to pay a premium for XFC is definitely a luxury.
- Note that the pandemic has changed work-home travel patterns, such that there will be less travel and more work at home. This should be taken into account.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the technical accomplishments and progress are satisfactory as measured against performance indicators.

Reviewer 2:

The reviewer stated that it was not always clear in the review what the inputs were to the simulation versus the outputs from the simulations. For example, it is assumed input to the simulation was that "charging for electrification of 1million vehicles (16% of the fleet)" while the output plots of power draw were shown on the right of the chart. Then, to complete the flow of logic, it would be good to explain or estimate how this information could be used by grid planners to improve utilization.

Reviewer 3:

The reviewer stated that this is still early in the project and more time and data are needed to validate the analysis.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there were no real challenges. All the collaboration and coordination were among DOE national laboratories.

Reviewer 2:

The reviewer stated that the milestones need to show what lab is performing that function and, if both, then a percentage of effort needs to be included.

Reviewer 3:

The reviewer stated that this large of a project does require coordination across a large time. Based on the scope and the detail in the presentation, there seem to be no coordination issues. It is a bit surprising that there are not electric utilities on the team since the output from the project seems most applicable to this industry.

Reviewer 4:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the investigators did include information on the AMR slides about future research within this project.

Reviewer 2:

The reviewer stated that as more extended range vehicles approach this market, their effect needs to be included. More time in this project will lead to a better conclusion on future research potentials.

Reviewer 3:

The reviewer stated that future research is needed to address the points made in response to “the technical accomplishments and progress are satisfactory as measured against performance indicators.”

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project very directly supports several of the DOE’s goals but is primarily aimed at efficient use of the grid to charge EVs.

Reviewer 2:

The reviewer stated that passenger cars may use more f XFC in highly populated areas, but their effect needs to be included in other, less densely populated cities.

Reviewer 3:

The reviewer expressed that this research is premature and far ahead of its time because neither the adoption rate of EVs nor the need or want for XFC are known. As mentioned previously, the costs of XFC have not been justified. The reviewer is of the humble opinion that XFC will benefit the affluent.

Reviewer 4:

Not applicable was indicated 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 stated that the modeling tools are well defined, more results are needed to validate the predictions.

Reviewer 2:

The reviewer observed no issues or apparent negative impact of the COVID-19 pandemic.

Reviewer 3:

The reviewer considered that a budget of $3 million is excessive for a modeling project that looks at a speculative technology impact that is not needed until the future and will be used by a small percentage of primarily EV owners, benefiting the affluent.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: elt259
Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions
Principal Investigator: Marcus Malinosky (Daimler Trucks North America)

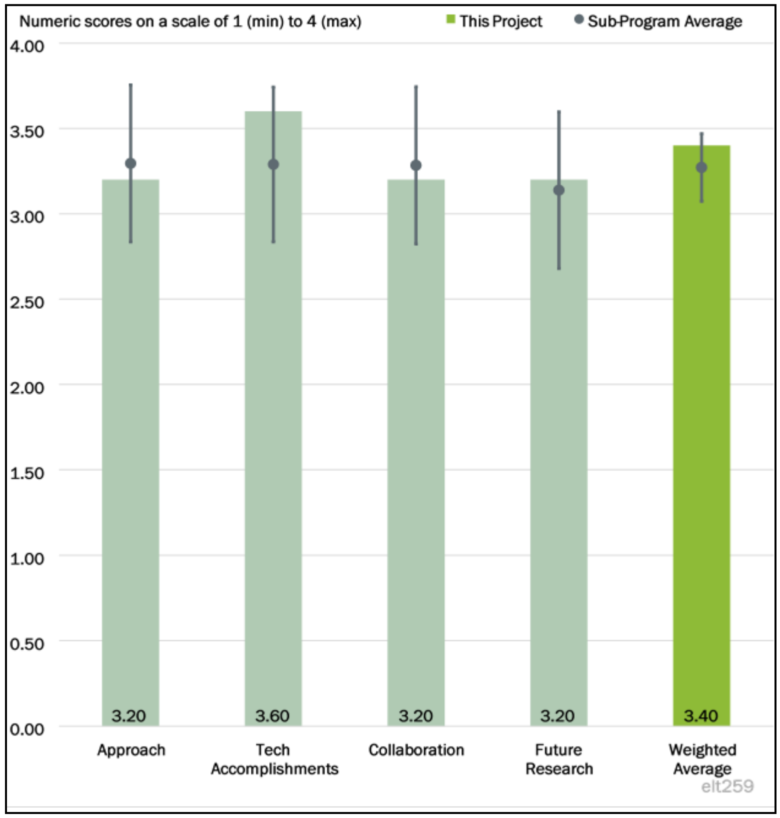


Figure 4-32 - Presentation Number: elt259 Presentation Title: Development and Commercialization of Heavy-Duty Battery Electric Trucks Under Diverse Climate Conditions Principal Investigator: Marcus Malinosky (Daimler Trucks North America)

Presenter

Marcus Malinosky, Daimler Trucks North America

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the main objective seems to have been to demonstrate that an electric Class 7/8 truck could travel 250 miles in a day, and that was successfully achieved, so the project team was clearly doing the right things to get there. Actual road tests were crucial for identifying issues to be addressed in later models.

Reviewer 2:

The reviewer stated that the aspect of diverse climate conditions was not described extensively. The weatherization aspect of the research should be better represented. Additionally, is the 50 miles per hour (mph) speed assumed in the range analysis sufficiently high? It seems that the average speed may be higher based on the content of freeway driving in the various drive-cycle scenarios. It would be nice to see the actual speed-level content for the assumed drive cycles in this analysis.

Reviewer 3:

The approach to deliver a demonstration vehicle is reasonable. However, it appeared to the reviewer that the process taken may limit the ability to transfer to a high-volume design-for-manufacturability, design-for-service. Aspects’ business approach was neglected in order to focus on the technical challenges.

Reviewer 4:

The reviewer remarked that the project is tied to commercial development efforts for HD EVs. As such, there are parallel activities going on that are contributing to progress but are outside the scope, funding, and control of this project. That said, this project is well on track in developing, validating, and entering commercial production of a Class 7/8 EV tractor capable of stated goals and timeline. The barriers and contingency work have been identified and proactive steps taken to mitigate issues and maintain schedule. Seasonal environmental and operational aspects of risk were not discussed in the review; however, the parallel commercial activities appear to be addressing validation through vehicles to be deployed in early fleets and a substantial number of early prototypes already fielded with fleets.

Reviewer 5:

The reviewer remarked that the stated barrier to adoption of Class 7/8 trucks is limited range and lack of full-line manufacturers. The primary barrier to range is battery technology. As described, this project does not place adequate emphasis or resources on understanding, designing, verifying, and improving battery technology. Very little information was given about battery pack and cell design, development, and testing. A secondary barrier is efficiency of the electric powertrain. Again, very little information was shared about what Daimler Trucks North America (DTNA) is doing to understand design factors that affect efficiency and exploit these to maximize efficiency. Finally, despite the project's title, very little information was provided on how the truck is being designed to ensure range, battery life, and system efficiency in diverse climates and at temperature extremes.

Good work has been done to understand customer use cases and set targets that meet customer needs in those cases. The philosophy of minimizing complexity of the electric powertrain and avoiding deviation from conventional truck design to the extent possible is a good one. This is a powerful means to avoiding reliability and durability problems.

The incorporation of accelerated component and system testing based on real-world data to replace on-road testing that was not possible due to COVID-19 is good, although the reviewer was surprised that this kind of accelerated component and system testing was not already part of DTNA's product development process and planned in this project. Based on the presenter's response to a reviewer question, it sounds like DTNA has much more design verification testing planned than was described (e.g., dynamometer testing by a subcontractor and by Daimler in Germany). More information should be shared next year about the comprehensive design verification plan.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that this project is ambitious and the progress, considering COVID-19-related delays, seems on track and notable.

Reviewer 2:

The reviewer stated that the team made substantial progress and was very creative in overcoming barriers of the 2020 pandemic.

Reviewer 3:

The reviewer stated that the team has stayed on schedule, despite challenges due to COVID-19, by carefully managing its supply chain, working hard to complete prototype builds with limited staff, and by applying sound, accelerated testing techniques.

Reviewer 4:

The reviewer remarked that the main performance indicators for this project were range, which has been achieved, and the corresponding fuel efficiency. Unfortunately, no estimates of the TCO were provided.

Reviewer 5:

Phase 1a and 1b progress was on track, including B sample build and testing, and C sample specification. Track and road testing has been conducted sufficient to have confidence in the next iteration of the vehicle to meet program performance targets. The reviewer would have liked to see more explanation of where duty-cycle profiles of actual real-world routes with EV trucks were obtained, to ensure that proving ground track and shaker table modeling were truly representative of these cycles. The parallel activities of launching and certifying a production, new model truck at an OEM are far beyond the budget and capability of this project, so it is challenging to determine what is specifically and actually part of this DOE project versus what is being done in parallel by the OEM and supply base. However, the milestone of commercializing a truck within the time frame of this project appears to be on track.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the DTNA team is leveraging significant internal resources well and has partnered with two relevant fleet partners.

Reviewer 2:

The reviewer said that the role of the project partners (besides shipping customers) was not particularly clear, but it looks like the majority of the work is being performed by the PI.

Reviewer 3:

The reviewer indicated that it is assumed that test runs with the trucks will be carried out by the partners; the presentation does not clarify which actions were carried out by which partners, but the reviewer assumed that on-road tests in actual operation on routes will be performed.

Reviewer 4:

The reviewer stated that the great collaboration and partnerships. Adding a partner to the team who could help to further expand the possible freight use cases via a generalized modeling approach (INL, ANL, and NREL for example) based on field data from the current partners could lend even further credence to the ability of a BEV to meet customer needs and expectations and potentially help speed the technology to market.

Reviewer 5:

The reviewer remarked that the project team has managed to stay on schedule, coordinating activities, and adapting to challenges presented by COVID-19-related supply chain shortages of equipment, materials, and labor. The team discussed is largely Daimler personnel and supply base. Industry group participation is inferred through Daimler, but was not specifically mentioned, so things like standards were not discussed as part of commercialization or market adoption. Also, no mention of DOE participation as either consultants or participants from DOE laboratories, where clearly there is expertise and potential assets and resources. Where this project is being assisted by or benefitting industry groups such as CharIN, SAE, IEEE, ISO, etc., should be detailed as part of the standards part of "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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the scope of the future work is good. It is expected that the diverse climate condition testing will be better addressed in future presentations to understand the performance of the system in real-world driving use cases.

Reviewer 2:

The trucks will be tested on actual routes. Presumably, range and fuel efficiency will be verified. The reviewer would have liked to see volume cost estimates and also more about the batteries. Will the batteries last?

Reviewer 3:

As stated above, adding another partner who could model even more use cases and validate field testing from the demonstration trucks could help to address adoption barriers. In addition, the reviewer suggested that addressing some challenges around depot charging scenarios may be valuable.

Reviewer 4:

The reviewer remarked that the project has been planned out and is in the process of procurement for C-sample vehicle and testing and the further refinement of the D-sample vehicle in BP 2. The project reports it is 70% complete as of AMR 2021. The remaining 30%, however, is tied to production start of a commercial product line at the OEM and testing for certification of the product; these activities are largely outside the direct control of this project. Additionally, the project specifically states that it will include diverse climate conditions, so winter and summer testing may need to be simulated in environmental test facilities and may not be validated in real-world fleet use in the timeframe of the project.

Reviewer 5:

The reviewer stated that the future plans include continuation of component procurement, design, prototype builds and integration, testing, fleet demonstration, and data collection—the standard (and appropriate) steps for a vehicle development project of this kind. However, details on future work are sparse. A design verification plan and plan for demonstration data collection and analysis, with emphasis on critical questions that need to be answered, should be developed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the electrification of trucks will provide a major impact on the DOE mission of sustainable transportation and energy independence.

Reviewer 2:

The reviewer stated that in order to maximize U.S. displacement of diesel fuel by electricity, trucks must be electrified. That is non-trivial for local delivery fleets, but medium-range and long-haul trucking have issues with battery range, mass, and time to charge. This project demonstrates that medium-range trucks can practically be electrified.

Reviewer 3:

The reviewer stated that the project is highly relevant to the DOE objective for increasing adoption of low carbon transportation tools.

Reviewer 4:

The reviewer remarked that the project directly supports DOE and the administrations goals of accelerating zero- emission vehicle adoption for hauling freight by HD EV tractors by assisting in commercialization of a viable 250-mile range EV tractor below 20,000-pound tare weight. Many of the challenges to EVs by detractors can be quantifiably addressed with success of this project. Combined with other DOE projects in XFC, this project builds confidence that HD EV tractors can accomplish significant portions of freight hauling's duty cycle.

Reviewer 5:

The reviewer stated that developing the capability to produce long-range battery-electric class 7/8 trucks is core to DOE objectives for reducing the cost, energy consumption, and emissions of goods transport.

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 sufficient for the proposed future scope.

Reviewer 2:

The reviewer stated that it is hard to answer this, since there was no information about how many trucks were being built all together.

Reviewer 3:

The reviewer stated that the project is sufficiently budgeted to achieve the stated objectives.

Reviewer 4:

The reviewer remarked that the project did not report that budget was a limiting factor. Combined with the progress to date and the parallel activities of the OEM in ramping up a production line for EV tractors that are benefitting this project, the project appears to have sufficient resources to meet its technical objectives of commercializing an EV tractor. Whether the market will invest in the product is an unknown, but marketing is not part of the project, only bringing a capable performing product to market. A viable, competitive manufacturing cost for the truck does not appear to be a factor directly tied to this project, although relevant to commercial success.

Reviewer 5:

The reviewer remarked that the in light of the significant delays and hardships incurred by the COVID-19 pandemic, the project team may need more time to complete the project. The reviewer commended the team for their hard work and ingenuity to stay on schedule; the project team will undoubtedly continue to do all it can to remain on schedule, but it already has compressed schedules. Any additional delays may push completion later. Uncertainty due to supply chain shortages is a significant risk that may be beyond the team's control.

Presentation Number: elt260
Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management
Principal Investigator: Teresa Taylor (Volvo)

Presenter

Teresa Taylor, Volvo

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

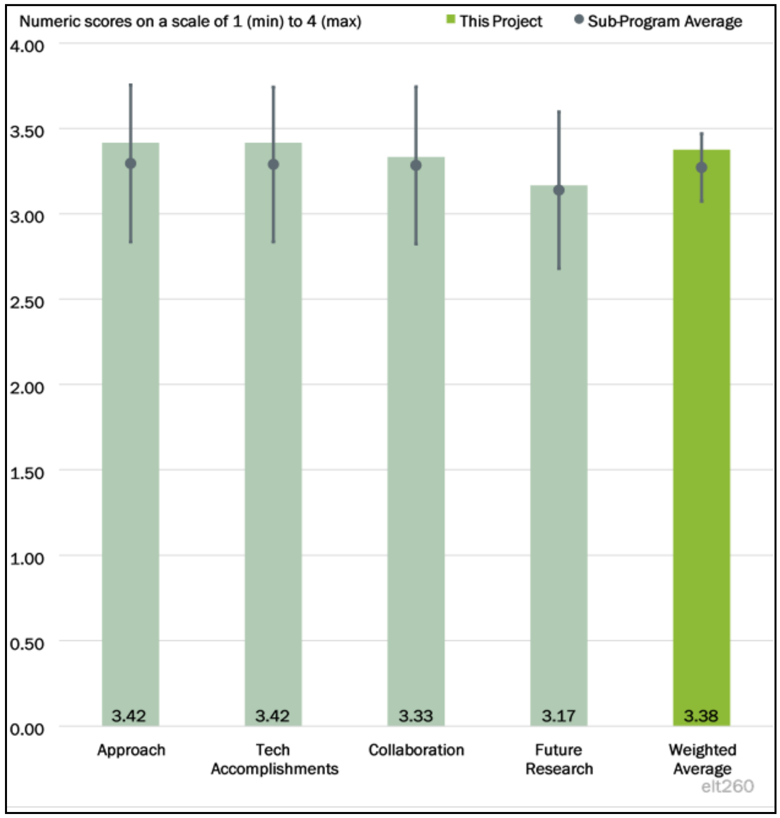


Figure 4-33 - Presentation Number: elt260 Presentation Title: Improving the Freight Productivity of a Heavy-Duty, Battery Electric Truck by Intelligent Energy Management Principal Investigator: Teresa Taylor (Volvo)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the use of machine learning will enable this team to obtain the maximum performance from the two trucks the project team is acquiring. Not only will the trucks be able to maximize miles per charge, but the intelligent management system under development will enable optimal placement of the charging infrastructure to minimize charging time and number of stops, while not installing more stations than are required.

Reviewer 2:

The reviewer remarked that the project addresses EV adoption in MD and HD markets by studying current utilization and developing demonstration vehicle property and software to show feasibility. These steps are all needed to provide a convincing demonstration.

Reviewer 3:

The reviewer stated that, overall, the project and approach are relevant and interesting.

Reviewer 4:

The reviewer commented that the project is well planned and, given that it is near the end, expected that it will be completed. There is not a great deal of evidence in the budget details corresponding to deliverables and outcomes.

Reviewer 5:

The reviewer noted that the project will develop and demonstrate a driver-decision support tool for a HD battery-electric truck that recommends an energy-efficient route and recommends the minimum charging energy needed on-route to arrive at the truck's destination. Results will be compared to conventional diesel trucks and BEV trucks without decision support. The project will also develop a method for choosing optimal location for charging stations.

The project is using a machine learning algorithm recurrent neural network (RNN) to predict energy needed to complete the designated route and to recommend minimum charging energy required on-route to arrive at the destination; this is a novel and worthwhile approach. Likewise, the approach for energy-efficient routing (based on past data using a look-up table or based on model for trip links that have not been driven before using deep neural network (DNN) is good. Including a constrained budget in the charger placement optimization is important and often not included in academic research. Finally, the practice of validating the system in real-world demonstration using prototype human-machine interface and display in hot and cold climates using two trucks with different specifications (265 kWh and 565 kWh batteries) is excellent.

The reviewer suggested the following items for the project team to consider:

- The project will validate the developed energy consumption model against OEM model, which is good, but it should also validate the model against actual truck performance and energy consumption during the demonstration.
- The project's outcome will be limited if it cannot apply the routing algorithm to include re-routing for charging.
- Clarification of what demand data will be used for charger placement optimization is necessary. To be effective, a large set of trips will be needed.
- Comparing demonstration results to past BEV truck performance without decision support and to a conventional diesel truck will be difficult to accomplish in a meaningful way. More emphasis should be placed on the approach for this comparison and ultimate metrics by which success will be judged.

Reviewer 6:

The reviewer noted that the approach to this project focuses heavily on overcoming technical barriers. However, many barriers for adoption are related to behavior and economic factors. These have not been addressed in the model. Also, justification for the value of using trained neural net models instead of a heuristic modeling approach was not sufficiently described. Access to training and validation data and the expansion of this approach could be difficult for a more generalized solution.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team has made good progress on the truck build and excellent progress on vehicle modeling and the energy management software aspects of eco-routing for delivery fleet EVs.

Reviewer 2:

The reviewer stated that the team made good progress toward achieving the planned activities of their project.

Reviewer 3:

The reviewer said that the project has accomplished its major analytical tasks on time, with successful outcomes demonstrated. Delays in hardware procurement are to be expected due to the COVID-19 pandemic.

Reviewer 4:

The reviewer stated that, luckily, the development of machine learning hardware and software and data acquisition were not impacted by the COVID-19 pandemic.

Reviewer 5:

The reviewer commented that there are good accomplishments to date on the project. It would be useful to put dates on the milestones. Some of the plots in the Accomplishments slides are difficult to read. On Slide 8, it is not clear if the SOC chart labels are flipped. On the same slide, the title for a couple of figures indicate that velocity is being plotted, but the units are labeled as “m.”

Reviewer 6:

The reviewer said that, in the past few years, the reviewer has been seeing a decrease in evidence presented in these AMR reviews to confidently share that technical accomplishments have been made. Specifically, the reviewer expected to see more details in a waterfall chart on the improvements in freight efficiency.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that there is excellent collaboration between industry partners (fleet business and technology suppliers) and the academic team.

Reviewer 2:

The reviewer stated that good collaborations seem to be happening with the team members.

Reviewer 3:

The reviewer noted that both Volvo and the University of Minnesota have moved on to complete their tasks; the company partners are waiting in the wings to perform their parts as soon as the trucks are ready.

Reviewer 4:

The reviewer commented that the partnerships between academia and industry were good. However, there seemed to be limited interaction between the University of Minnesota and Volvo trucks. More regular interaction could contribute to improved understanding of real-world needs of industry partners by the university researchers, and the industry could gain better insights into the type of data needed by the models to reduce the need for training sets and increase prediction robustness for additional use cases.

Reviewer 5:

The reviewer stated that there seems little evidence to the claims made concerning industry engagement outside of the specific partners that are funded. The reviewer believed there should be more effort on fleet and other engagements in these programs.

Reviewer 6:

The reviewer observed that the organizations making up the team seem to be working mostly independently at this point in the project, with Volvo providing University of Minnesota data and guidance. Closer collaboration will be needed to succeed in the second half of the project to successfully plan and complete the demonstration, algorithm validations and improvements, and performance assessment.

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 state project ended.

Reviewer 1:

The reviewer stated that the next steps are absolutely needed to demonstrate the project successfully and are well developed.

Reviewer 2:

The reviewer said that, overall, the proposed future research is good.

Reviewer 3:

The reviewer commented that the plans are good.

Reviewer 4:

The reviewer stated that all the calculations that have been done will form the basis for guiding the actual road tests. The theoretical work is interesting but does not mean a thing until vehicles are actually out on the road delivering freight under real-world conditions. So, the future work is key to proving the utility of the intelligent management.

Reviewer 5:

The reviewer said that most of the future work proposed is focused on model and algorithm improvement. The testing and demonstration phase needs to be much better defined to be successful.

Reviewer 6:

The reviewer remarked that overcoming barriers related to having sparse datasets will be a substantial challenge. It may benefit the project team to reach out to other organizations to help overcome this limitation, for example, local grid operators, charger operators, DOE labs (like ANL or NREL) who may have access to more travel data, and city planners who can help to understand policy and planning barriers to adoption of charging infrastructure, etc.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that the project is directly aligned with VTO goals and objectives. It is highly relevant and important work.

Reviewer 2:

The reviewer stated that the project contributes to the DOE goal of wider EV adoption to reduce GHG emissions. MD and HD trucks are challenging transport segments that produce significant carbon dioxide (CO_2).

Reviewer 3:

The reviewer said that the demonstration of electric trucks at medium range is a key step in electrification of transportation.

Reviewer 4:

The reviewer asserted that this project helps to support DOE objective for adoption of low carbon transportation solutions.

Reviewer 5:

The reviewer remarked that the improving productivity of HD EVs through intelligent energy management contributes to the overall DOE objectives of minimizing energy consumption.

Reviewer 6:

This reviewer indicated that this project very much 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:

The reviewer stated that the resources appear to be sufficient to complete the project based on current reporting from the project team.

Reviewer 2:

According to the reviewer, the budget seems appropriate.

Reviewer 3:

The reviewer said that the resources appear to be sufficient.

Reviewer 4:

Resources appeared to be sufficient to the reviewer.

Reviewer 5:

The reviewer said that, yes, resources are sufficient.

Reviewer 6:

The reviewer remarked that the resources seem sufficient to achieve the remaining milestones.

Presentation Number: elt261
Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter
Principal Investigator: Ben Marquart (Ricardo)

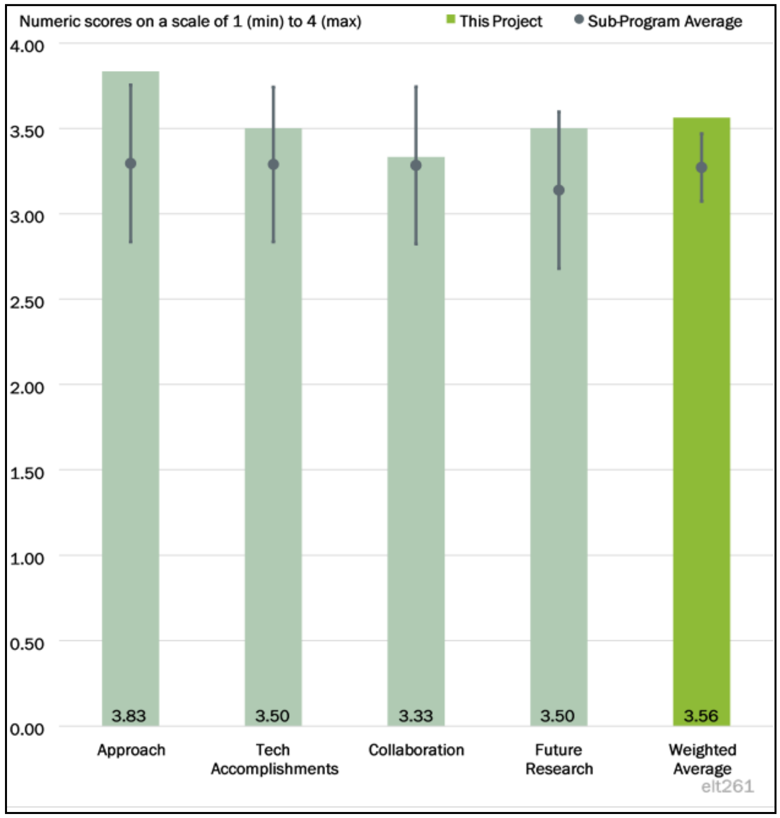


Figure 4-34 - Presentation Number: elt261 Presentation Title: High-Efficiency Powertrain for Heavy-Duty Trucks using Silicon Carbide Inverter Principal Investigator: Ben Marquart (Ricardo)

Presenter

Ben Marquart, Ricardo

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project is largely on track to successfully demonstrate a life cycle, cost-effective Class 8 BEV using a 250 kW SiC high-voltage inverter for a vehicle capable of greater than 250 miles/day operation with increased efficiency versus a baseline diesel unit. The interim development testing and analysis has provided confidence that the final designs can exceed project performance targets.

Reviewer 2:

The reviewer commented that the project is following contemporary system engineering practices and a define, design, and verify product development approach.

Reviewer 3:

The reviewer said that, overall, the approach is exciting. There does seem to be a lot left to do; it would be useful to provide specific timelines for the milestones.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has achieved outstanding results and exceeded goals for A-sample inverter efficiency.

Reviewer 2:

According to the reviewer, the project has dealt with parallel component development of the powertrain, including moving targets on major specification such as voltage level and motor and other system placement. Thermal testing and system-level analysis at lower power have substantiated trends that higher power can achieve or exceed performance targets. Bench-model inverter units have been successfully built and tested.

Reviewer 3:

Overall, the technical accomplishments are good, though there seems to be a lot that still needs to be done. Some more details of the motor being utilized will be helpful. The module maximum temperature could be driven to much higher than 125°C at this point. Some additional information about the coolant flow configuration would also be useful to the reviewer to understand the technologies being utilized.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration team is lean but with qualified resources and assets at Ricardo Inc., NCSU, and Meritor Inc. The project leadership has effectively tapped these resources to develop, model, build, and validate designs using both emulation and hardware. Engagement with DOE laboratory resources was not mentioned and may represent opportunities for both the labs and the project.

Reviewer 2:

The reviewer remarked that the project has good collaborations with NCSU and Meritor Inc.

Reviewer 3:

The reviewer stated that the collaboration seems to be excellent, although the presentation lacks detail on how the organizations are working together.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed future research is excellent. It will be good to also quantify the fuel savings.

Reviewer 2:

The project effectively described future research plans culminating in a 10-month demonstration in fleet operations. Challenges from COVID-19- related supply chain shortages may impact the ultimate schedule, but the reviewer commented that the project is taking proactive steps to order long lead items.

Reviewer 3:

The project has defined data to be collected during the system-level demonstration, but the reviewer suggested that more attention should be given to the vehicle test plan. How will the vehicle duty cycle be determined, and how will that cascade to the component level to ensure that the inverter duty-cycle during testing is sufficiently rigorous?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project is needed for DOE to meet its objectives of developing the technology for widespread electrification of HD vehicles.

Reviewer 2:

The reviewer indicated that this project directly supports DOE and the administrations goals of accelerating zero- emission vehicle adoption for hauling freight by HD EV tractors. The project does this by demonstrating inverter efficiencies greater than 98.5% at charging levels of 250 kW, a key factor in maximizing the net efficiency of HD BEV tractors versus alternatives and baseline diesel units. Commercially viable technology must also be cost effective, and the project is on track toward showing this feasibility.

Reviewer 3:

According to the reviewer, the project supports the overall DOE objectives of design, development, evaluation, and demonstration of electric-drive HD vehicles, which can help with reduction of fuel consumption and GHG reductions.

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 indicated that the project appears to have sufficient resources.

Reviewer 3:

This reviewer stated that the project did not identify resources as a limiting factor. The state of the project appears to be on track, barring significant unknown schedule impacts from potential part availability challenges in the supply chain. The reviewer suggested that contingencies for added costs for expedited work, shipping, and arranging testing windows should be considered by the project team.

Presentation Number: elt262
Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging
Principal Investigator: Brian Lindgren (Kenworth)

Presenter

Brian Lindgren, Kenworth

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

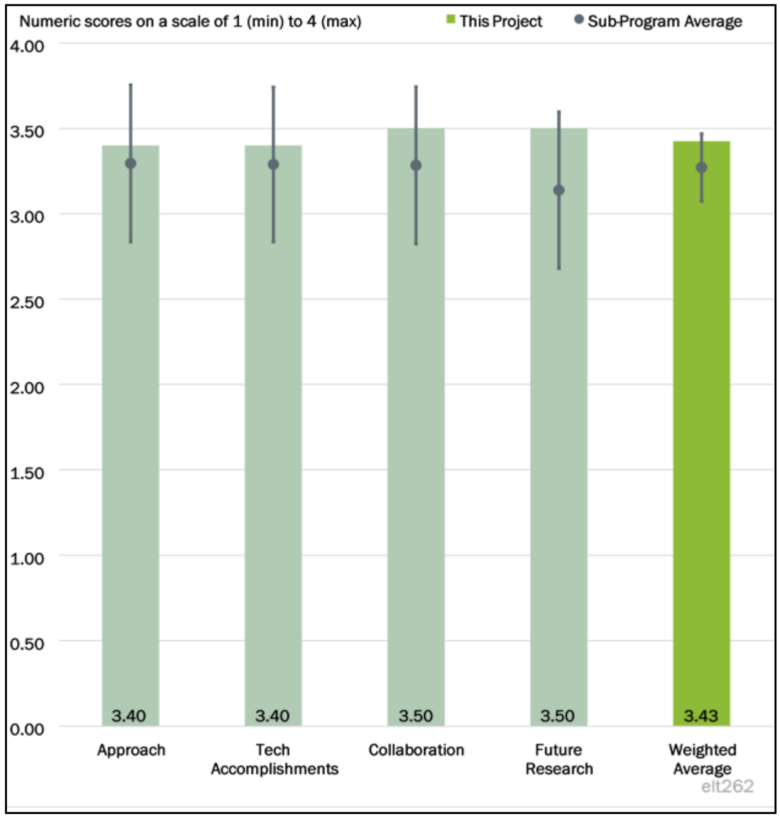


Figure 4-35 - Presentation Number: elt262 Presentation Title: Long-Range, Heavy-Duty Battery-Electric Vehicle with Megawatt Wireless Charging Principal Investigator: Brian Lindgren (Kenworth)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project has identified barriers and proactively taken steps to address them through research, testing, and advance work with affected agencies, such as permitting groups, utilities, and fleets, while effectively dealing with complications from COVID-19 travel and supply chain issues. Smart choices were made to adapt available systems where feasible while maintaining a focus on developing the key new technologies. Using extended-range EVs early to obtain actual vehicle performance profiles on the actual routes was an excellent step.

Reviewer 2:

The reviewer commented that the approach to this ambitious project goals is appropriate due to the development, deployment, and demonstration of the technology. The demonstration and operation across several months or a year are valuable to capture the operational variations due to ambient temperature impacts.

Reviewer 3:

The technical barriers that this team set for themselves are daunting, but when achieved will represent a major step toward practical application of battery trucks beyond local haul. The reviewer found the wireless fast charging to be particularly impressive.

Reviewer 4:

The reviewer stated that the approach to HD electrification is good. Since vehicle efficiency is a high priority in EVs, the reviewer asked if the team had looked into maximizing vehicle efficiency, particularly aerodynamics measures for highway trucks.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated very good progress on the wireless charging components, vehicle electrification, and the battery system.

Reviewer 2:

The reviewer remarked that the progress has been on schedule in spite of setbacks caused by the pandemic. Test runs to understand test route characteristics were very useful. The wireless charger design is particularly impressive, as is the truck modification to go with it.

Reviewer 3:

The project is on schedule overall, with some level of risk from industry-wide supply chain challenges. Proof of concept validation of coil design at Utah State University (USU) and chassis layout at Kenworth were completed. The project team has had appropriate concern and has paid attention to static vehicle charging, thermodynamics of cooling systems, and the potential for recirculation of hot air at charging sites that impact performance. Using extended range EVs early to obtain actual vehicle performance profiles on the actual routes was an excellent step. The reviewer indicated a concern about whether the project is attaining adequate seasonal effect evaluation prior to project completion—including severe winter and summer conditions between Seattle and Portland environments.

Reviewer 4:

The accomplishments indicate the developed wireless charging system and vehicle systems will fulfill the requirements of the designed route. Despite COVID-19 logistics issues, the project has fulfilled technical accomplishments. The battery aging/thermal limitations are presented indicating the potential charging limitation resulting in longer charging time. The table of battery charge profile results on Slide 9 is unclear, indicating longer charge time when starting at higher initial SOC (47 min. charging from 20% to full compared to 29 min. charging from 10% to full), which this reviewer questioned.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project requires a number of contributors from different organizations. The collaboration appears to be excellent.

Reviewer 2:

The reviewer said that the project team consists of all the necessary collaborators to successfully complete this ambitious project.

Reviewer 3:

The reviewer stated that the several partners are needed to work in concert to design and build the wireless charging system; likewise, to get the on-truck components designed and built to be compatible with the charger is a major accomplishment requiring significant cooperation.

Reviewer 4:

The project team is composed of the appropriate technical expertise with representation from utilities, fleet, academia, and industry. The project, however, did not mention any DOE national laboratory engagement from high power charging subject matter experts. According to the reviewer, engagement of DOE assets might benefit both the project and parallel work by those DOE assets.

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 state project ended.

Reviewer 1:

The reviewer stated that the project has actively managed the project plan, addressing schedule challenges, identifying risk areas and scheduling go/no-go decision points. Several influencing factors are somewhat beyond control of the project team such as industry-wide supply chain issues, permitting processes, and unknowns regarding site work for installation of the charging systems. The team is proactively communicating with parties to streamline the process. But these three items this year have led to automotive industry production stoppages from lack of computer parts, permitting always seems to take longer than expected, and site work always seems to discover unknown issues causing some delay and added expense. The project appears to be actively keeping all participants engaged and communicating and attempting to spot issues in time to take corrective steps to prevent delays.

Reviewer 2:

The reviewer said that the team plan looks at the main challenges ahead and is appropriate.

Reviewer 3:

The reviewer indicated that integration, full system (wireless charger and vehicle systems) operation, and evaluation are critical to the success of this project. The proposed plan shows a clear path for completion of these project tasks. Operation of the vehicle and wireless charging system for many months to a year is important to understand and quantify the operational performance variation due to ambient temperature impacts as well as resilience and durability.

Reviewer 4:

The reviewer said now that everything is designed, it will be necessary to complete the building and make it work. This could involve some challenges.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that this project directly supports DOE and the Administrations goals of accelerating zero emission vehicle adoption for hauling freight by HD EV tractors. Rapid recharging will be critical for regional haul operations with longer ranges and multi-shift use of truck assets by companies. Eliminating driver interaction with plug-in connections also is an industry need to simplify adoption of EVs Minimizing transmission losses and establishing that adequate energy transmission efficiencies can be achieved is important to the credibility of accurate total cost of ownership modeling in comparison to alternatives.

Reviewer 2:

The reviewer said that the project objectives and accomplishments directly support the DOE objective for advanced electrified transportation and enabling potential autonomous charging solutions required for fully autonomous transportation.

Reviewer 3:

The reviewer affirmed that the project addresses HD electrification, which is a significant hurdle for the DOE goal of more widespread EV adoption.

Reviewer 4:

The reviewer indicated that the electrification of trucking is key to reducing 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 stated that the work is progressing well with the available resources.

Reviewer 2:

The reviewer said that the resources are sufficient given the high power and capacity levels required to meet the objectives.

Reviewer 3:

The project did not present spend-to-date information, only the overall budget and 50% completion as of the 2021 AMR. The project did not identify budget as a risk area. This, combined with the confidence in the progress shown in the milestone schedule as expressed by the project, led the reviewer to conclude that sufficient budget exists to complete the schedule and deal with any contingencies.

Reviewer 4:

The reviewer said that this project involved a significant amount of hardware design and testing, which could get costly.

Presentation Number: elt264
Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams
Principal Investigator: Joe Picarelli (Exelon/Pepco Holdings Inc.)

Presenter

Joe Picarelli, Exelon/Pepco Holdings Inc.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

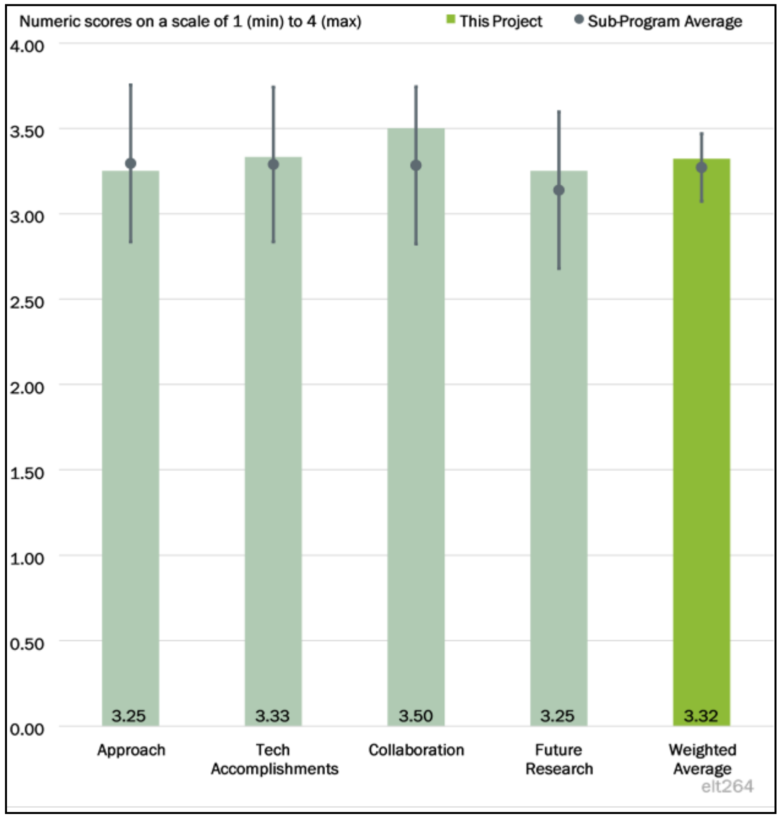


Figure 4-36 - Presentation Number: elt264 Presentation Title: Demonstration of Utility Managed Smart Charging For Multiple Benefit Streams Principal Investigator: Joe Picarelli (Exelon/Pepco Holdings Inc.)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project is well planned and well thought out. Significant barriers have been identified and addressed; however, identified risk of regulatory approval could be significant. To overcome regulatory approval risk, the project might need to include a demonstrated financial commitment from Baltimore Gas & Electric (BG&E) rather than only relying on the offset from DOE funding. Some commissions will evaluate a company’s commitment based on the company’s financial contribution rather than relying on federal or rate payer funding. The project could also benefit from additional focus on customer engagement. It might be beneficial to utilize research from organizations like the Smart Energy Consumer Collaborative, which talks directly with consumers and potentially incorporates focus groups to glean additional insights and feedback on program design. The project will provide important research on the impacts to both transmission and distribution circuits. The different project targets—residential (passive and active), fleets, and public charging—will provide insights across different segments, which will be important.

Reviewer 2:

The approach appears to be very broadly based, including considerations ranging from cybersecurity to signing up customers to completing a final assessment. However, the reviewer pointed out that it is very difficult to get a good picture of such a large project from a 20-minute presentation.

Reviewer 3:

The reviewer liked the overall approach and raised some questions regarding the threat modeling portion of the "perform cybersecurity testing" objective. How is the project team looking at nation-state sponsored cyberattacks? By 2019, roughly 25% of attacks were state sponsored, and that number has increased in the past 2 years. How is the project team developing the threat matrix and is the project team artificially downplaying an enemy state? Also, why is cybersecurity and telematics placed in different silos? It seems these two are very much related.

The reviewer looked forward to next year's briefing to see what the BP 2 cybersecurity impact analysis has to say. How is the project team developing the assessment plan?

Reviewer 4:

The reviewer stated that this is an exciting and ambitious project that wisely addresses both EVSE-based and vehicle-based communication to manage charging. The project is actively learning from other utilities who have already conducted smart charge management pilots, which is important to build on the findings of the others. However, much of the planned cybersecurity work is duplicative with other VTO-funded research. The project should draw on existing threat models and past EV and EVSE vulnerability assessments conducted by others.

Reviewer 5:

The overall objective of the project seemed clear to the reviewer. Specifically, to conduct R&D and a wide-scale demonstration of a Smart Charge Management (SCM) system to develop optimal managed charging structures for grid value, to evaluate the impact of EV charging on local distribution utility operations, and to evaluate the utilities' ability to control EV charging load based on grid conditions.

The reviewer reported that proposed impacts include the following: identifying managed charging techniques that can be shared industry wide; reducing the impact EV charging has on the utility's distribution and transmission systems; lessening the ratepayer capital investment required to manage EV charging demand; identifying cybersecurity risks and vulnerabilities of EVSEs and vehicle telematics software; and understanding the grid impact of EV charging. Overall, the project is proposing to cover an awful lot of ground—maybe too much. It does give pause to the reviewer as to whether the project is being too aggressive and should maybe consider narrowing the scope down somewhat. For example, is it fully appropriate to be exploring the cybersecurity risks and vulnerabilities of telematics software as part of this project?

An extensive list of milestones has been provided, which seemed logical and relatively comprehensive to the reviewer. Some milestones though do invite inquiry. For example, the cybersecurity milestone for November 2021 regarding attack graphs and a threat model—how does this effort potentially dovetail with and augment the threat modeling previously conducted by SNL and PNNL? For the December 2022 milestone to install L2 chargers and DCFC at utility-owned public stations, it may be good to consider XFC up to 350 kW as part of these demonstrations.

It seemed odd to the reviewer that the approach does not appear to include demonstration of SCM for workplace charging. Workplaces may be the most suitable applications for SCM due to consistent, long, and flexible dwell times, which facilitate implementing and maximizing the benefits of SCM. Furthermore, since the preponderance of charging will take place at home and the workplace, opportunities for greater benefits exist there.

The approach would have benefitted from a clearer explanation of why certain elements are being included. For example, it was not entirely clear to the reviewer why the project would incorporate cybersecurity testing and validation of specific EVSE equipment within the context of this effort.

The reviewer noted that it appears, ostensibly, that the project will also focus on distribution and transmission grid impacts. This is good as distribution impacts in particular are likely to pose the biggest challenges and have not been extensively studied.

The reviewer commented that a satisfactory list of barriers has been provided, including those involving regulatory issues, the value proposition, and the establishment of a user base.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project team has only just begun; so, just laying out the broad scope and plan of such a large project at this early stage represents significant progress.

Reviewer 2:

The reviewer asserted that the project is making good progress moving forward. The aggressive schedule and some tasks have been delayed, but do not appear to affect overall program implementation. However, attention is needed in order to avoid further delays.

Reviewer 3:

Market research and the SCM design accomplishments seem particularly strong and certainly show this as a fine project. The reviewer did not see any industry partners for the telematics component of the project threat model and asked if the project team is contemplating adding such an entity. If not, there is an open-source "reference" produced by NMFTA, which may yield utility.

Reviewer 4:

The market research and program design accomplishments are strong. It was unclear to the reviewer why the cybersecurity milestone was not met.

Reviewer 5:

The reviewer indicated that a satisfactory listing of technical accomplishments has been provided, especially given the relatively recent initiation of the project in October 2020. These accomplishments include market research for rate design, best practices for marketing, and best practices for customer classes. The design of SCM programs includes collection of charging data and unique incentives, as well as smart charge actions for each customer segment. The initiation of the acquisition of EVSE is through the request for proposal (RFP) process. The reviewer also stated that the project does appear to be falling a little behind the schedule out of the gate, though.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration appears to be excellent at this early stage of the project.

Reviewer 2:

The reviewer remarked that the project team appears strong and appropriate encompassing a utility, national laboratory, an association, an EVSE and charge network operator, telematics software solutions provider, and smart charge adapter company. The role of each of the project partners has been identified and seems to cover all necessary program elements.

Reviewer 3:

The reviewer asserted that there are good project collaborators representing breadth of stakeholders. Outreach to other utilities with similar projects is worthwhile and helpful for designing programs.

Reviewer 4:

The reviewer commented that it appears that all members of the team have been involved in the initial planning, which bodes well for both future cooperation and also assuring buy-in for actions at later stages.

Reviewer 5:

Collaboration is excellent, but there was not a clear breakdown of activities performed and how different performers were coordinating and integrating their efforts. It would be useful in future presentations to show some participant responsibilities on sub-tasks and perhaps describe how collaboration was happening. The reviewer acknowledged that this is a new project so some of that material may not yet exist; it is clearly a well-thought-out program, but the reviewer asked the project team to present more evidence of collaboration in future briefings.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed future research for BP 3 and 4 seems reasonable and does lay out a high-level pathway of what will be done, tools that will be used, and what the expected outcomes are.

Reviewer 2:

The reviewer acknowledged good project planning. The project team has allowed for recruitment of participants in two budget years that would allow for modifications and adjustments. Key decision points have been incorporated into the plan. More information about overcoming potential participation barriers and challenges would be good.

Reviewer 3:

The reviewer stated that the project team appear to have all the bases covered, but again stressed the dearth of information these presentations provide.

Reviewer 4:

The reviewer asked how adding 1,000 customers in this pilot project meaningfully provides intelligence to achieve and/or supports the goal of understanding the impact of high EV adoption. This seems like an insignificant number for the market area the project is serving and conducting research in. How does the project team draw enough information to model a truly widespread adoption?

The project team asserted that the cybersecurity assessment, etc., is complete in BP 3, but the reviewer wanted to know why the project team does not revisit it or verify it during the demonstration phase of BP 4 That seems like a perfectly reasonable opportunity. The project team also emphasizes the cyber-physical aspect and call out networks. The reviewer would be very interested in how that modeling is performed and the state of assumptions.

Reviewer 5:

The reviewer stated that the future work plan is strong at a high level. Some details are lacking. The presenter stated that the project will use OpenADR "and any other communication protocol we might use." The presenter also stated that one of the project's biggest challenges is determining which communication protocol to use. What criteria will be used to select the protocols? How will success be determined? Also, ATEAM simulation will be conducted to model the grid impact of charging. How will the data be collected and used to accurately model customer charging behavior? Finally, how will the value of smart charge management be assessed and weighed against the cost?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that this project looks like exactly what DOE is prioritizing and is central to it mission.

Reviewer 2:

The reviewer stated that this project is highly relevant and addresses top DOE priorities for enabling widespread EV adoption without negatively impacting the grid.

Reviewer 3:

The reviewer commented that this research is very relevant to DOE objectives and will provide important findings for other utilities implementing smart charge management. Understanding impacts to distribution and transmission circuits will be critical for widespread adoptions.

Reviewer 4:

The reviewer said that aggressive implementation of smart charge management is essential to integrate large numbers of EVs within the electric grid without massive and costly scale-up of infrastructure. The wide-scale demonstration of SCM is necessary to determine the feasibility of SCM, identify and resolve critical barriers, determine optimum implementation strategies, and build confidence.

Reviewer 5:

The reviewer indicated that this project seeks to make EV charging more efficient and economical, furthering DOE's goal of electrifying U.S. 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 said that the budget and other resources seem appropriate given the level of research and work.

Reviewer 2:

The reviewer remarked that the project has an excellent team and significant funding that should be sufficient to successfully complete this important and ambitious project.

Reviewer 3:

According to the reviewer, the project appears sufficiently funded at this time and pointed out that the project has a 58% utility cost share.

Reviewer 4:

The reviewer found that the resources seem fine.

Reviewer 5:

The reviewer asserted that there is lots of work that will be required; it is difficult to judge costs with so few details provided.

Presentation Number: elt265
Presentation Title: A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicle's-At-Scale
Principal Investigator: Duncan Woodbury (Dream Team LLC)

Presenter

Duncan Woodbury, Dream Team LLC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 20% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

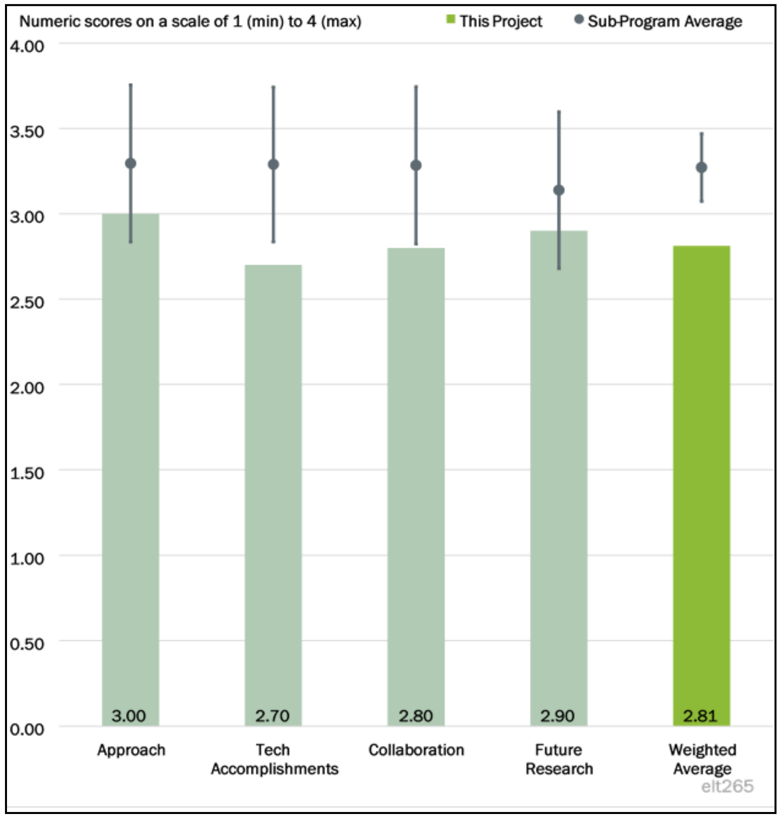


Figure 4-37 - Presentation Number: elt265 Presentation Title: A Secure and Resilient Interoperable SCM Control System Architecture for Electric Vehicle's-At-Scale Principal Investigator: Duncan Woodbury (Dream Team LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the approach as excellent thus far, but the project team is just getting started. The PI has put together a strong technical team.

Reviewer 2:

The reviewer said that the approach is appropriate and well defined with the challenges identified. More detailed information on potential risks would be beneficial. Open source will be valuable for integrating additional devices and overcoming proprietary solutions that can increase costs.

Reviewer 3:

The reviewer remarked that there are a lot of general statements, but no specifics. More details on the scale of the EV and EVSEs used on this project and input and output expectations are needed.

Reviewer 4:

The reviewer noted that there are a number of existing standards being worked on to develop communications protocols to enable interoperable charging systems. Instead of working within those existing activities, the approach used in this project seems to be to "develop an open-source, open standards-based utility Smart Charge Management system." No alternative approaches seem to have been considered (unless the approaches were reviewed at an earlier AMR).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project is on track and system requirements have been identified. The progress is appropriate given the timeframe for the award.

Reviewer 2:

The reviewer said that this project is in the preliminary stages so further reviews may provide more information on the accomplishments and progress.

Reviewer 3:

The reviewer indicated that the project is "good" here. The reviewer thought that the project itself may be "understated" as to how large of a project this is, and the details as outlined here are just "very broad." The reviewer emphatically noted the concern that there are issues now that need to be fixed with current EV charging and the grid, and there are issues in the future that need to be carefully planned and thought through, such as XFC.

Reviewer 4:

The reviewer observed very little progress to date and reported that the project start was October 2020 and planned completion is December 2024. The project is currently 17% over based on the calendar and 15% complete based on the AMR slides; so, this is close. However, the milestone chart shows only 1 task (row) complete, 4 in progress, and 14 planned. Based on the milestone chart, the project is only 6% complete, which is far short of 15%.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed that the project has good partnerships.

Reviewer 2:

The reviewer remarked that the project has a great technical team thus far, but now the project team has to explain it to more people.

Reviewer 3:

The reviewer commented that the partners are diverse and more needs to be identified regarding the roles and assignments of each and how they fit into the overall plan.

Reviewer 4:

The reviewer indicated that there are a number of existing standards being worked on to develop communications protocols to enable interoperable charging systems. The reviewer suggested that the existing standard organizations should have been brought into the discussion along with members of the industries that support EV 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The project is well planned with appropriate go/no-go decision points. The project could benefit from identifying risk mitigation strategies and more detailed milestones. The "demonstrate grid services capability" seemed somewhat vague to the reviewer.

Reviewer 2:

The reviewer remarked that the project team is just getting started, so most of the project is still in the future. Is the project team going to be able to fix the current EV charging and infrastructure? Is the project team going to be able to plan (well planned) so that future EV charging and infrastructure has "cyber" built in?

Reviewer 3:

The reviewer stated that clarity needs to be included as to the maturity selected for various protocols. For example, the protocol OCPP has several versions (1.6, 2.0, etc.), and the version selected has significant effects on how it is used in this project. The other protocols also have the same approach to updates. Interoperability will depend on matching specific functional capabilities when used in this project.

Reviewer 4:

The reviewer said that the project team seems to have a plan for additional work. One concern here is that one task is labeled "demonstrate cybersecurity use case"; cybersecurity should be considered for every aspect of the project and not confined to a single use case.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer emphasized that the project is super relevant. The reviewer asked if this team could get more money and technical resources to put this project on steroids.

Reviewer 2:

This is an important project as electrification increases and the grid also changes to include more clean energy options. According to the reviewer, matching these needs will continue to be a challenge as these changes are evaluated.

Reviewer 3:

The reviewer said that interfaces and integration with legacy utility equipment will be important for broader deployment and cost-effective approaches for SCM.

Reviewer 4:

This project does support DOE goals, but as the reviewer previously stated, it may not be the best approach.

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

Reviewer 1:

Resources are sufficient to start, but the reviewer emphatically stated that they are miniscule for getting at this large problem that is now and needed.

Reviewer 2:

The budget seemed appropriate for the project scope.

Reviewer 3:

The reviewer commented that the assignments need to be identified to point out their strengths and how they will best fit in obtaining expected results.

Reviewer 4:

Again, to succeed long term, this activity needs to connect with appropriate industry partners. Without these resources, it was very unclear to the reviewer how the output from this project will make the leap to successful deployment.

Presentation Number: elt266
Presentation Title: ANL High Power Charging Charge Profiles
Principal Investigator: Dan Dobrzynski (Argonne National Laboratory)

Presenter

Dan Dobrzynski, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

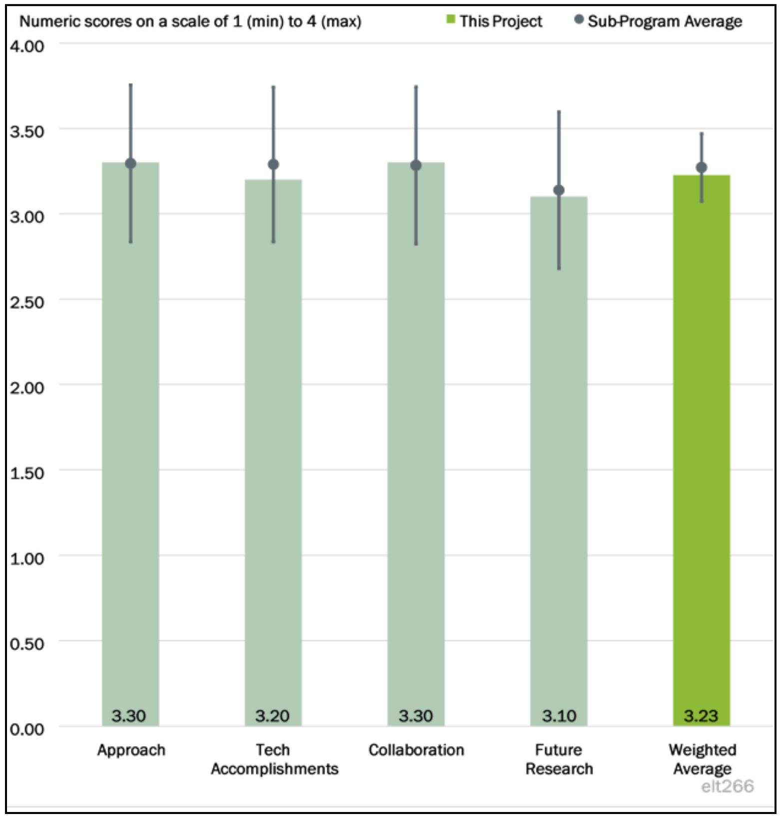


Figure 4-38 - Presentation Number: elt266 Presentation Title: ANL High Power Charging Charge Profiles Principal Investigator: Dan Dobrzynski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The research team has engaged a wide range of stakeholders and is leveraging established testbeds to obtain a range of profiles. The reviewer recommended that the team seek more engagement of standards-making bodies in the later stages of the project.

Reviewer 2:

Although it is a little early in the project to comment about this, the reviewer indicated that the approach appears to be sound.

Reviewer 3:

The overall approach to the project is adequately outlined; however, the mission statement needs focus. The reviewer indicated that "high" power should be accurately defined as above 350 kW, since SAE J1772 and CCS connectors are rated up to 350 kW for DC L 2 charging, whereas the Ll 3, or extreme fast charging, and others are above 350 kW. Inadequately defining "high" in quantifiable terms perpetuates marketing nomenclature that is confusing the industry, where it is common to find a range of interpretations of "high." This project could feed value-added information into SAE and International Electrotechnical Commission (IEC) standards development and help clarify definitions, but at a minimum, terminology should not be in conflict with those standards.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that, in this first year, the team has been successful in establishing sound test plans and forging partnerships that will be essential over the course of the project.

Reviewer 2:

The reviewer remarked that the project had not been reviewed previously and started in FY 2021. Progress mid-first year is difficult to assess as the project presented few measurable, auditable deliverables, only discussion of draft work, and initial contractual or legal arrangements in process with unnamed OEM collaborators, named fleet operators, named EVSE manufacturers, named utilities, and DOE lab participants. The project spend-to-date was not included in the presentation, only the annual allocation levels.

Reviewer 3:

This reviewer stated that there are not many light-duty (LD) vehicles that have 200 kW+ charging capability. Even the ones that claim to have that capability perhaps do not charge at that rate for too long, because the currently available production batteries may not handle high rates of charging very well. Given that, the reviewer found it likely that the charging profiles obtained in the current crop of LD vehicles are not necessarily going to remain the same in the future. It may be necessary to rely more on MD/HD vehicles obtain representative charging profiles.

Another consideration suggested by this reviewer is that as the grid gets upgrades to handle the EV charging load, it is likely that the charging profiles may also change as the grid capability goes up. However, including EVSE OEMs and utility companies among the collaborators will account for some of the above-mentioned variables.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

As the PI indicates, some of the collaboration agreements are still in process. According to the reviewer, it is essential to finalize these as soon as possible. If one or more partners cannot agree to terms, the team will need to redesign their test plan accordingly.

Reviewer 2:

This reviewer referenced prior comments and stated that including EVSE OEMs and utility companies brings in a expertise that is essential for this project. It could also benefit from the involvement of battery OEMs at the same time.

Reviewer 3:

The reviewer stated that the planned project DOE lab participants are inclusive of the correct centers of expertise. The goal for industry participation is good; however, no detail was presented on who the EV OEMs were, what their product vehicle types were, and when or if they would have production products in place in a time frame and at specification levels consistent with the project. There was no mention of participation of industry groups, such as SAE or CharIN. This is troubling since the intent is to emulate production installations and operations. A gap analysis of project needs versus industry availability was not presented with respect to vehicles, chargers, or standards. If individual lab engagements with industry groups are being relied on, then that should be stated, and the specific industry groups clarified.

Reviewer 4:

Not applicable 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that the research team has a sound plan for rolling out its testing. The project team has identified some of the challenges and has plans in place to mitigate any issues.

Reviewer 2:

The project has just started and the while the choices made so far appear reasonable, the reviewer noted that course corrections may be needed depending on how many and which partners come on board.

Reviewer 3:

The reviewer stated that the majority of this project is future work as of mid-first year of project. The technical approach appears appropriate in light of the fact that industry has not yet put much of this into production yet, so both the technology and standards are in a state of development with limited field history. Rapid changes may be required to the project once real-world systems are in use in the field for charging above 350 kW levels. The emulation of OEM donor vehicles was stated as being needed because the vehicles may not be designed to handle the higher-level charging conditions required for the project. This highlights where the modeling may differ from the real world and may devalue the project effort. Similarly, considering only single vehicle charging may not accurately model real-world installations where multiple vehicles may be on the same circuit.

Reviewer 4:

Not applicable was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that, yes, the project supports the overall DOE objectives.

Reviewer 2:

The reviewer stated that to facilitate high-power charging projects, DOE needs to have good data on actual high-power charging equipment. This project will provide essential data for a wide range of researchers.

Reviewer 3:

The reviewer commented that the project supports DOE and administration objectives to help quantify operational details and requirements for faster charging at higher power levels to facilitate adoption of zero-emission vehicles. The details of operations are currently in industry development with few if any production trucks or cars or installed chargers above 350 kW in use, so to some extent, the project is tied to a moving target. Decisions on relevance may change if the market shifts directions on technologies or power levels. The research can be value added for industry groups developing standards, such as SAE, IEEE, and others like CharIN.

Reviewer 4:

This reviewer explained that understanding charging profiles helps understand grid impact, impact on battery life, charging efficiency, etc., all of which influence the overall energy consumption and adoption of EVs.

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

Reviewer 1:

At this point, the resources appeared sufficient to this reviewer.

Reviewer 2:

This reviewer saw no issues with the resource allocation. Obtaining field data is always expensive; the research team has adequately balanced time and efforts with partner commitments.

Reviewer 3:

The reviewer stated that the project did not present spend-to-date information. That is critical to determine if first-year efforts have been adequate. Any delays in inking non-disclosure agreements or contractual arrangements with participants might have highlighted inadequate resources applied to those efforts. The overall planned program spend for 3 years appears adequate, but the spending profile being flat over the 3 years may show that the project has not been adequately planned around costing, since procurement of materials, facilities, and personnel typically vary over the course of this type of project as it moves from planning to execution. The lack of firm commitments on test articles and the reliance on emulated vehicles and potentially donated or borrowed real vehicles and other equipment have some risk with respect to budgeting.

Reviewer 4:

Not applicable was indicated by this reviewer.

Presentation Number: elt267
Presentation Title: ORNL Resilient High Power Charging Facility
Principal Investigator: Madhu Chinthavali (Oak Ridge National Laboratory)

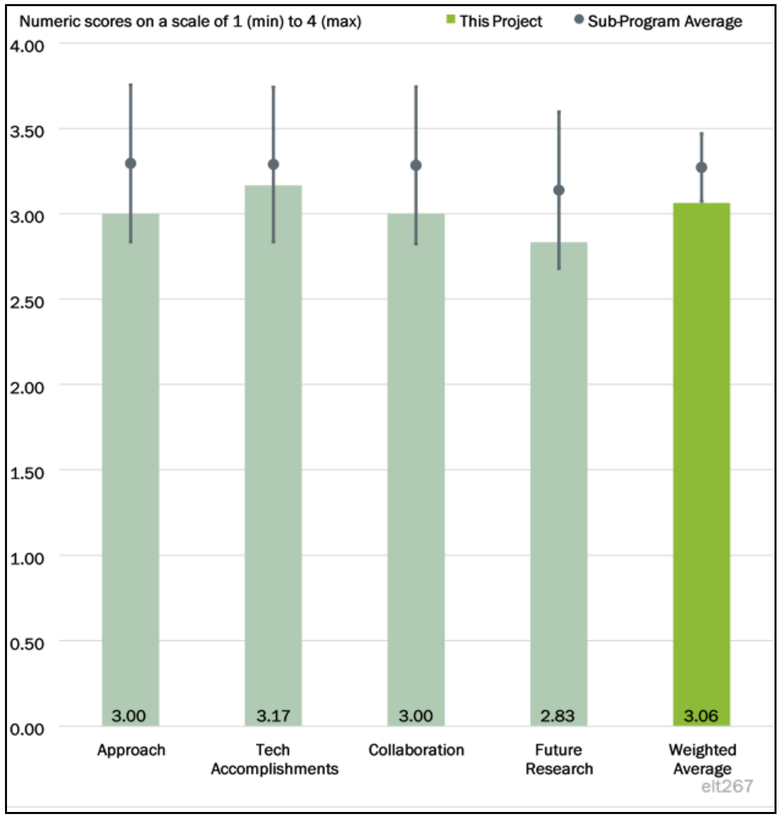


Figure 4-39 - Presentation Number: elt267 Presentation Title: ORNL Resilient High Power Charging Facility Principal Investigator: Madhu Chinthavali (Oak Ridge National Laboratory)

Presenter

Madhu Chinthavali, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the division of effort is clear, and the roles expected to contribute to a successful project are included. The timeline shows a natural progression of steps required to meet the goals of the project.

Reviewer 2:

The reviewer observed that this project is intending to model real-world production systems that are not yet in production and not yet governed by published standards. Trying to model systems that are themselves still in flux puts the benefit of the project somewhat at risk since decisions made may not reflect real-world systems once they enter production. There is value in attempting to independently model these evolving systems and developing a framework for common discussion that may help influence those developing systems. This begs the question if this open-source deliverable is what industry would use. Some level of gap analysis is needed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the organization and assignment of tasks are representative of accurate site conditions and should lead to positive results. Resiliency for charging stations is a critical factor to promote electrification, and planning for issues using multiple sources is a reasonable means to insure this.

Reviewer 2:

The reviewer noted that the project had not been reviewed previously and started in FY 2021. Progress mid-first year is difficult to assess as the project presented few measurable, auditable deliverables. Development of nine use cases was presented, and the overall program has been planned. The project reported that a goal is to deliver an open-source software architecture for managing XFC, but there was not an indication that industry is in need of this or will accept an open-source solution in place of proprietary systems.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that the mix of labs, a university, and an EVSE manufacturer matches the capabilities of the project. The tasks also match the capabilities to meet the expectations of the project.

Reviewer 2:

The reviewer stated that the planned project DOE lab participants include the appropriate centers of expertise. The industry involvement includes a major systems company in ABB, but it would help if industry groups were engaged because the project is attempting to model systems that are still evolving, have not yet been put into production, and have limited field experience. If individual lab engagements with industry groups is being relied on, then that should be stated, and the specific industry groups clarified.

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 state project ended.

Reviewer 1:

The reviewer commented that the majority of this project is future work as of mid-first year of project. The technical approach appears appropriate in light of the fact that industry has not yet put much of this into production yet, so both the technology and standards are in a state of development with limited field history. Rapid changes may be required to the project once real-world systems are in use. Interim go/no-go decision gates should include a review of the project with respect to the state of the industry at those times to validate that the project is still representing production intent.

Reviewer 2:

The reviewer remarked that the distance of the photovoltaics (PV) and energy storage (ES) to the dispensers may be appropriate for some installations and using AC energy between these is a good start. If these could be closer, an alternate approach of DC/DC inverters (PV or ES) to the dispensers] could be used in future projects so the conversion efficiency losses could be reduced. Converting from DC to AC at the PV and ES sources, then AC to DC at the dispensers is less efficient and should not be the only approach.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the goal this project is to establish controls and support to vehicle charging during grid interruptions. These interruptions occur due to climate conditions or planned outages, and vehicle charging needs to be maintained. EVs may need to charge to power homes and other needs, other than for transportation, and this available source needs to be available at sites during these events.

Reviewer 2:

The reviewer said that the project supports DOE and administration objectives to help quantify operational details and requirements for faster charging at higher power levels to facilitate adoption of zero-emission vehicles. The details of operations are currently in industry development with few if any production trucks or cars, or installed chargers, so to some extent, the project is tied to a moving target. Decisions on relevance may change if the market shifts directions on technologies or power levels. The research can be value added for industry groups developing standards, such as SAE, IEEE, and others like CharIN.

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 the project lead and partners are well versed in the requirements and have the capabilities to led to successful results.

Reviewer 2:

The reviewer indicated that the project did not present a spending profile by year but did present a BP 1 estimate of $650,000. A spending profile plan for the course of the project is needed to assess adequacy of resources. Funding was not identified as a challenge by the project presenter, and the bulk of spending will be in BP 2 and 3. Some contingency should be evaluated for keeping the systems up to date with industry changes over this period, as changes may occur from field feedback on introduced systems, and development of new standards.

Presentation Number: elt274
Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management
Principal Investigator: David Coats (ABB)

Presenter

David Coats, ABB

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

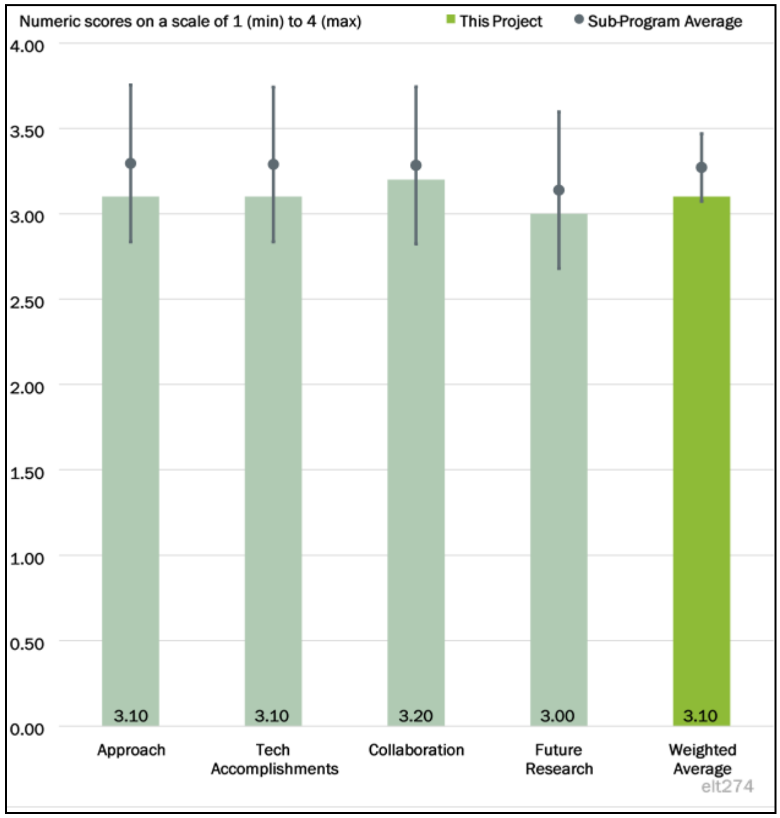


Figure 4-40 - Presentation Number: elt274 Presentation Title: eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management Principal Investigator: David Coats (ABB)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the approach to this project is very good and should address the technical barriers for the project.

Reviewer 2:

The reviewer found that the project plan is detailed and well planned to include important tasks and milestones for each partner.

Reviewer 3:

The reviewer believed that the approach is clear and reasonable. The reviewer strongly urged moving the cybersecurity design review from BP 3–4 to BP 1–2 since it is only a design review. The cybersecurity design review should be accomplished earlier in the program because if there is a poor cyber design, then that will either take much more time and/or resources to fix later in the project or will be ignored. There are many examples of the results of systems for which the cyber design or implementation was poor—and that is not the direction nor result the reviewer suspected is the goal here. This change should not significantly impact approach or schedule.

The next question is not something the reviewer would have expected to see in the slides (too detailed)—how does the project team account for modeling of energy gathering needs and charging assets needs? Specifically, what kinds of communications (and the security thereof) would be planned for a dynamic system, and how would the project team account for weather affects, if any?

The system functionality test task is clearly important (and it is too early for the project team to give much detail), but the reviewer was looking forward to hearing a lot more about this and about the local versus cloud components of that task next year.

Reviewer 4:

The reviewer stated that the slides presented at the AMR give very little insight into the goals or approach for the project, simply giving three, very high-level but nebulous objectives (develop eMosaic platform, field test, and then demonstrate "a reference EV charging aggregation and control" [system?]). The reviewer asked if eMosaic is a reference to this company's software.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project has accomplished important tasks that will move the project forward and keep the effort on schedule. The project has begun working with a utility to identify sites this helps for mitigating and avoiding delays—and the project has also identified data for use in models.

Reviewer 2:

The reviewer indicated that the project team has made good progress toward meeting its milestone objectives.

Reviewer 3:

The reviewer stated that this is the first year of the program, so many of the accomplishments will happen in the future—and the reviewer does like the plan of action as described.

Forecasting and grid service algorithm development are essential to success. The reviewer was looking forward to details on these subjects next year as there were not enough details on them in this first presentation to ascertain progress on them though.

The reviewer remarked that the Caldera milestone is due in September but did not see mention of progress on that (much may have been accomplished, but there would be benefit in capturing that—even if just as a percentage-complete graphic—to show progress against in-year milestone goals).

Are load predictions exclusively historically based, or are there dynamic needs-driven data being considered in projections? If the latter, then the reviewer did not see that represented on Slide 10. It seems a dynamic, needs-driven component would be valuable.

Reviewer 4:

The reviewer reported that the project start was October 2020 and planned completion is December 2024. The project is currently 17% over based on the calendar but only 10% complete based on the AMR slides. The Milestone chart shows the Milestone 1 planned completion as June 30, 2021 (9 months in and no major accomplishments), but the Technical Accomplishments slides provide a more complete picture of the work thus far. The reviewer based the rating on the Accomplishments slides.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that the project has a fantastic project team with all important stakeholders identified and involved.

Reviewer 2:

This is early in the project and, from the schedule in the slides, it is clear that ABB is performing most of the BP 1 work. There is an indication of using each teammate at least a little bit, and there is clear evidence that INL and USU (and therefore Rocky Mountain Power [RMP]) are engaged in the design and initial research and modeling input phases., The reviewer indicated that this is a strong team approach, which seems better than most in being highly inclusive in the project's first year.

Reviewer 3:

The reviewer stated that the project shows good collaboration between existing partners.

Reviewer 4:

The reviewer suggested that the project would benefit from additional companies being involved, such as more EVSE manufactures, a charge point operatory, and more electric utility input. They will help with the goal of obtaining industry-wide acceptance of the project results. It would also help with several of the bullet points listed on the "Remaining Challenges and Barriers" slide.

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 state project ended.

Reviewer 1:

The reviewer stated that the project tasks and milestones for future work are identified. Challenges and barriers are identified and being addressed.

Reviewer 2:

Although proposed future work is reasonable, the reviewer observed that cybersecurity and model validation/verification are not present in the proposed future work. The reviewer referenced prior comments about where to consider placing this as a priority and schedule item. The reviewer was also concerned that cybersecurity and model validation/verification are not identified for future work either. Insecure systems will increasingly be disadvantaged and have lower likelihood of long service lifespans as there is movement into the soft-war cyber age. The reviewer urged moving this forward and enshrining it in the project team's future work plans.

Reviewer 3:

It seemed to the reviewer that there is some lack of process details for doing real-world validation studies. These will be critical to ensure the tools are sufficiently robust to be commercialized.

Reviewer 4:

The reviewer stated that the AMR slides list the major tasks for the next year-and-a-half of the project. The AMR slides do not show plans that run to December 2024, which is listed as the project end date.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that this kind of activity clearly supports the direction that DOE is demonstrably intent upon, and which also clearly supports societal and industry intent and prioritization of moving from fossil fuels to electrification across the energy consumption sectors. This project does exactly that and seeks to improve availability of energy product at point of demand and helps forecast needs.

Reviewer 2:

The reviewer noted that the project will be instrumental in advancing grid services for transit and buses. These vehicles have the most potential for offering benefits and to help offset peak load. The project is looking at aggregation and what can be better handled locally versus what is more beneficial or can be handled through aggregation. This is important information and research to further potential for grid services.

Reviewer 3:

The reviewer stated that the project helps to address DOE objectives around adoption of low carbon transportation technologies.

Reviewer 4:

The reviewer found it very hard to evaluate this question since the goals and approach of the project are not clear from the presentation or the AMR slides.

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 seem to be in line with the work and effort being performed.

Reviewer 2:

Resources looked fine to the reviewer.

Reviewer 3:

The reviewer stated that the resources are sufficient to meet objectives of this project.

Reviewer 4:

The reviewer noted no resource issues.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three-dimensional
AC	Alternating current
ACM	American Center for Mobility
AMP	Assured Micropatching Program
AMR	Annual Merit Review
B	Boron
BEV	Battery electric vehicle
BG&E	Baltimore Gas & Electric
BP	Budget Period
C	Charge rate
CCS1	Combined Charging System
CEC	California Energy Commission
CNG	Compressed natural gas
CO_2	Carbon dioxide
COVID-19	Coronavirus disease 2019
CPUC	California Public Utilities Commission
CSRL	Cybersecurity Research Laboratory
DARPA	Defense Advanced Projects Research Agency
DC	Direct current
DER	Distributed energy resources
DHS	U.S. Department of Homeland Security
DNN	Deep neural network
DOE	US. Department of Energy
DOT	U.S. Department of Transportation
DTNA	Daimler Trucks North America
Dy	Dysprosium
EDT	Electric Drive Technology(ies)
EERE	Office of Energy Efficiency and Renewable Energy
EETT	Electrical and Electronics Technical Team
EMI	Electromagnetic interference

EPRI	Electric Power Research Institute
ES	Energy storage
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FCA	Fiat Chrysler Automobiles
Fe	Iron
Fe_4N	Iron nitride
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Year
GaN	Gallium nitride
Georgia Tech	Georgia Institute of Technology
GHG	Greenhouse gas
GM	General Motors
HCE	High-consequence events
HD	Heavy-duty
HIL	Hardware-in-the-loop
HRE	Heavy rare earth
ICE	Internal combustion engine
IDS	Intrusion detection system
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IIT	Illinois Institute of Technology
INL	Idaho National Laboratory
ISO	International Organization for Standardization
JRC	Joint Research Center
kV	Kilovolt
kW	Kilowatt
L	Level
LCC	Inductor-capacitor-capacitor
MD	Medium-duty
Missouri S&T	Missouri University of Science and Technology
MOSFET	Metal-oxide semiconductor field-effect transistor

mph	Miles per hour
MV	Medium-voltage
MVA	Megavolt-ampere
MW	Megawatt
NCSU	North Carolina State University
Nd	Neodymium
NIST	National Institute of Standards and Technology
Nm	Newton-meter
NMFTA	National Motor Freight Traffic Association
NREL	National Renewable Energy Laboratory
NVH	Noise, vibration, and harshness
NYPA	New York Port Authority
OCPP	Open charge point protocol
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PCB	Printed circuit board
PE	Power engineering
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid vehicle
PI	Principal Investigator
PII	Personally identifiable information
PKI	Public key infrastructure
PNNL	Pacific Northwest National Laboratory
PTO	Power take-off
PV	Photovoltaic
PZLT	Piezoelectric
Q&A	Question and answer
R&D	Research and development
RDD&D	Research, development, demonstration, and deployment
RE	Rare earth
ReFUEL	Renewable Fuels and Lubricants Laboratory
RE-PM	Rare-earth permanent magnet

RESS	Rechargeable energy storage system
RFP	Request for proposal
RMP	Rocky Mountain Power
RNN	Recurrent neural networks
ROI	Return on investment
rpm	Revolutions per minute
RTO	Recovery time objective
SAE	Society of Automotive Engineers
SCE	Southern California Edison
SCM	Smart charge management
SiC	Silicon carbide
SIS	Safety instrumented system
SMC	Soft-magnet composite
S-NIC	Secure network interface card
SNL	Sandia National Laboratories
SOC	State of charge
SpEC	Smartgrid EV Communication
SPIN	Smart Power Integrated Node
SST	Solid-state transformer
SUNY	State University of New York
TCO	Total cost of ownership
TOU	Time of use
TTSI	Total Transportation Services Inc.
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UPS	United Parcel Service
USCAR	United States Council for Automotive Research
USD	Unified School District
USU	Utah State University
V2G	Vehicle-to-grid
VGI	Vehicle-grid integration
Virginia Tech	Virginia Polytechnic Institute and State University

VTO	Vehicle Technologies Office
WBG	Wide bandgap
XFC	eXtreme fast charging
XSS	Cross-site scripting

5. Fuel Technologies

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Fuel Technologies (FT) subprogram supports research and development (R&D) necessary for industry to develop efficient engines that can utilize renewable fuels, such as advanced biofuels, hydrogen, and e-fuels, to reduce GHG emissions and achieve a net-zero economy by 2050, all while creating good paying jobs with the free and fair chance to join a union and bargain collectively. Internal combustion engines will continue to be an important power source for medium- and heavy-duty onroad trucks and off-road vehicles including construction, agriculture and forestry, and rail and marine, during the next several decades. Increasing their efficiency and reducing GHG and criteria emissions will ensure that the clean energy economy benefits all Americans. Optimization of high efficiency engines and emission control systems, integration of hybrid powertrains, and utilization of renewable fuels has the potential to improve heavy-duty engine efficiency.

The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of fuels and emission control catalysts.

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
ft098	Propane Engine with Controlled Endgas Autoignition	Daniel Olsen (Colorado State University)	5-3	3.50	3.50	3.33	3.17	**3.44**
ft099	Propane Long-Stroke Engine	Derek Splitter (ORNL)	5-6	3.25	3.25	3.25	3.38	**3.27**
ft100	Co-Optima: Hyundai Multimode Engine	Phillip Zoldak & Shengron Zhu (Hyundai)	5-10	3.38	3.25	3.38	3.25	**3.30**
Overall Average				**3.36**	**3.32**	**3.32**	**3.27**	**3.32**

Presentation Number: ft098
Presentation Title: Propane Engine with Controlled Endgas Autoignition
Principal Investigator: Daniel Olsen (Colorado State University)

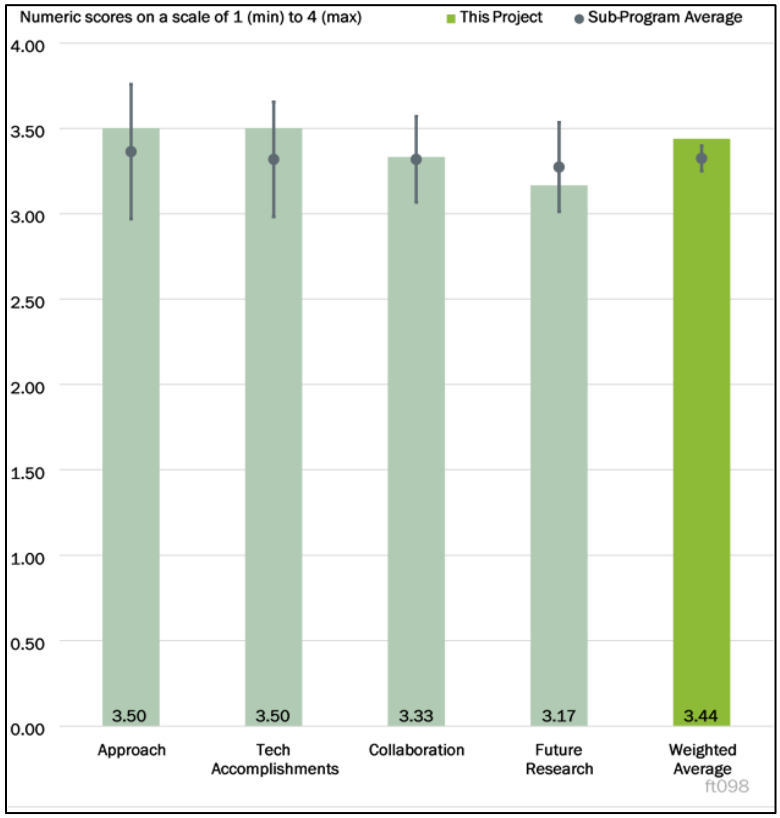


Figure 5-1 - Presentation Number: ft098 Presentation Title: Propane Engine with Controlled Endgas Autoignition Principal Investigator: Daniel Olsen (Colorado State University)

Presenter

Daniel Olsen, Colorado State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated it is a well-designed project to improve liquefied petroleum gas (LPG) engine efficiency by developing a reduced kinetic mechanism for computational fluid dynamics (CFD) modeling, fuel spray visualization and modeling, and experimental investigation using a single-cylinder engine (SCE).

Reviewer 2:

The reviewer commented that a thoughtful approach was planned, including rapid compression machines (RCMs) experiments, kinetic mechanism development, fuel spray characterization, spray model development, CFD, and engine experimentation (Cooperative Fuel Research [CFR] and Cummins X15 engines). The activities to address the barrier of advanced "real-time" combustion control near the knock limit needs further detailed planning.

Reviewer 3:

The reviewer said a combination of RCM experiments, CFD modeling, and SCE experiments are a great strategy to proceed with developing a high-efficiency propane engine. The evaluation of the efficacy of the chemical kinetic mechanism is crucial, which is being pursued by the team. The reviewer said modifications to the injector and the fuel pump are critical for operating with a low-lubricity LPG direct-injection (DI) system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said for a less than 1-year project, technical accomplishments are in line with the schedule. The chemistry mechanism work and CFR engine work in the short period of time are impressive. In addition, the reviewer said setting the spray chamber also seems to be very impressive.

Reviewer 2:

The reviewer stated that the Principal Investigators (PIs) made good progress. The PIs accomplished about 18% of this 3-year project, which started October 2020, and includes RCM testing to support developing the reduced chemical kinetics; LPG DI test rig design; hardware integration; and initial simulation for high-pressure LPG injection.

Reviewer 3:

The reviewer commented the technical accomplishments are substantial, being only 8 months into the project. These accomplishments include chemical kinetic model development and high-performance scientific computing (HPSC) setup, and experimental results linked with CONVERGE CFD results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented collaboration is well planned with clear tasks for each participating partner. All three partners have provided valuable contributions to the project's Phase 1, including chemical kinetic model and RCM testing by Colorado State University, CFD spray results by Argonne National Laboratory (ANL), and hardware design for engine integration by Cummins.

Reviewer 2:

The reviewer observed great collaboration among team members. Team composition is really good as each team member—be it university, national laboratory, or small and large business—bring in their unique expertise.

Reviewer 3:

The reviewer said the project is still at an early stage. Overall, there is a good plan to collaborate across the project 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the PI listed the major tasks for each budget period but did not provide details.

Reviewer 2:

The reviewer commented the planned activities are logical next steps. A successful integration of LPG fuel injection with a new cylinder head with DI will be critical.

Reviewer 3:

The reviewer said much of it depends on the functionality and durability of the DI fuel injection system. Work performed by Czero is hence critical in the success of this project. The reviewer said it will be nice to have a plan B if the intended plan fails, which this reviewer has seen with several LPG DI systems. The reviewer said other candidate high-pressure pumps and injectors need to be selected in case the ones selected do not function as planned.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated this work is relevant to the Department of Energy (DOE) objectives to improve understanding and ability to manipulate combustion processes and generating the knowledge and insight necessary for industry to develop the next generation of engines.

Reviewer 2:

The reviewer commented that, yes, this project directly supports DOE's overall mission to "ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions."

Reviewer 3:

The reviewer said LPG DI is something the LPG industry has been interested in for a while, but it is risky for the industry to venture; therefore, DOE funding is required to enable this service. This project aligns well with what the industry is looking for.

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 sufficient resources are planned. Cummins involvement is a great asset for proper engine design and integration to accomplish project objectives.

Reviewer 2:

Overall, the reviewer noted the team has resources to conduct the relevant research—RCM, HPSC, engine, modeling tools.

Reviewer 3:

Project resources were deemed sufficient by this reviewer.

Presentation Number: ft099
Presentation Title: Propane Long-Stroke Engine
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

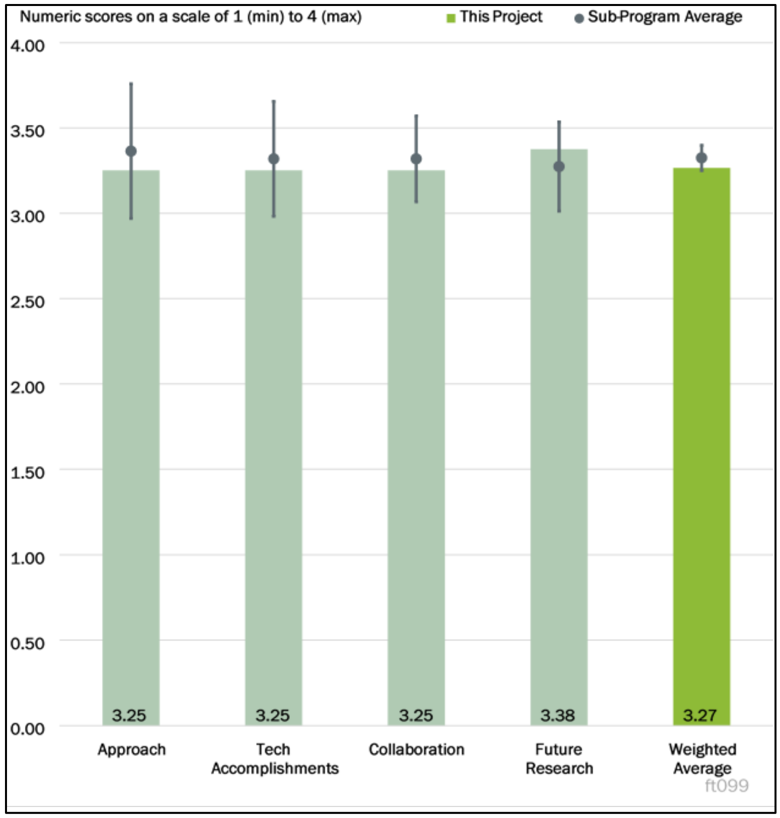


Figure 5-2 - Presentation Number: ft099 Presentation Title: Propane Long-Stroke Engine Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a comprehensive and well-designed project involving fundamental and applied CFD modeling, experiments, and system-level analysis, along with total cost of ownership (TCO) and life-cycle assessment (LCA) analysis.

Reviewer 2:

The reviewer stated that DI, exhaust gas recirculation (EGR)-diluted LPG engines do not exist; hence, learning that LPG is more tolerant to EGR is really useful. Using Katech’s DI (and ethanol) experience is critical to delivering a DI solution. The reviewer noted that it is interesting to see how the G-equation model performs for propane under dilute conditions.

Reviewer 3:

The reviewer said the planned approach including fundamental chemical kinetics, CFD, engine design and experimentation, one-dimensional (1-D) system simulation, and LCA analysis is excellent. This approach will lead to a proper understanding of assessing the potential of using propane for medium-duty (MD) engines. The reviewer said the proposed approach will enhance propane engine efficiency and provides contributions toward increasing the engine brake thermal efficiency (BTE) for MD engines. These are important barriers, and the proposed approach is well designed to address them.

The reviewer remarked it could have been even better if the aftertreatment system was also studied along with the existing integrated approach, perhaps via collaboration with other teams if possible.

Reviewer 4:

The reviewer stated it is unclear if the stroke length selected is compatible with engine packaging constraints in the target vehicle. Also, it is not clear how much of this project differs from recent Cummins development programs on their small displacement engine. Although the research is all interesting, it is largely straightforward work given the existing understanding of propane engines.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the PIs made good progress, accomplished about 15% of this 39-month project, which started in October 2020. The PIs performed initial experiments to identify key aspects of engine performance; initial three-dimensional (3-D) CFD using Reynolds-averaged Navier-Stokes (RANS) turbulence and G-equation models; flame simulations; and a literature review of propane mechanisms.

Reviewer 2:

The reviewer said the work progress to date seems fine.

Reviewer 3:

Although the project is at the early stage, the reviewer noted that the team has made very good accomplishments, despite coronavirus disease 2019 (COVID-19) challenges. In particular, the new findings for the chemical response of LPG and study from the literature for chemical mechanisms and effects of fuel types are very helpful. The project is on track building upon prior studies and new simulations. Progress toward measurable metrics for accomplishments will become clearer in the next phases of the project. Referencing the goal of increasing efficiency with no cost premium, the reviewer indicated that aftertreatment system cost needs to be considered because the project mainly focuses on the engine side. For instance, whether the cost of propane oxidation catalyst will increase in the proposed engine (e.g., Generation [Gen] 2) if the same engine covers all engine speed and load conditions and also includes varying thermal conditions.

Reviewer 4:

The reviewer commented that limited progress was achieved since this project was contracted in November 2020. Much of the work presented was from the Gen1 engine.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although the team is well structured, it was unclear to this reviewer how much of the work is currently shared across the partners.

Reviewer 2:

The reviewer commented the project is still at an early stage. Overall, the team developed a good plan to collaborate across the project team.

Reviewer 3:

The reviewer said there was good collaboration among the partners—a national laboratory (Oak Ridge National Laboratory [ORNL]), Oakland University, Katech, University of Wisconsin, Wisconsin Engine Research Consultants [WERC], and Stellantis—although the role of Stellantis in LPG is unclear apart from donating an engine. Katech's participation can help with General Motors (GM) engine conversions to LPG.

Reviewer 4:

The reviewer commented the project is well coordinated among the two universities, a national lab, an engine design company, and engine research consultants. Tasks are well divided among different team members, and each participant provides meaningful contributions to the project. The reviewer commented no major issue was observed. The project might benefit from collaborating with the project FT098 to utilize their RCM results for chemical kinetic models that are developed in that 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said the project plans look good for future work.

Reviewer 2:

The reviewer described future research as well planned.

Reviewer 3:

The reviewer stated planned activities are logical next steps. An on-time Gen 2 prototype engine build will be critical.

Reviewer 4:

The reviewer said the role of direct numerical simulation (DNS) is critical to understanding the fundamental reasons for EGR tolerance. Chemistry mechanism improvements and CFD modeling work are also critical as there is a lack of information on LPG. The reviewer indicated that developing the Gen 2 engine with a belt-driven pump will be interesting to the LPG industry as a potential commercial solution.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated the project support aligned with the current objectives.

Reviewer 2:

The reviewer commented the work is relevant to the DOE objectives to develop and demonstrate an LPG-specific, spark-ignition MD engine that achieves diesel engine efficiency parity and shows pathways for dramatic engine efficiency increases.

Reviewer 3:

The reviewer stated that yes, the project directly supports DOE’s overall mission to “ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solutions.”

Reviewer 4:

The reviewer indicated that LPG DI engine development with or without EGR is something with which the LPG industry needs help. Hence, public-private partnerships, such as DOE funding is critical in accomplishing 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, overall, the team has resources to conduct the relevant research—engine and modeling tools.

Reviewer 2:

The reviewer indicated that planned resources are sufficient to meet the project objectives.

Reviewer 3:

The reviewer described the resources as fine.

Reviewer 4:

The reviewer asserted that more funding could be provided for multi-cylinder engine testing as the work will not be picked up by the LPG industry after SCE experiments. The total budget of $1.55 million seems less for this work as this project has tremendous potential for commercialization but needs additional funding from DOE to accomplish it.

Presentation Number: ft100
Presentation Title: Co-Optima: Hyundai Multimode Engine
Principal Investigator: Phillip Zoldak & Shengrong Zhu (Hyundai)

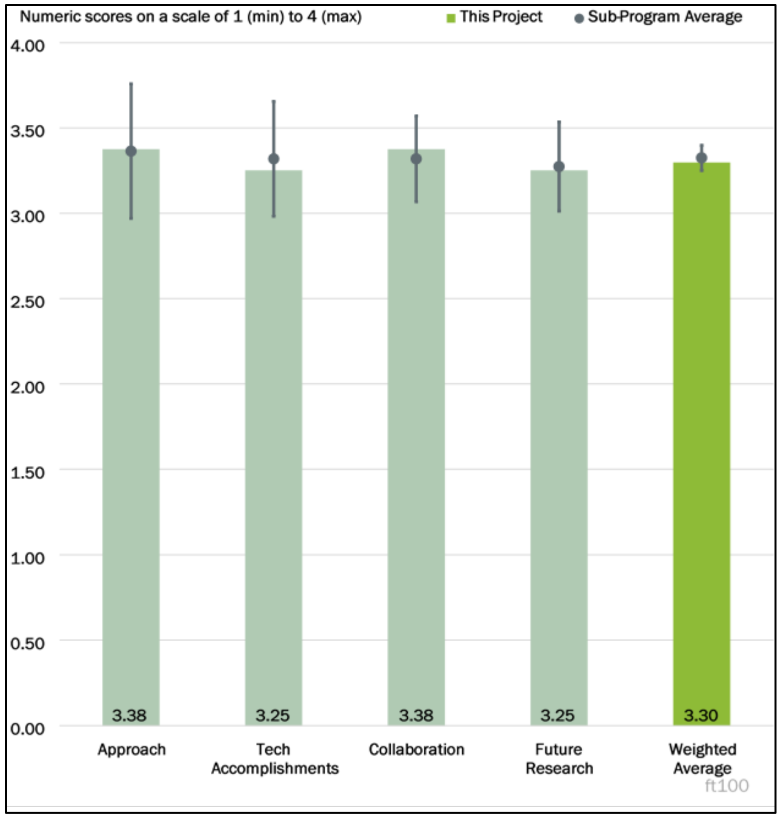


Figure 5-3 - Presentation Number: ft100 Presentation Title: Co-Optima: Hyundai Multimode Engine Principal Investigator: Phillip Zoldak & Shengrong Zhu (Hyundai)

Presenter

Phillip Zoldak & Shengrong Zhu, Hyundai

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that combustion mode switching will be very difficult and there is not a clear path to solve the problems, but the researchers are designing the system with production in mind. The project has a good handle on the levers it can use to solve the mode-switching barriers.

Reviewer 2:

The reviewer stated the work covers a fair amount of ground pertaining to gasoline compression ignition (GCI) and low-temperature combustion (LTC) engine performance and operating parameters. However, there was not much here that was truly novel. The reviewer stated most of the work that was done in this presentation was done in other places by Aramco, Delphi, or Argonne. For example, it is unclear why ethylhexyl nitrate (EHN) was explored for ignition enhancement; it is known to have a significant effect on ignition, but it is also known to have a detrimental effect on oxides of nitrogen (NO_x) emissions and EHN is inherently unstable if stored for too long.

Reviewer 3:

The reviewer observed an outstanding approach to the work, particularly identifying the various challenges that must be addressed. In the long term, a minor criticism is the Federal Test Procedure-75 (FTP-75) cycle may not result in use of the complete engine map and thus not show the complete spectrum of challenges the engine will encounter. The reviewer said a more aggressive cycle, such as the US06 or a Real Driving

Emissions (RDE) cycle, would ensure the complete engine map is encountered and thus "exercised" the engine more fully.

Reviewer 4:

The reviewer emphasized that it is terrific to see such a dedicated industry partner/collaborator at work in Co-Optima. Industry partnership always helps focus on practical application issues and that is certainly the case here. The reviewer commented the work appears to be well planned and executed to date; however, there are some inconsistencies in the presentation that must be resolved in the remaining stages of work before the project closeout. There is an indication that spark-assisted LTC (SA-LTC) will be employed to improve lightload performance and mode switching. The reviewer remarked, however, that Slide 7 shows no effect of spark assist. Similarly, one of the challenges recognized early on is that high load burn rate is too slow, but one of the issues in operation is that pressure rise rate is too high. It was not quite clear to the reviewer how these somewhat competing technical issues will lead to a fuel specification that is adequate across the entire operating range and how the currently identified "ideal" fuel specifications, including isobutanol, will play out at high load. Continuously variable valve duration (CVVD) and continuously variable valve technology (CVVT) certainly will be beneficial in all this, which the reviewer described as definitely a clever and valuable machine innovation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that accomplishments included extending the load limit, incorporating cylinder pressure feedback control, and investigating fuel reactivity, fuel injection pressure, and combustion bowl effects—all of which are major accomplishments.

Reviewer 2:

The reviewer commented progress of the work was reasonably good as- there are certainly plenty of results and tests that were accomplished. However, it does not genuinely appear the work has gotten pushed any closer to a production-ready technology as was hoped at the beginning of the project. The reviewer had the distinct impression that all this interesting work will be done, and the project will simply sit on a shelf without moving forward because little attention was paid toward the commercialization aspect.

Reviewer 3:

Overall, the achievements are very good as noted by this reviewer. The reviewer emphasized that the walkup on Slide 15—in which progressively better FTP-75 fuel economy is shown through various technology and fuel changes—was highly misleading. Based on the presenter's responses to reviewer questions, while all configurations could drive the FTP-75 cycle, they would all have different performance (e.g., 0–60 miles per hour [mph] times, grade capability, etc.). Thus, it is very misleading to show these data on such a plot as they can grossly misconstrue the source of the benefits that are obtained. For example, the reviewer explained that downsizing any engine and significantly degrading its performance would likely result in an efficiency improvement, irrespective of anything about the GCI technology that is the focus of this effort. Likewise, hybridizing any engine will result in an efficiency improvement.

Reviewer 4:

The reviewer stated good progress was made to date, as indicated by the results summary across engine operation, combustion chamber design, combustion visualization, and fuel specifications. However, much of the focus has been on light load operation, so it is too soon to tell if high load and low load performance requirements can be reconciled in a single, effective fuel blend. The reviewer stated it might have been better in retrospect to at least have a bit more balance in the engine mapping with engine GCI_01. Some of the final objectives might be ambitious given the time remaining.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated the project team is very well coordinated and, furthermore, this project is an excellent example of collaboration between multiple industries, academia, and (at limited scope) national laboratories.

Reviewer 2:

The reviewer said the extensive list of team members, obvious fuel blending support, and combustion visualization experiments reported from Michigan Technological University (Michigan Tech) certainly give the impression that team collaboration is very good, though it was not addressed explicitly during the review.

Reviewer 3:

The reviewer stated that partners are Phillips 66 and Michigan Tech, along with a variety of suppliers for engine modifications. It was not stated how often they had meetings scheduled. The reviewer asserted that the project's meeting nonreporting could be an area of improvement.

Reviewer 4:

The reviewer commented that collaboration and communication among the team members appear to be quite good. The project has a good mix of contributions from industry, national labs, and universities. The reviewer indicated that, if anything, a bit more attention could have been paid toward the opportunity to move this technology toward the product end of the scale.

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 state project ended.

Reviewer 1:

The reviewer stated future engine improvements, particularly valvetrain improvements, should be very conducive toward pushing the engine operation into a regime of better performance.

Reviewer 2:

Although the project has a good plan, the reviewer was not confident the project can be completed in the time left on the contract. The engine will be installed shortly, but the project team has quite a few tests to run. The reviewer expected that the project will run into some problems with control issues.

Reviewer 3:

The reviewer commented that proposed future research was not explained in great detail in the presentation but appears to be logical and sound. The focus on low load is logical but demonstrating transient capability—especially during mode transients—will be more important.

Reviewer 4:

The reviewer stated this topic was not reviewed in detail (e.g., no detailed project plan or Gantt chart), so one must only go by impressions. Slide 4 and slide 20 do give high-level project plans and expected results. The reviewer stated these plans seem ambitious, but without detailed knowledge of current status and finer-grained elements of work, it is hard to judge. One of the risks is that it might take longer than expected to converge on a fuel blend that adequately satisfies the entire engine operating range. The reviewer stated there is a lot to do to develop and implement an in-cylinder condition estimator into the active engine control system, especially with all the degrees of freedom afforded by CVVD/CVVT and injection pressure. The reviewer expressed great eagerness in seeing the final report.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer highlighted a big opportunity for fuel economy improvements. The project team is designing the system with production in mind; so, it is addressing all the production issues as well.

Reviewer 2:

The reviewer commented that the project addresses the DOE mission of improving engine efficiency and reducing criteria emissions.

Reviewer 3:

The reviewer stated that the project aims to ultimately develop a cleaner and more efficient engine and thus supports DOE's objectives.

Reviewer 4:

The reviewer said Co-Optima's program objective is to identify complementary changes in fuel specifications and engine design to significantly increase engine efficiency, which is exactly what this project is doing. So, yes, it definitely supports 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 said resources allocated appear to be sufficient to achieve the stated goals and milestones.

Reviewer 2:

The reviewer commented that this is a sizable undertaking with an equally sizable and capable team behind it. The resources appear to be sufficient for completion of the planned tasks in a timely fashion.

Reviewer 3:

Based on progress to date and reviewing the individuals who are involved in the project (Slide 21), it certainly appeared to this reviewer that resources are adequate.

Reviewer 4:

The reviewer said resources should be about right but was concerned the project will be unable to complete all tasks in the time allowed. The contract may have to be extended.

Acronyms and Abbreviations

AFC	Alternative Fuel Corridor
1-D	One-dimensional
3-D	Three-dimensional
BTE	Brake thermal efficiency
CFD	Computational fluid dynamics
CFR	Cooperative fuel research engine
COVID-19	Coronavirus disease 2019
CVVD	Continuously variable valve duration
CVVT	Continuous variable valve technology
DI	Direct injection
DNS	Direct numerical simulation
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EGR	Exhaust gas recirculation
EHN	Ethylhexyl nitrate
FT	Fuel and Lubrication Technologies
FTP	Federal Test Procedure
GCI	Gasoline compression ignition
Gen	Generation
GHG	Greenhouse gas
HPSC	High-performance scientific computing
LCA	Life-cycle assessment
LPG	Liquified petroleum gas
LTC	Low-temperature combustion
MD	Medium-duty
Michigan Tech	Michigan Technological University
NO_x	Oxides of nitrogen
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
R&D	Research and development
RANS	Reynolds-averaged Navier-Stokes

RCM	Rapid compression machine
RDD&D	Research, development, demonstration, and deployment
RDE	Real Driving Emissions test
SA-LTC	Spark-assisted low-temperature combustion
SCE	Single-cylinder engine
TCO	Total cost of ownership
WERC	Wisconsin Engine Research Consultants

6. Materials Technology

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Materials Technology subprogram supports the Vehicle Technologies Office goals of achieving 100 percent decarbonization of the transportation sector by 2050. This ambitious goal will be realized through the increased deployment of electric and hydrogen fuel cell vehicles. Materials play an important role in increasing the efficiency of electric vehicles through weight reduction as well as enabling additional functionality such as faster charging and new sensing technologies. Lighter weight vehicle structures and electric drivetrains will require fewer batteries to achieve the same range, which in turn reduces battery cost, material needs, and reduces the greenhouse gas emissions from battery production. Functional materials with improved properties such as electrical conductivity, thermal conductivity, and unique sensing capabilities will enable innovations in charging and autonomous vehicles. The materials and manufacturing methods used to make vehicles also contribute to greenhouse gases and the Materials Technology subprogram supports research, development, and deployment to increase recyclability and reduce the overall embodied energy of vehicles. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, national laboratories, and industry.

Lightweight Materials supports national laboratory, academia, and industry-led research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites, and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly, with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles.

Powertrain Materials supports research at national laboratories, academia, and industry to develop higher performance materials to address the future properties needs of electric and hydrogen fuel cell vehicles to increase efficiency and decrease manufacturing cost, supporting the transition to all electric light duty vehicles by 2035. Research funded through this activity applies advanced characterization and multi-scale computational materials methods, including HPC, to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for lighter and more efficient powertrains.

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
mat146	Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites	Vlastimil Kunc (ORNL/Ames Laboratory)	6-9	2.83	2.83	2.67	2.83	**2.81**
mat149	Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components	Scott Whalen (PNNL/LBNL)	6-13	3.50	3.50	3.50	3.38	**3.48**
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute/ LANL)	6-17	2.88	3.38	3.25	3.00	**3.19**
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University/ NREL)	6-20	3.10	3.30	3.50	2.60	**3.19**
mat153	Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints	Miki Banu (University of Michigan/ ORNL)	6-24	3.63	3.50	3.75	3.50	**3.56**
mat162	Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys	Dongwon Shin (ORNL)	6-28	2.67	3.00	2.83	2.50	**2.83**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat163	Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components	Mei Li (Ford Motor Company)	6-31	3.00	3.20	3.40	2.90	**3.14**
mat164	Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	6-35	3.40	3.10	3.30	2.90	**3.18**
mat173	Self-Sensing Fiber-Reinforced Composites	Christopher Bowland (ORNL)	6-39	3.33	3.33	3.17	3.50	**3.33**
mat174	Carbon-Fiber Technology Facility (CFTF)	Merlin Theodore (ORNL)	6-42	3.25	3.00	3.00	3.25	**3.09**
mat183	High-Temperature Coatings for Valve Alloys	Sebastien Dryepondt (ORNL)	6-44	3.50	3.50	3.25	3.25	**3.44**
mat184	Development of Cast, Higher Temperature Austenitic Alloys	Yuki Yamamoto (ORNL)	6-48	3.25	3.38	3.25	3.38	**3.33**
mat185	Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing	Derek Splitter (ORNL)	6-52	3.70	3.60	3.50	3.60	**3.61**
mat186	Modeling of Light-Duty Engines	Charles Finney (ORNL)	6-56	3.50	3.63	3.75	3.25	**3.56**
mat187	Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys	Dongwon Shin (ORNL)	6-59	3.50	3.63	3.13	3.50	**3.52**
mat188	Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys	Amit Shyam (ORNL)	6-63	3.38	3.38	3.50	3.25	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat189	Fundamental Development of Aluminum Alloys for Additive Manufacturing	Alex Plotkowski (ORNL)	6-66	3.25	3.50	3.38	3.00	**3.36**
mat190	Oxidation Resistant Valve Alloys	G. Muralidharan (ORNL)	6-70	3.33	3.33	3.33	3.33	**3.33**
mat191	Overview of Advanced Characterization within the Powertrain Materials Core Program	Tom Watkins (ORNL)	6-73	3.63	3.50	3.63	3.50	**3.55**
mat192	Fundamentals of Austenitic Alloys via Additive Manufacturing	Sebastien Dryepondt (ORNL)	6-77	3.63	3.75	3.38	3.38	**3.63**
mat193	Higher Temperature Heavy-Duty Piston Alloys	Dean Pierce (ORNL)	6-80	3.50	3.50	3.00	3.30	**3.41**
mat195	Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks	Brian Knouff (ORNL)	6-84	3.25	3.00	3.25	2.75	**3.06**
mat196	High Temperature Carbon Fiber Carbonization via Electromagnetic Power	Felix Paulauskas (ORNL)	6-87	3.25	2.88	3.13	3.25	**3.05**
mat197	Multi-Functional Smart Structures for Smart Vehicles	Patrick Blanchard (Ford Motor Company)	6-91	3.00	3.33	3.00	2.83	**3.15**
mat198	Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure	Venkat Aitharaju (General Motors, LLC)	6-93	3.00	3.00	3.50	3.00	**3.06**
mat199	Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)	Kevin Simmons (PNNL)	6-97	3.40	3.20	3.20	3.00	**3.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat200	Additive Manufacturing for Property Optimization for Automotive Applications	Seokpum Kim (ORNL)	6-100	3.50	3.17	3.00	3.17	**3.23**
mat201	Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage	James Lewicki (LLNL)	6-103	2.83	2.83	3.17	2.83	**2.88**
mat202	3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles	Rigoberto Advincula (ORNL)	6-106	3.50	3.50	3.50	3.50	**3.50**
mat203	Low-Cost, High-Throughput Carbon Fiber with Large Diameter	Felix Paulauskas (ORNL)	6-108	3.38	3.00	3.13	3.38	**3.16**
mat204	New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry	Tomonori Saito (ORNL)	6-112	3.00	3.00	2.17	3.00	**2.90**
mat205	Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites	Amit Naskar (ORNL)	6-116	3.33	3.00	3.00	3.17	**3.10**
mat206	Soft Smart Tools Using Additive Manufacturing	Jay Gaillard (SRNL)	6-118	2.63	3.00	3.13	2.63	**2.88**
mat207	Multi-Material, Functional Composites with Hierarchical Structures	Christopher Bowland (ORNL)	6-123	3.25	3.25	3.00	3.00	**3.19**
mat208	Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste	Lelia Cosimbescu (PNNL)	6-126	3.50	3.33	2.50	3.33	**3.27**
mat209	Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling	Gregg Beckham (NREL)	6-129	3.50	3.63	2.88	3.38	**3.47**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat210	A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite	Patrick Blanchard (Ford Motor Company)	6-133	3.50	3.75	3.50	3.50	**3.63**
mat211	Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles	Masato Mizuta (Newport Sensors, Inc.)	6-135	3.10	3.00	2.70	3.00	**2.99**
mat212	Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles	Amrita Kumar (Acellent Technologies, Inc.)	6-140	3.50	3.38	3.50	3.50	**3.44**
mat213	Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor	Halina Tran (Intellisense Systems Inc.)	6-144	3.25	3.38	3.38	3.17	**3.32**
mat214	Multifunctional Composites for Vehicles	Henry Sodano (Trimer Technologies, LLC)	6-148	3.63	3.50	2.88	3.33	**3.43**
mat215	Short Fiber Preform Technology for Automotive Part Production - Phase II	Dirk Heider (Composites Automation, LLC)	6-152	3.50	3.50	3.17	3.33	**3.44**
mat216	Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II	Henry Sodano (Trimer Technologies, LLC)	6-154	3.33	3.67	2.67	3.00	**3.38**
mat217	New Higher Temperature Performance Alloys (1A2)	Amit Shyam (ORNL)	6-157	3.50	3.67	3.50	3.33	**3.56**
mat218	Selective Material Processing to Improve Local Properties (2B2)	Glenn Grant (PNNL)	6-160	3.50	3.33	3.33	3.17	**3.35**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat219	Fundamentals of Non-Equilibrium Processing	Ying Yang (ORNL)	6-163	3.20	3.30	3.30	3.00	**3.24**
mat220	Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2)	Peeyush Nandwana (ORNL)	6-168	3.40	3.60	3.30	3.50	**3.50**
mat221	Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials	Dean Pierce (ORNL/ Cummins)	6-172	3.75	3.50	3.63	3.63	**3.59**
mat222	Extending Ultrasonic Welding Techniques to New Material Pairs	Jian Chen (ORNL)	6-175	2.80	3.10	3.00	2.70	**2.96**
mat223	Extending High Rate Riveting to New Material Pairs	Kevin Simmons (PNNL)	6-178	3.25	3.25	3.25	3.25	**3.25**
mat224	Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness	Piyush Upahdyay (PNNL/ORNL)	6-182	3.38	3.50	3.38	3.00	**3.39**
mat225	Surface Modifications for Improved Joining and Corrosion Resistance	Mike Brady (ORNL/PNNL)	6-185	3.30	3.20	3.00	3.20	**3.20**
mat226	Machine Learning for Joint Quality and Control	Keerti Kappagantula (ORNL/PNNL)	6-189	3.50	3.40	3.60	3.40	**3.45**
mat227	Prediction of Aluminum/Steel Joint Failure	Chris Smith (PNNL/ General Motors Company)	6-193	3.13	3.00	3.50	2.75	**3.06**
mat228	New Technologies for High-Performance Lightweight Aluminum Castings	Paul Jablonski (NETL/ General Motors Company)	6-196	3.00	3.00	3.20	3.20	**3.05**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat229	Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components	Govindarajan Muralidharan (ORNL/FCA LLC)	6-200	3.13	3.13	3.38	3.13	**3.16**
mat230	Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction	Aaron Greco (ANL/General Motors Company)	6-204	3.00	3.00	3.25	3.13	**3.05**
mat232	Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet	Darrell Herling (PNNL)	6-207	3.25	3.25	3.00	3.25	**3.22**
mat233	Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings	Glenn Grant (PNNL)	6-211	2.63	2.88	2.75	3.00	**2.81**
mat234	Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings	Vineet Joshi (PNNL)	6-214	3.50	3.50	3.38	3.25	**3.45**
mat235	Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle	Arun Devaraj (PNNL)	6-217	3.13	2.88	3.00	3.00	**2.97**
Overall Average				**3.28**	**3.29**	**3.22**	**3.16**	**3.26**

Presentation Number: mat146
Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites
Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory/Ames Laboratory)

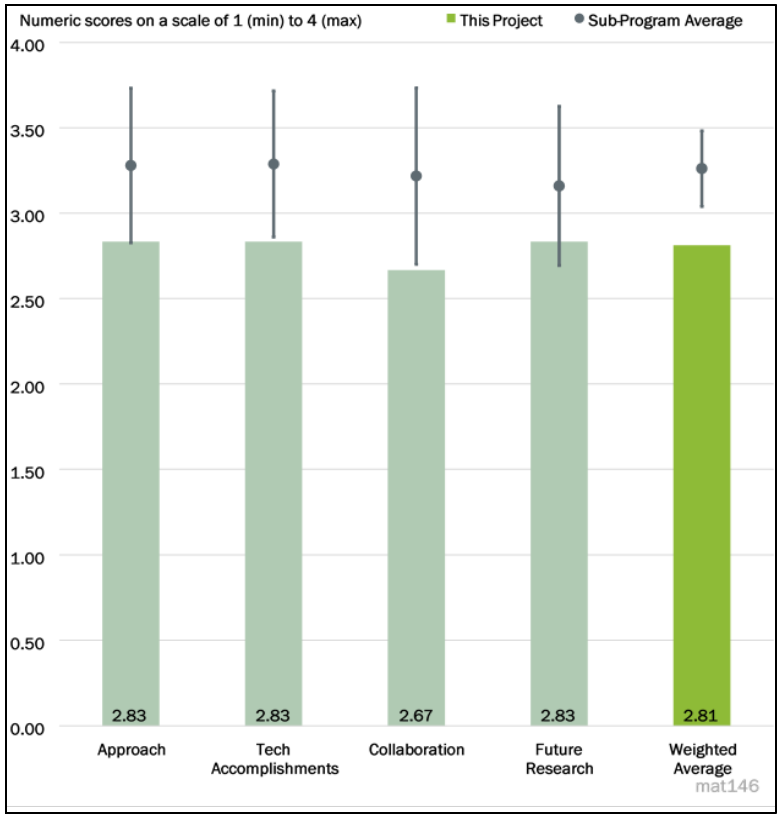


Figure 6-1 - Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory/Ames Laboratory)

Presenter

Vlastimil Kunc, Oak Ridge National Laboratory/Ames Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a novel approach relative to the current state of the art (SOA) that increases speed. The project focused on stiffness and dampening, but there are limited data or information on strength, fiber length effects, fiber orientation, and fiber volume fraction effects on strength.

Reviewer 2:

The reviewer noted that the technical barrier addressed on the Overview slide is “Barrier: Use of lower-density materials with suitable mechanical properties, i.e., materials with higher strength-to-weight and/or higher stiffness-to-weight ratios.[1]” with reference one being the “U.S. DRIVE MTT Roadmap, section 4.” The text in section four of that referenced document lists “use of lower-density materials with suitable mechanical properties, i.e., materials with higher strength-to-weight and/or higher stiffness-to-weight ratios” as an element of traditional, historic approaches to reduction of vehicle weight. The reviewer commented that weight reduction is the goal of the issues and challenges identified in that Roadmap, but the work of MAT146 addresses none of the five Critical Challenges Identified for Carbon Fiber (CF) composites: low-cost, high-volume manufacturing; low-cost fibers; predictive modeling; joining, non-destructive evaluation (NDE), life monitoring, and repair; and recycling. The current project impressively advances new concepts for high strength-to-weight and stiffness-to-weight materials, but the technical barrier identified that the project approach addressed is not one of the prioritized barriers listed in the referenced source. Additionally, the reviewer stated that the approach does not address one of the five critical challenges mentioned therein.

Reviewer 3:

The reviewer stated that the systematic approach of mixing Voigt and Reuss layering mechanisms to produce the tunable stiffness and damping is a solid one to overcoming the barriers. The efforts on the print heads for improving extrusion speed and robustness are the next step being addressed in the next budget period. However, the reviewer questioned the project management scheme, given the milestones appear to have been modified from the 2020 Annual Merit Review (AMR) list.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project has done a great job in developing new processes, designing structures for efficiency, and developing materials.

Reviewer 2:

The reviewer reported that examples are provided on the significant improvement in capabilities established and properties measured in the current status of the work compared to the status at an earlier point in the project.

Projection design and lighter weight optics are apparently enabling faster exposure and scanning, though it was unclear to the reviewer what the status was before and after these improvements (i.e., how much faster?).

This reviewer observed that the transition from a truss-lattice geometry to a plate-lattice geometry resulted in improved normalized stiffness versus relative density. An increase in volume fraction of the bi-material plate-lattice soft phase resulted in significant improvement in absorbed energy. The use of bi-material rather than CF-only plate lattices led to significantly higher normalized absorbed energy with some reduction in normalized peak strength.

The stated overall objective of the work is the creation of materials that are ultralight, strong, and tough. The reviewer asserted that definite progress is being made in design and demonstration of ultralight geometries with strong specific weight and specific toughness. What is not clear is the strength and toughness of the demonstrated materials, not only relative to other materials normalized by density, but relative to material performance requirements of components in commercial vehicles. What is a target application on a vehicle of the materials being developed? What are the strength and stiffness requirements of a material used in that application? If the bi-material cubic+octet plate-lattice is envisioned to replace and thereby reduce the mass of a current structural member or foam or panel fill, what are the strength and/or stiffness performance requirements that drive material selections for the envisioned application and how close is the current performance of the material in development to that requirement? The reviewer commented that future work includes developing the ability to control CF alignment and orientation. How is performance of the printed structures with achieved alignment and orientation anticipated to compare with that of current materials?

Reviewer 3:

This reviewer observed solid progress on the technical accomplishments in the last year. Printing a 200 millimeter (mm) × 200 mm × 100 mm lattice structure in under 4 hours is a good start, but far below required production targets. The reviewer questioned how the project milestones have morphed from the 2020 AMR presentation to those listed in this year's 2021 AMR presentation. This changing project management structure with different milestones in different presentations made the reviewer question what the project team is really doing and whether it is aligned for success.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The described work includes strengths of both the University of California at Los Angeles (UCLA) group and the Oak Ridge National Laboratory (ORNL) group. At least one publication includes co-authors from both partners. It was not apparent to the reviewer from the slides which elements of the described work were performed by which partner institution.

Reviewer 2:

It was not clear to the reviewer from the presentation the contributions by the team collaborators. It would enhance the presentation to clearly delineate who did what work to give some indication of the team participation and contributions to the overall project.

Reviewer 3:

While the progress suggests good cooperation, there is nothing in the AMR presentation that defines the roles and responsibilities of the partners, the typical interaction timing, or the project management tracking scheme. It was not clear to the reviewer what is being done at ORNL and what UCLA is contributing. How often do the project teams meet and exchange project information?

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 state project ended.

Reviewer 1:

The proposed future work was logical to the reviewer and addresses some of the concerns that should be focused on, such as rheological behavior, fiber orientation, and fiber length distribution.

Reviewer 2:

The proposed work for the next year addresses the next most pressing project needs. The extrusion of the carbon fiber reinforced polymer (CFRP) and the size and speed of producing design artifacts and the integration of multi-materials for tailored stiffness and damping all need to be addressed, according to the reviewer.

Reviewer 3:

The reviewer stated that the go/no-go milestone targets a micro-lattice with a density of less than 500 kilograms per square meter (kg/m^3) and specific strength greater than 1 kilopascal ($kPa)/(kg/m^3$). This target density is very low compared to the 1,500–2,000 kg/m^3 of CF and epoxy or glass fiber (GF) and polyester composites. The target strength is normalized by the density: $1\ kPa/(kg/m^3) \times 500\ kg/m^3 = 500\ kPa$. This is equivalent to the compressive strength of expanded polystyrene insulation foam. What strength is required for use of the developed material in vehicle lightweighting? What is the potential or anticipated vehicle weight savings or market penetration for the production cost of the considered material?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the design and materials could reduce the weight of vehicles if the material performance is achieved.

Reviewer 2:

This project addresses the need for lower cost, higher energy absorbing printed structures. The reviewer asserted that the focus on multi-material and extruded CFRP is a high risk and high reward project.

Reviewer 3:

This project seeks to develop and demonstrate novel geometries, compositions, and the manufacturing methods to produce ultra-low density, high specific strength, and high specific toughness materials. These aims support vehicle mass reduction and weight reduction. Notably, the U.S. Department of Energy (DOE) objectives target mass reduction at equal affordability ("50% mass reduction at equal affordability" [stretch objective long term]); cost-based weight reduction ("U.S. DRIVE Target 2025* – 25% weight reduction (Glider) < $5/lb"); and weight reduction at equal performance relative to currently relied upon materials ("Equal performance (Crash, NVH, Durability, Reliability & Recyclability)").

According to the reviewer, a challenge for the current project approaches will be identifying a path to weight reduction that is "high volume" and meets DOE affordability and cost premium targets. Also, the goal of density reduction at equal performance will need to be met, requiring competitive absolute strength and toughness performance apart from specific strength and toughness, and acknowledging that lighter parts might have lower performance requirements to support themselves.

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

Reviewer 1:

Project funds appear to have 50% expended. Based on progress to date, the reviewer said that the remaining funds should be sufficient to address some of the identified future work targets of improved fiber alignment, increased print speed, increased print area, and increased material inclusion flexibility.

Reviewer 2:

The reviewer found that the project is adequately funded, and the project team has done a good job of dealing with project impacts due to coronavirus disease 2019 (COVID-19).

Reviewer 3:

The funding level is sufficient for the project goals. The reviewer had concerns over the tracking and use of the budget, given the shifting milestones.

Presentation Number: mat149
Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory)

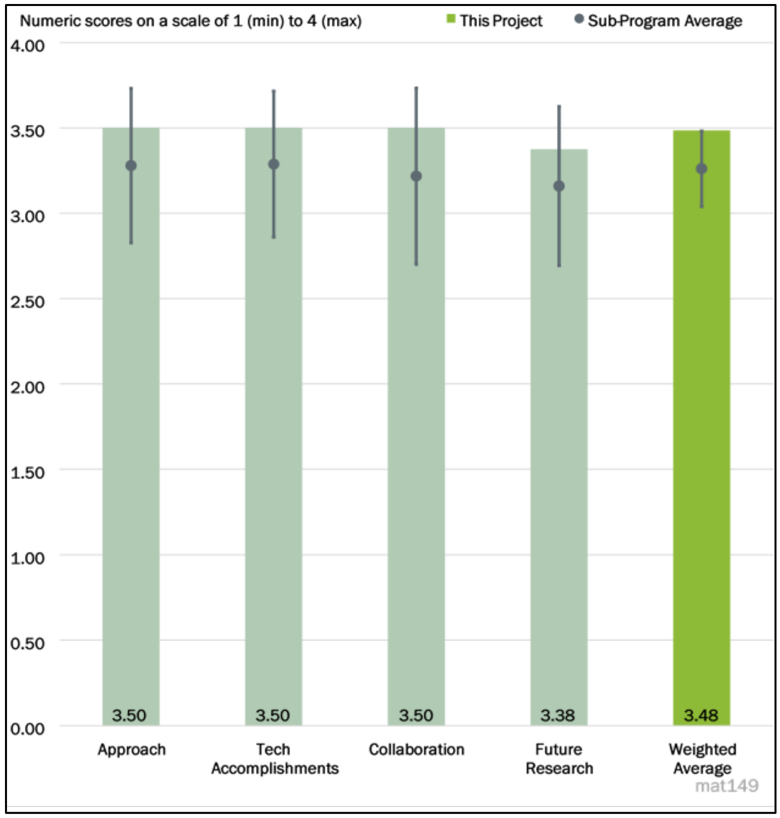


Figure 6-2 - Presentation Number: mat149 Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory)

Presenter

Scott Whalen, Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed an excellent approach to systematically attacking the barriers to magnesium (Mg) extrusions and reducing the cost of aluminum (Al) extrusions.

Reviewer 2:

Benefits for utilization of Al and Mg with Shear-Assisted Processing and Extrusion (ShAPE™) processing was outlined clearly. The researcher explained the approach well and followed up with responses to the requests made by the reviewer.

Reviewer 3:

The project is strong and addresses some important areas for extrusion improvement. The emphasis on using a secondary alloy is important; however, the project could address more on chemistry sensitivity (as part of using cast billet as feedstock). It would also be useful to have some targets for extrusion speed improvement better defined when compared to the conventional process. Textures, microstructure uniformity, and the ability of the process to hold to dimensional tolerances are also important considerations, and those measurements would make project objectives stronger. It was unclear to the reviewer if those are part of the future work.

Reviewer 4:

The reviewer said that the project is exploring the viability of the ShAPE process for light metals. The plan for experiments for A6063 and ZK60 is good; all parameters that affect the process, including temperatures, speed, and ingot quality, are being assessed. Also, the influence of the process on properties in as-fabricated and heat-treated conditions is being evaluated.

A new tool for port hole extrusion is being designed to explore the potential for multi-wall thickness. The reviewer noted that all these efforts are well supported by the industrial partner.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that progress on all three critical areas—Mg ZK60, Al 6061 from scrap turned into briquets, and the starting efforts on a porthole extrusion—is impressive.

Reviewer 2:

The project seems to have accomplished quite a bit on producing extrusions. Porthole die results will be interesting. The reviewer said that it is good that there is engagement with the die maker.

Reviewer 3:

The reviewer stated that experiments demonstrated that the process is viable for extruding both Al and Mg alloys. Both extrusion speeds and quality of Al alloys appear to be closer to normal operation, making it acceptable for use. Use of recycled scrap material seems to make the process attractive from a sustainability perspective. It also provides an economic incentive for recycling of machining chips.

One of the major advantages cited for Mg extrusion is the lack of orientation developed due to high shear rates. This aspect does not seem to provide any improvements in the symmetry. Also, the reviewer asserted that the speed required to have an economic advantage in the case of Mg is yet to be achieved.

Reviewer 4:

With ShAPE processing, the reviewer reported that T6 properties were achieved with a T5 temper for several extrusion speeds and process temperatures. With the new process, energy can be saved and the cost of solutionizing is eliminated. The team is aware that eliminating the solution treatment can lead to heterogeneity in properties.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is excellent collaboration between the industry partner and a national laboratory in this Lightweight Materials Consortium (LightMAT) project. The research license for ShAPE from Magna was encouraging to the reviewer.

Reviewer 2:

The project team seemed well aligned and complete to the reviewer.

Reviewer 3:

The reviewer noted that industrial partner, Magna, is fully integrated in the project. With the supply of raw materials (including consolidated chip billets) and the design of tools, the reviewer found that Magna has contributed significantly to the project. However, the full supply chain is not involved in the project; most probably, Magna is pursuing separate supply chain development. However, in this situation, all members of the supply chain can contribute to resolving many roadblocks that may arise later. The process is being promoted as an economic success with the use of recycled chips. The reviewer indicated that the following should be present, at least in advancing capacity: characterization of chips (machining firms); preparation of billets; tool designers; and extruders.

Reviewer 4:

The accomplishments show how the team must be working together. The reviewer would have liked to see a chart or table with the typical interactions (i.e., weekly, monthly, and/or quarterly) and a clear list of roles and responsibilities plus a "gives and gets" table showing the interactions between the partners and the major vendors as the porthole die is 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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the proposed work addresses the remaining major barriers. The team has an excellent plan.

Reviewer 2:

The proposed plan seemed logical and well thought out to the reviewer. It would be good to make sure there are more metrics assigned as targets on the manufacturability of the porthole bridge die tooling, such as extrusion speed, dimensional accuracy, surface quality, etc.

Reviewer 3:

The reviewer commented that plans for the future take advantage of progress made in the current fiscal year (FY).

Reviewer 4:

The plan is to complete the circular and non-circular tube extrusions using both Al and Mg alloys. The reviewer noted that there is no plan for modeling of the process of using chips for extrusion. This could help improve the process. Also, modeling can help to optimize the extrusion speed for magnesium alloys.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that reducing the energy use for transportation is one of the prime objectives of DOE. Developing a recycling process for chips will contribute to sustainability and reduced energy use.

Reviewer 2:

This project supports lightweighting efforts for the glider with a novel extrusion technology. The reviewer stated that it also incorporates the use of secondary feedstock to reduce the carbon footprint.

Reviewer 3:

Both from a Mg replacement of Al (i.e., weight reduction) and scrap reuse point of view, the reviewer remarked that this project supports DOE objectives.

Reviewer 4:

Mg and Al lightweighting helps to improve fuel economy and extend electric vehicle (EV) range. The use of 100% recycled Al scrap is a huge cost and greenhouse gas (GHG) savings for OEMs. The reviewer opined that developing a procedure for both Al scrap and Mg to be effectively extruded with a porthole closed section and ideally a multi-cell closed section is critical to adoption in the automotive sector.

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

Reviewer 1:

The funding seemed sufficient to the reviewer to complete this work. The supplier partners appear to be very engaged and have made significant in-kind contributions.

Reviewer 2:

Resources are sufficient, according to the reviewer.

Reviewer 3:

The reviewer found no plans for modeling; if modeling is included, then additional resources can be justified.

Reviewer 4:

The reviewer opined that resources might be a bit shy to develop a porthole extrusion die and procedure.

Presentation Number: mat151
Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints
Principal Investigator: Adam Powell (Worcester Polytechnic Institute/Los Alamos National Laboratory)

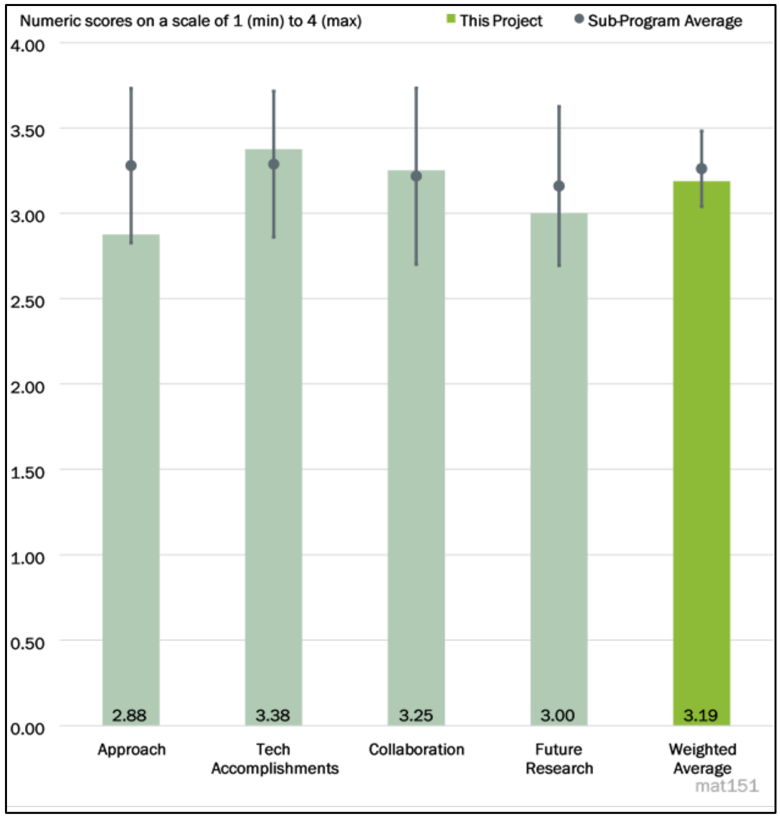


Figure 6-3 - Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute/Los Alamos National Laboratory)

Presenter

Adam Powell, Worcester Polytechnic Institute/ Los Alamos National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The main barrier addressed in this work is the limited understanding of Mg-Al joint corrosion and fracture, and the technical approach is well focused on the critical barriers. The combination of modeling and experimental work is excellent. In the remaining approximately one-third of the project, the reviewer suggested that the team will need to focus on integrating the many different experimental findings into a cohesive model.

Reviewer 2:

Validation of the corrosion model on the Mg pitting was a good approach to then investigating the general corrosion of the joint leading to mechanical property degradation. Intermetallics of Mg-Al were cited as a major difference in friction-stir welding (FSW) compared to Mg-iron (Fe), yet the reviewer did not see any work to incorporate these particles in the corrosion model. Also, despite the 5-week salt spray testing being a standard, it was not clear to the reviewer that this level of testing created measurable mechanical property degradation. Also, how the mechanical property degradation caused by corrosion will be calculated is not clear.

Reviewer 3:

The presenter outlined the project approach through milestones. The reviewer was not sure what the basis was for the go/no-go milestones. What is the significance of predicting corrosion pit depth within plus or minus (±) 2x, and how does it relate to predicting corroded joint strength or fatigue strength within ±10%?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent work in identifying the supremacy of the triangular tool for the Al-Mg material combination. The reviewer asserted that timing may be a bit tight in completing the corrosion exposure and measuring the mechanical property degradation as validation of the corrosion and mechanical property degradation simulations.

Reviewer 2:

The reviewer found that good progress is being made across multiple aspects of the project, with some very promising work underway in the experimental investigation of the “swirl” regions using multiple techniques. The nanoindentation study to investigate spatial variations of mechanical properties within the swirl was particularly clever. It will be interesting to see how the team leverages the new nanohardness map and phase map data to improve the mechanics model. Also, the team seems to have been successful in adapting their FSW technique for welding from hard-to-soft as needed for the challenge problem application (opposite of soft-to-hard convention).

There is no explicit mention of whether the first go/no-go milestone (i.e., prediction of pit depth) was achieved; possibly, it was not achieved (based on the comment that the modeled pitting rate was faster than observed). Because that is the only milestone past its planned completion date, it was difficult for the reviewer to assess whether the project plan is on schedule or not.

Reviewer 3:

The phase-field galvanic corrosion oxidation model predicts experimental data. The reviewer observed that the team completed a validated model that predicts corrosion and mechanical failure.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaborators appeared to the reviewer to be well coordinated and effective, with each participant making valuable contributions and delivering results.

Reviewer 2:

The reviewer asserted that there is great teamwork involving national laboratories, an industrial manufacturer, and a university.

Reviewer 3:

The reviewer found good use of ORNL microscopy of weld sections to highlight challenges in creating constitutive models for mechanics performance simulation.

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 state project ended.

Reviewer 1:

The future work plan seems appropriate, though perhaps a bit open ended. For example, one idea for future work is to “understand fracture based on nanohardness maps.” More specifics on how the team might accomplish this would be useful. Future work plans do not explicitly include a study of grain size effects as suggested by reviewers both this year and last. In a verbal response to a reviewer question, it was suggested to possibly use small angle neutron scattering to investigate grain size further. The reviewer hoped that the team will consider integrating this into future work if the budget and time allow.

Reviewer 2:

The reviewer felt that it is correct to understand the differences in fracture mode of the Al-Mg versus the prior Mg-Fe fracture where the model was validated. Referencing Slides 10 and 12, the reviewer explained that nanohardness stratification is certainly one aspect, but a macro difference is that with the Mg-Al fracture, there is only a single hook whereas the Mg-Fe exhibited two, i.e., on both sides.

Reviewer 3:

The team plans to modify the models, particularly the electrochemical and mechanical models. The reviewer observed that the team also plans to correlate performance during cyclic loading.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form and in the right application, it is imperative to achieve dissimilar material joints. Knowledge of corrosion on mechanical performance is necessary to implement such dissimilar material joints.

Reviewer 2:

According to the reviewer, this project is well aligned with DOE objectives in multi-material joining capability and joint corrosion performance.

Reviewer 3:

High volume manufacturing of corrosion resistant joints for vehicles is needed. Also, the reviewer opined that predicting their performance is critical.

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

Reviewer 1:

The team has a variety of experimental equipment at its disposal and has been able to shift to new techniques as needed and without running into resource limitations. As for the monetary resources, they appeared to the reviewer to be on pace.

Reviewer 2:

The reviewer noted that resource allocation is adequate.

Reviewer 3:

The reviewer observed that 71% of the DOE funding has already been spent. The project states that a weak coupling exists between the corrosion and mechanical performance. The remaining 29% of the budget may make it difficult to investigate the nature of this gap and potential solutions.

Presentation Number: mat152
Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives
Principal Investigator: Roozbeh Dargazany (Michigan State University/National Renewable Energy Laboratory)

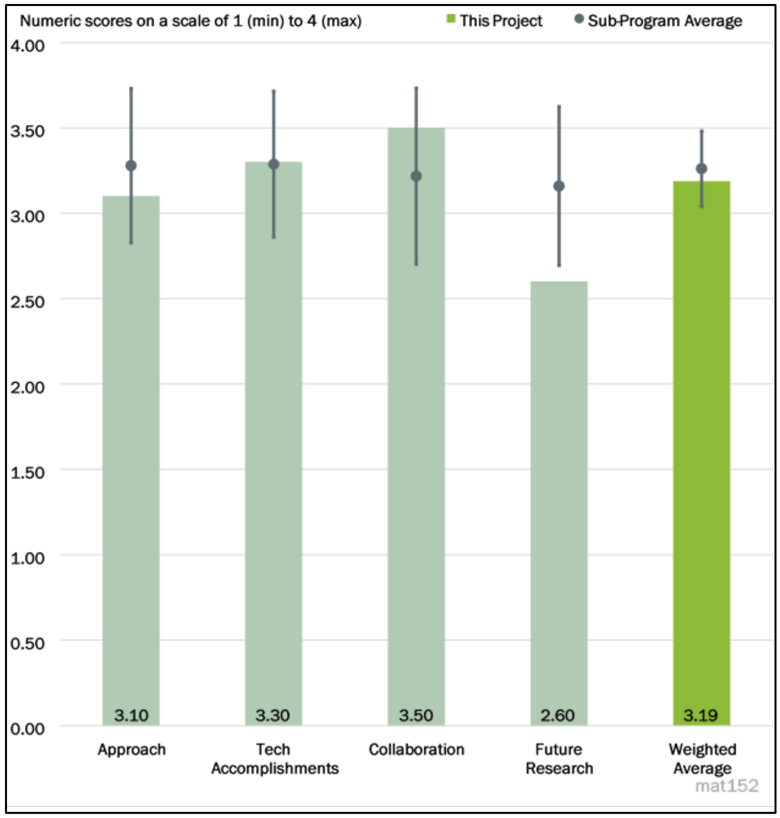


Figure 6-4 - Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University/National Renewable Energy Laboratory)

Presenter

Roozbeh Dargazany, Michigan State University/National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach presented for the overall project is very detailed with well-defined areas of development and their respective performers identified over the entire project timeline. Each task area and the respective subtasks are designed to address all the technical barriers that are identified early in the presentation. The approach is coupled with the milestones for each fiscal year and specifics for each subtask that is either completed or in progress. A second slide presented the approach for modeling, which is broken down into four areas associated with separate damage mechanisms. The modeling approach is also well designed and progresses from data requirements to mechanical analyses, to neural network design and validation, to software development, and to prediction of the various failure modes. With both a well-designed project approach and a well-designed modeling approach, this physics-based, the reviewer asserted that this data-driven effort to model damage accumulation caused by corrosive effects is completely feasible.

Reviewer 2:

The reviewer said that the test plan was clearly defined and executed.

Reviewer 3:

The team is developing a theoretical constitutive model for various adhesives. The researchers have considered various damage mechanisms including mechanical deformation-induced decay in performance as well as chemical degradation-induced deterioration of adhesive performance. The project team has studied all probable degradation, including hydrothermal, thermal, hygrothermal, photooxidation, etc. The reviewer was not sure if all these degradation models are common for all adhesives. Therefore, a key question remains: how would those models be integrated into a generalized platform?

Reviewer 4:

The reviewer stated that the project only focuses on adhesives without considering the material substrates, which may very well affect the behavior and aging of the adhesives.

The project focuses only on acrylic, polyurethane, and silicone adhesives instead of epoxies, which are much more widely used in automotive structures due to the higher modulus. Because the project does not include epoxies, then the reviewer opined that it is not helpful in a vast majority of potential lightweight and multi-material structural joining applications.

It is not clear how this project will speed up the design of composite joints and/or reduce the time and cost required for testing corrosion failure. Also, it was not clear to the reviewer how the results of this project are to be used by the automotive industry. What input is required? What output is expected?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presenter had too many slides (54 for the presentation and 16 backup slides for a total of 70 slides) to cover all of the technical accomplishments and progress in the twenty minutes allowed and was cut short by the AMR facilitator. Because of this, only the first 16 slides were presented. The technical accomplishments presented (and a review of those not presented) demonstrate several outstanding accomplishments in this project for modeling damage in adhesives caused by effects of corrosion. When the progress is measured against the milestones and performance indicators, the reviewer praised the project manager as having done an outstanding job of conducting research that addresses the technical barriers identified earlier in the presentation.

Reviewer 2:

According to the reviewer, the team made significant progress in analyzing various degradation models and associated validation of the models by use of experimental data.

Reviewer 3:

Substantial technical accomplishments indicated good progress to the reviewer.

Reviewer 4:

Good progress has been made toward achieving the overall project goal. It was not clear to the reviewer as to the contribution of individual participants.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is an outstanding team for collaboration on this project, which includes a university (for early-stage research and modeling) with two facilities for database and modeling and for materials characterization and testing. It also includes a supplier of commercial software, a supplier of the joining technology to be used, a company in the chemicals industry, and a lightweight materials consultant. This team exemplifies elements needed for acceptance of a joining technology and predictive models for the end-user. Close coordination during the planning phase for this diverse yet coordinated team was apparent to the reviewer.

Reviewer 2:

Overall, the project results to date indicate that the large group of dissimilar collaborators are to be working in a well-coordinated manner. It was not clear who the auto industry joining expert is and how the expert's guidance is being implemented.

Reviewer 3:

The reviewer observed an excellent team involving multiple industries and experts from other industries on advisory roles. However, it was not clear to the reviewer who is doing what. The approach and milestone chart shows involvement of entities, but it does not list the High Performance Material Group (HPM). Perhaps HPM is involved in all the tasks. Also, it is unclear which entity is responsible for what milestone.

Reviewer 4:

The contribution of individual participants was not clear 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Future research is described in three brief bullet points. The reviewer asserted that degradation of adhesion properties should have been already studied based on the models for chemical degradation-induced decay in performance of the adhesives.

Reviewer 2:

The presenter did not offer any future research, which is described on Slide 53. The reviewer said that the work described is a continuation of the current modeling effort to perform more material characterization experiments and determination of other effects causing degradation of adhesion for joining materials. A statement is also made regarding validation of multi-agent simulators and the development of methods to minimize the data needed for training the models. This is a logical progression of further work that is needed to increase the understanding and model the effects of damage accumulation on adhesive materials.

Reviewer 3:

According to the reviewer, the proposed future research does not identify any plans to evaluate adhesives with lightweight material substrates. The proposed future research does not specify how this work will be made useful to auto industry users.

Reviewer 4:

The reviewer remarked that the discussion did not include a description of the remaining tasks.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that this project directly supports the overall DOE VTO technical targets and United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) partnership (includes DOE) roadmap goals and high priority research needs for multi-material joining and predictive modeling for dissimilar material joining.

Reviewer 2:

The reviewer opined that designing adhesive joints will be effective if there is a model that can predict the adhesive performance. DOE has a very ambitious goal; therefore, this project is highly relevant.

Reviewer 3:

The reviewer commented that the research did not include application of the predictive model relative to real-world joining of dissimilar materials.

Reviewer 4:

It was difficult for the reviewer to see how a project focusing only on adhesives with no material substrates being considered and no validation with industry type tests will be useful to industry. The project does not appear to be focusing on the types of adhesives most widely used in the auto industry to enable lighter weight structures. None of the work seems to be well defined for improving reliability of joining of dissimilar joints. In fact, the project report does not even mention substrate materials anywhere (e.g., Al, steel, Mg, polymer composites, etc.).

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

Reviewer 1:

Significant progress has been made with the available resources. The project appeared to the reviewer to be within budget constraints.

Reviewer 2:

The reviewer observed that the DOE investment is about $333,000 per year average, which is sufficient to achieve the stated milestones within the 3-year performance period. The majority of the work is modeling, so the physical resources needed are minimal. The collaboration partners are well chosen and sufficient to perform the material testing and model validation.

Reviewer 3:

The reviewer said that the team has adequate resources.

Reviewer 4:

Although the relevance of the work is not well defined, the resources seemed sufficient to the reviewer to conduct the type of work that is being performed.

Presentation Number: mat153
Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints
Principal Investigator: Miki Banu (University of Michigan/Oak Ridge National Laboratory)

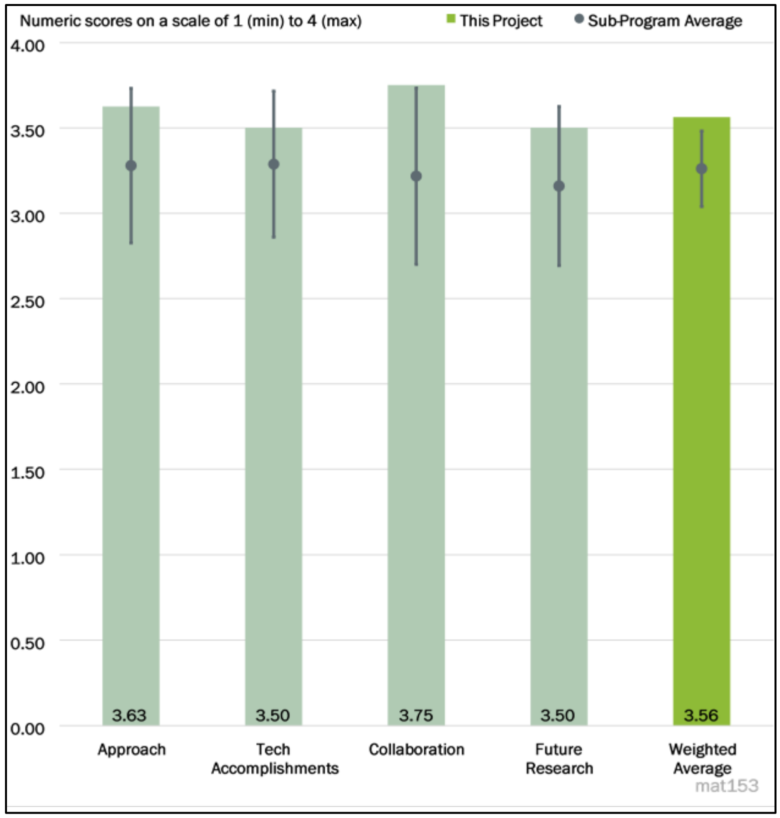


Figure 6-5 - Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: Miki Banu (University of Michigan/Oak Ridge National Laboratory)

Presenter

Miki Banu, University of Michigan/ Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team aims at developing multiscale models for predicting corrosion rates and their impact on joining performance of Al and of steel based on structure property performance interaction at different scales. The team considered resistive spot welding, riveting, and rivet welding. Joining and subsequent corrosion at the Al and steel interface lead to formation of intermetallic compounds and deterioration in mechanical deformation behavior. Grain-level phase field modeling delivers prediction of corrosion sites, corrosion rates, and mechanical performance of the homogenized mechanical response. Integration of atomic level and grain-level modeling will deliver performance prediction. The reviewer praised the approach outlined and presented as excellent.

Reviewer 2:

This is a well-designed and executed experiment with a very good correlation of results. The reviewer indicated that significant involvement of original equipment manufacturers (OEMs) ensures correct test methods for the targeted application.

Reviewer 3:

The project seemed to the reviewer to be well planned, well coordinated, and focused on the final goals.

Reviewer 4:

Evaluation of three different joining methods enables better understanding and evaluation of model predictive capability and robustness. However, considering the size of the budget for this project, it seemed to the reviewer that more joint types and material combinations could be evaluated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presentation indicates good accomplishments for this project to date. The reviewer was particularly impressed with the team's decision to take advantage of the imposed 2-month shutdown of the General Motors (GM) corrosion chamber to evaluate the real-world occurrence of breaks in corrosion exposure.

Reviewer 2:

It appears that a lot of good work is being done here. For example, the experimental work correlating patterns in lap -shear, force-displacement curves to the corrosion exposure time (Slide 9) looked quite interesting to the reviewer, and the force-displacement curve predictions (Slide 15) look promising.

In general, the reviewer wished that the plots and figures had been made a bit bigger and easier to read in the presentation. Quite a few of the results and graphics were tiny and difficult to decipher, even when zooming in. That made it difficult for the reviewer to provide more detailed technical comments.

Reviewer 3:

The reviewer commented that the team has made very good accomplishments.

Reviewer 4:

The project is expected to end by the end of this calendar year. COVID-19 indeed impacted the progress. Still, the reviewer indicated that a lot more examples showing experimental validation of the predicted corrosion failure of the joints would have been good. The good news is that the code would be available for others to test.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is an excellent team, and the reviewer found that the diverse expertise of the investigators is an asset for this project.

Reviewer 2:

The reviewer appreciated Slide 20, which clearly laid out the specific contributions of each participant to the project. This seems to be an effective collaboration.

Reviewer 3:

According to the reviewer, the project shows good collaboration of academia and industry, and the accomplishments thus far indicate the collaborators are functioning well together.

Reviewer 4:

Discussion did not include who did what, but the reviewer indicated that the results speak for themselves.

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 state project ended.

Reviewer 1:

Overall, the proposed future work appeared to the reviewer to be well aligned with meeting the project's stated goals. The proposed future work is to formulate guidelines to assist automakers in prediction of corrosion and "end of life" solutions, and proposing solutions for designing new alloys less susceptible to corrosion for use in multi-material assemblies will be very valuable for helping the automotive industry meet DOE's lightweight multi-material glider weight reduction goals.

Reviewer 2:

The project is 80% complete and is wrapping up in December. While the project is progressing on track, there are quite a few milestones still remaining, which the reviewer warned will require a focused effort to complete over the next 6months. It appears that the research team has a sound strategy.

Reviewer 3:

The reviewer noted that the team will make the code available for others and the project data would also be available.

Reviewer 4:

The reviewer found that the future work is well defined.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Corrosion-resistant multi-material joints are essential for automobiles. This project and the overall joining program are highly relevant, according to the reviewer.

Reviewer 2:

Performance degradation over time is a critical component of reliability and performance. The reviewer asserted that models to predict performance of dissimilar materials are needed to efficiently design structures and define useful life.

Reviewer 3:

The reviewer stated that the project focuses on corrosion prediction of dissimilar material joints, which is a key challenge in the development of lightweight multi-material automobile structures.

Reviewer 4:

This project supports DOE objectives around multi-material systems and also aligns with goals to advance multi-scale computation and other Integrated Computational Materials Engineering (ICME) approaches.

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 is well planned and executed, deploying sufficient resources in an efficient manner.

Reviewer 2:

Resources (equipment and monetary) appeared sufficient to the reviewer. The project is progressing on track.

Reviewer 3:

The reviewer remarked that resources are sufficient.

Reviewer 4:

Although it is good that the project is planning to evaluate three unique joining processes for the joining of Al and steel, it seemed to the reviewer that the budget should be sufficient to evaluate (and therefore further validate the models) of more joining processes and material combinations than are planned for this project.

Presentation Number: mat162
Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers felt that the project was relevant to current DOE objectives, 33% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

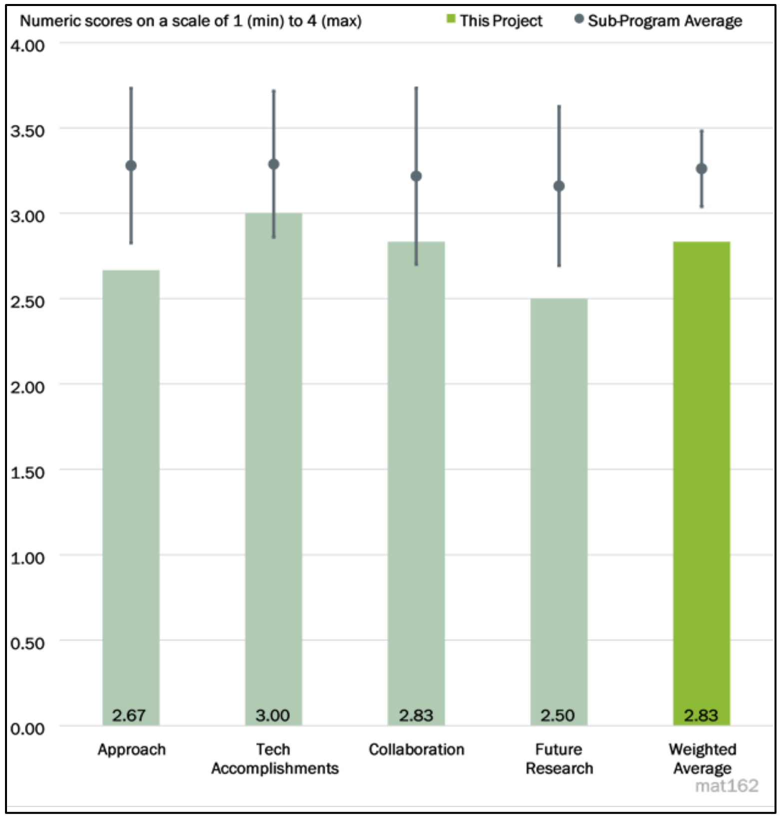


Figure 6-6 - Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the presenter did a good job of describing the approach to performing this work. However, when the machine learning regression training topic was discussed, the presenter would benefit from collaboration with a data scientist. For example, using the Hadamard-Autoencoder for missing data would help (because the presenter said that significant gaps exist with the experimental because it was not conducted with a data analytics focus). Self-supervised learning (SSL) is one of the most promising ways to build background knowledge and approximate a form of common sense for high-performance valve alloys.

Reviewer 2:

In the project team’s approach (Slide 4), there does not seem to be experimental feedback to validate or improve the model(s). In the “data analytics” task, for those condition and alloy systems that are outside the predicted range, is there an effort to study why the current model cannot predict it well? Is it due to the lack of fundamental measurement? What is the plan to improve the model used? On Slide 15, the project team conducted successful machine learning (ML) model training but stated it “needs more ‘good’ reactive force field (ReaxFF) data to improve model accuracy.” The reviewer wondered if there is an effort in this project to obtain “good” ReaxFF data.

Reviewer 3:

The goal appears to be to reduce the parabolic constant (k_p), which the reviewer believed will be dominated by more than nickel (Ni). For example, it could be dominated by chromium (Cr) and Al (Slide 7).

The reviewer wanted to know what is the lowest k_p at the operating temperature that the team is targeting and what was that alloy? What k_p level is the research team trying to get to?

The reviewer suggested that the talk should have a summary slide on the mechanism(s) and model(s) around which the ML and some sort of ranking of the mechanisms take place to avoid teaching mechanisms with a limited effect. Basically, how were the ML values predicted?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project team introduced ICME-based physical constraints to the ML model. Nichrome (NiCr)-based alloys with better oxidation resistance were predicted. Hopefully, the reviewer noted, these data can be provided to the experimental team to further evaluate these alloys.

Reviewer 2:

Good progress has been made toward the goal. It would also be nice to show what missing gaps are in the data that are required to arrive at an optimized experimental alloy based on the oxidation prediction behavior. The reviewer thought that 18 degrees of freedom is very challenging. A more detailed focus on microstructure experimental and ICME could be helpful to reaching the researcher's goal.

Reviewer 3:

The reviewer indicated that good progress has been made if all that is trying to be done is to match the k_p of available alloys to the experimental data. How bad is the best alloy that is available today? What is the research team's goal and how far is the team from the goal or metric?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The researcher is a good metallurgist, but the reviewer opined that collaboration with a data scientist could help reach a good model to predict corrosion and oxidation.

Reviewer 2:

There is good collaboration between national laboratories, universities, and Industry. The reviewer would have liked to see an engine builder on the team.

Reviewer 3:

The reviewer was not clear how the tasks are distributed among the project teams. It seems the majority of the work was done by ORNL.

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 state project ended.

Reviewer 1:

The reviewer said that it appears the project is about to end in September 2021.

Reviewer 2:

The reviewer stated that proposed future research was not exactly shown during the presentation. More work on alloys with titanium (Ti) additions besides the main ones of Ni22Cr+xAl and one Ni22Cr+xAl+yTi could also help.

Reviewer 3:

This reviewer asked what the research team hopes to predict at the end and whether the team will make alloys if ML says something unusual. What about titanium aluminide (TiAl) and other alloy systems, or is it only NiCr? The reviewer further inquired as to whether the team has exhausted this well-studied system and if it is time to move on.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, if the new materials could allow the engine to run hotter, then the engine would be more efficient and have a lower carbon footprint.

Reviewer 2:

The reviewer would have answered “yes” if the research team were trying to make a big change, but the team is too focused on NiCr-based alloys that have already been studied in great detail. Also, there are too many factors other than temperature that drive fuel economy of engines. How will the team predict the unknown?

Reviewer 3:

The project seems to support the overall DOE objectives by developing tools to quickly narrow down the alloy systems with good corrosion and oxidation resistance. However, the reviewer was still struggling to understand how effective this project and approach can be. The effort proposed and made in this project does not seem to address the barriers listed by the project team. For example, “lack of fundamental alloy oxidation data (e.g., atomic mobilities in oxides, oxygen permeability)” seems to remain a barrier after the completion of 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 observed that the researcher has completed a lot of work in just Quarter (Q)1 of FY 2021 and Q2 of FY 2021.

Reviewer 2:

The reviewer opined that ORNL has sufficient computation resources to achieve the project.

Presentation Number: mat163
Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components
Principal Investigator: Mei Li (Ford Motor Company)

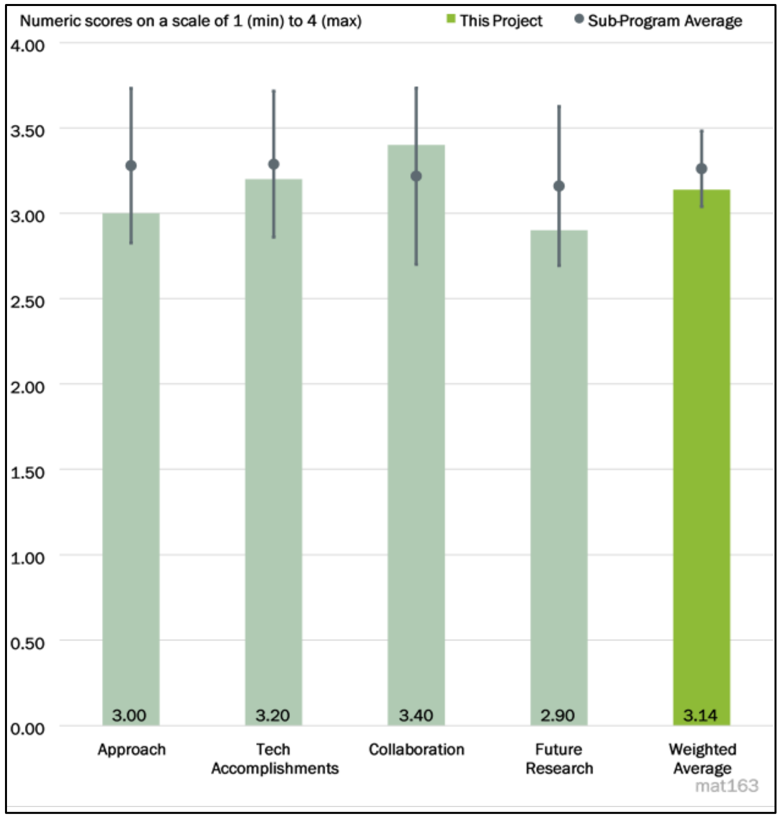


Figure 6-7 - Presentation Number: mat163 Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford Motor Company)

Presenter

Mei Li, Ford Motor Company

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The researcher has done a good job with the approach being both theoretical and experimental. The use of density function theory (DFT), ReaxFF molecular dynamics (ReaxFFMD), potential energy landscape (PEL), and diffusion-controlled phase transformation (DICTRA) was very interesting to the reviewer.

Reviewer 2:

The approach consists of applying a number of existing models (at different scales) and validating them through oxidation and thermomechanical fatigue simulations. Whether the models lead to any real insights or whether they serve as an exercise in complex curve fitting was not clear to the reviewer. Given the complexity of the physical phenomena being modeled, the reviewer thought that it may be the latter.

Reviewer 3:

While the individual ICME approaches intended to be used in the project are good at their respective length scale, the approach outlined to integrate among these ICME tools has a weakness. Also, atomistic simulations (DFT and ReaxFF) appear to be limited to very simple alloy systems (such as pure Fe or simple binary and ternary) instead of engineering alloys. Also, it was not clear to the reviewer how thermochemical fatigue (TMF) was predicted from the computational approaches in the project.

Reviewer 4:

The presentation should have included the barriers to deployment, but they are not specifically presented. The reviewer could infer what the research team is trying to do, but the actual failure modes that this is preventing are not presented.

According to the reviewer, it would improve the project to state what the barrier to deployment is and what the research team is trying to prevent from happening. The work jumps into issues that occur at a molecular level but does not relate that to in-service issues. Also, there are no data on possible cost implications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The multi-scale modeling of the oxidation process is well presented and the use of several existing models in tandem is a great approach. Understanding the contribution of each type of fatigue on the failure process is paramount in being able to design or select an alloy that is optimized in both performance and cost. The reviewer asserted that nice work has been done in this area.

Reviewer 2:

Good development has been made in understanding oxidation layer growth kinetics and the "elephant skin" surface structures that result in low TMF life and measuring the oxidation layers and failure analysis while comparing it to the predicted data. The reviewer indicated that a lot of good work has been completed between the last AMR and today.

Reviewer 3:

The reviewer noted that progress this year was good although it slowed down compared to the original plan due to COVID-19. Progress was made on both the experimental and modeling fronts such that this project is moving toward a successful conclusion.

Reviewer 4:

The theoretical components of the project appear to be too focused on the lower length scale, and it was not clear to the reviewer how these results can be correlated with the actual situation. Experimental evaluation is excellent and thorough; however, it is hard to connect to the theoretical studies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the Principal Investigator (PI) has assembled wonderful collaboration between industry (Ford Motor Company) and academia (Ohio State University, the University of Michigan, and Missouri University of Science and Technology) and national laboratories (ORNL).

Reviewer 2:

The reviewer praised the collaboration as excellent for the present effort with an OEM lead (Ford) and multiple university and national laboratory partners.

Reviewer 3:

The reviewer indicated that this project has a good combination of different ICME capabilities and experimental validation across multiple institutes.

Reviewer 4:

Regarding collaboration, the reviewer had to make an assumption as the data and samples presented are not attributed to any source, so it is hard to understand if all the team is involved. It would be good to identify the data, image, and sample sources in the presentation so that the collaboration is visible.

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 state project ended.

Reviewer 1:

The reviewer stated that the plan for future research was appropriate, given the wider goals of the program.

Reviewer 2:

A clear plan for future research includes basic research toward understanding energic properties of the Fe/graphite interface with the presence of impurities. It is always an issue trying to get multi-scale models to translate from micro-scale to meso-scale and macro-scale. The reviewer looked forward to seeing the demonstration results on CrNi-type austenite steels.

Reviewer 3:

The future research is presented but the reviewer remarked that it would be more impactful if the implications of successful completion of the listed tasks were explained. This is also more focused on the tasks and not the impact of the project.

Reviewer 4:

The reviewer asserted that theoretical components of future research are too focused on atomistic length scale, which cannot provide insights into long-term and large-scale phenomena that are relevant to corrosion and oxidation of alloys.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The project addresses a critical scientific gap for the thermomechanical fatigue life prediction of a material susceptible to oxidation damage. The generated knowledge will serve the larger community as well, according to the reviewer.

Reviewer 2:

The reviewer stated that this project is highly relevant to the DOE VTO mission.

Reviewer 3:

The reviewer commented that the development of heat-resistant alloy solutions meets the increased exhaust temperature requirement, which leads to reduced automotive emissions and a lower carbon footprint.

Reviewer 4:

The presentation explains that this project supports increased combustion temperatures, and that, in turn, leads to lower emissions, but lacks details about how this is necessary for that. The reviewer could infer that this is just a cost optimization activity from the presentation, but more information on this would help align it to the objectives.

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

Reviewer 1:

The multi-scale modeling requires a tremendous amount of resources, but the reviewer remarked that the PI is using the resources very well.

Reviewer 2:

The reviewer noted that the pandemic has affected the team's original timeline, and the researchers are rebounding.

Reviewer 3:

According to the reviewer, the project has sufficient and appropriate resources to carry out the research.

Reviewer 4:

The reviewer deemed resources available to be sufficient.

Presentation Number: mat164
Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials
Principal Investigator: Michael Tonks (University of Florida)

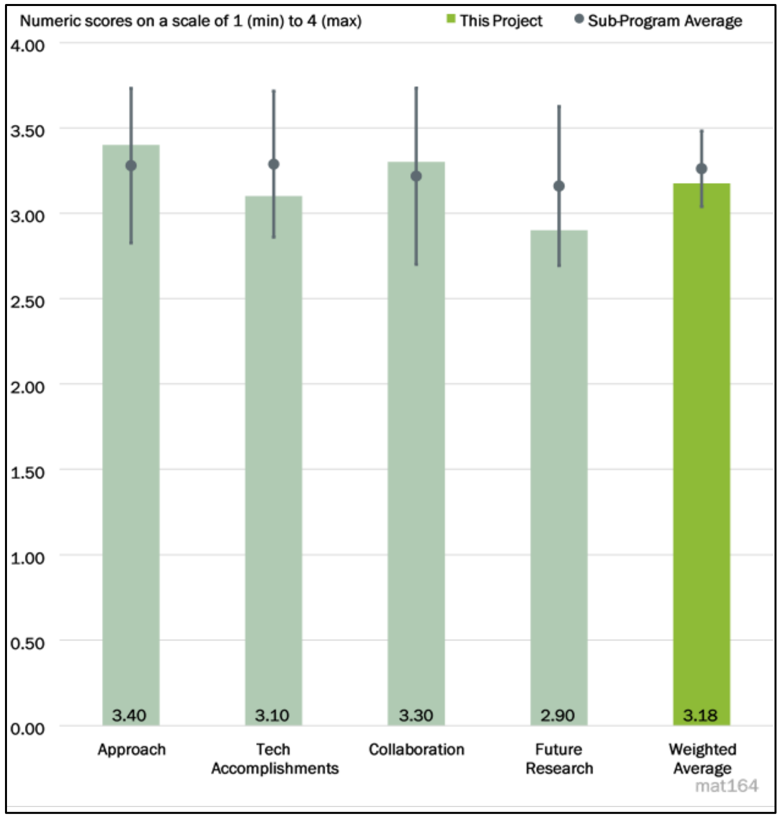


Figure 6-8 - Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida)

Presenter

Michael Tonks, University of Florida

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the PI's approach is good toward the goal of Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High Temperature Engine Materials. The calculations with DFT and MD being used to determine diffusion barriers was very interesting to the reviewer. The PI also investigated the diffusivity of metallic species in both alloy and oxide phases. The reviewer indicated that using the Idaho National Laboratory (INL) object-oriented C++ finite element framework for developing the tightly coupled multiphysics solvers multiphysics object-oriented simulation environment (MOOSE) program is a good approach toward this goal.

Reviewer 2:

There is a very clear set of expectations, and the project is well presented. It was clear to the reviewer what the research team intends to achieve and what barriers are needed to overcome.

According to the reviewer, it would improve the presentation if the team would quantify the extent and expense of current mandated "conservative design." This could be a huge win or maybe just a small victory, based on how conservative the design is, so that should be quantified. It could be as simple as comparing the recommendation from the project to the current production material in a real-world application at the end of the project or using historical data.

Reviewer 3:

The reviewer wanted more information on the following: What are the operating mechanisms being addressed by the tool? The multi-scale approach is shown, but what all goes into the model? It is interesting that higher Cr is not necessarily better. Is there anything specific to learn from this observation?

Reviewer 4:

This project envisions streamlining theoretical and experimental tasks at different length scales. While it is a highly ambitiously designed project to tackle grand challenges, some components heavily rely on input parameters for simulations. Also, MOOSE oversimplifies the mechanism of complex alloys oxidation scale formation and growth, and again, it highly depends on the parameters for the simulations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researcher has made good progress by using both theoretical and experimental data. The model was used to investigate mechanisms for oxide growth and then compares the results to the experimental data. The diffusion behavior, DFT, and MD are interesting. The vacancy transport and stable spinel are good accomplishments.

Reviewer 2:

The reviewer noted excellent conclusions/observations: oxide growth is limited by p-type MnCr2O4 spinel inner oxide growth; and 21Cr-2Ni-8.5Mn has parabolic growth but spallation was observed in 23Cr-8Ni-1.5Mn body-centered cubic (BCC) transformation near metal and oxide interface due to Mn depletion.

Reviewer 3:

It was clear to the reviewer that the research team is completing the process and working toward the deployment of the code. The details are well represented and clearly defined. It is very nice that the team has included a Gantt chart to explain the progress and what is happening next. It is, however, a concern that the tool does not yet consider the impact of microstructure or alloy composition. This is cited as an issue, but no resolution is offered.

Reviewer 4:

The team's accomplishment on atomistic calculations is good; however, it was hard for the reviewer to connect to the larger scale phenomena. Also, the SStAC tool appears to handle "flat" metal and oxide interfaces efficiently, but it is not clear how all of the parameters (such as diffusion kinetics and atomic mobilities of all of the species that participate in the oxide scale growth) are obtained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that the PI has assembled a wonderful collaboration between industry (Tenneco), academia (University of Florida and University of Wisconsin), and national laboratories (INL).

Reviewer 2:

The presentation clearly cites what entity created the data for this, making it obvious to the reviewer that the team collaborated and has leveraged resources from each of the participants.

Reviewer 3:

The reviewer found good collaboration between university partners and industry material suppliers.

Reviewer 4:

The team consists of individuals with diverse research expertise and backgrounds, according to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the researcher has to get to the point of using computer coupling of phase diagram and thermochemistry (CALPHAD) free energy bands of Mn and Cr and incorporating them into the model.

Reviewer 2:

The reviewer stated that the project offers a good proposed future research plan.

Reviewer 3:

While the presentation states that the research team is recommending adding alloy composition and microstructure from a mesoscale range, the issue for the reviewer is that these properties are driven at a much smaller scale and there is no opportunity to understand that relationship and add it to the model.

Reviewer 4:

The tool will explain the behavior within a certain boundary of chemistries. How is direction for a better alloy being defined? Can the tool be used to get out of this alloy system and develop a tool that looks at other alloy systems because not much more can be done with this alloy system? Although the reviewer noted that work did show that BCC transformation near the metal/oxide (M/O) interfaces due to Mn depletion was important, how can the depletion be reduced? While the work focuses on nanoscale phenomena, are there any micron-sized phases whose interfaces could be the problem?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the use of the SStAC tool for high-temperature engine materials will allow the engines to run hotter, be more efficient, and have a lower carbon footprint.

Reviewer 2:

The reviewer said that this project is highly relevant to DOE objectives.

Reviewer 3:

The presentation says that the SStAC tool must predict a corrosion rate with less than 10% error. It is not shown to the reviewer that this level of accuracy is sufficient or what level is necessary. Why does it have to be less than 10%? How would it change the capability if it were 20% or 5%?

Also, the presentation never ties this directly to an initiative at anything larger than a component scale. The reviewer wanted to know what the important is of getting this 10% ability in the model and whether it will change in the engine performance.

Reviewer 4:

The reviewer responded that the answer would have been “yes” if the team were trying to make a big change. How will the team predict the unknown?

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

Reviewer 1:

The predictive modeling of corrosion sensitization of valve steels at high temperatures requires a lot of resources but the reviewer said that the PI is using the resources well.

Reviewer 2:

The research team is on track to complete the project. The reviewer noted that nothing is missing. Additionally, the team is clearly not working ahead. It looks like the resource level is correct.

Reviewer 3:

The reviewer commented that the resource level is sufficient, at least from the list of contributors.

Reviewer 4:

The project has a sufficient level of funding to perform the proposed research, according to the reviewer.

Presentation Number: mat173
Presentation Title: Self-Sensing Fiber-Reinforced Composites
Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

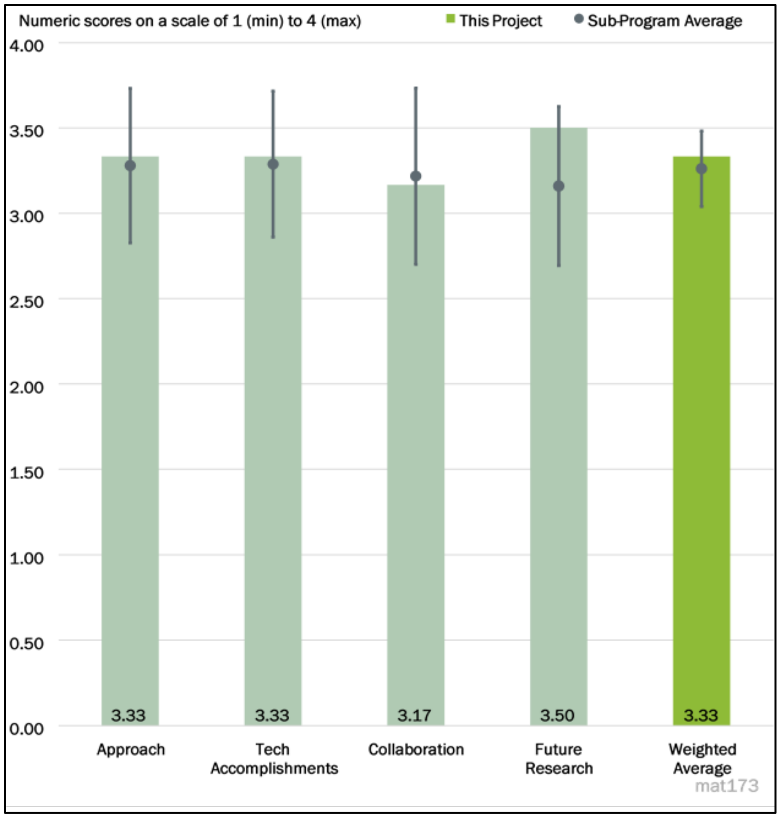


Figure 6-9 - Presentation Number: mat173 Presentation Title: Self-Sensing Fiber-Reinforced Composites Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Presenter

Christopher Bowland, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work has evolved since 2019. Overall, the concept is the use of titanium oxide nanoparticles with CFs to aid in structural health monitoring applications. The proof of concept was demonstrated via straining of the coated CFs to measure variation in a strain field. The interlaminar shear strength was optimal in the 1–2.5 weight percent (wt.%) range. Overall, the concept has been proven through systematic studies. The illustration of basalt-coated barium titanate ($BaTiO_3$) with CF as a hybrid system was demonstrated, which seemed to be an advancement to the reviewer.

Reviewer 2:

The project approach was well executed through testing various concentrations and their effect on material performance. The work also evaluated the effect of resistivity related to concentration and strain. This is an excellent approach to determine the gauge factor. The reviewer was impressed with how high the gauge factor was in relation to traditional strain gauges of two. The reviewer thought that the most challenging data to collect with this system will be the measurements transverse to the fibers, and they may be the most sensitive to strain. The concentration effects may be different on the transverse resistivity.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed a nice job of reaching and exceeding the target goals. Additionally, the milestones and metrics were all exceeded. The reviewer explained that one thing that could have improved the performance metric is comparing the measurements to a conventional strain gauge or using a strain gauge and comparing real-time data between the two.

Reviewer 2:

The project made advances in fabrication of multi-functional composites with a Ti-based coating of carbon (C) and basalt fibers and characterization of the interlaminar shear strength (ILSS). The research team demonstrated and characterized the active and passive sensing capabilities. For passive sensing the team used a hybrid composite approach. Researchers illustrated the power generation of the hybrid composite in response to strain. Overall, the reviewer found that the set milestones were aligned with the accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The main listed collaboration partner was Dronesat, LLC, although it was not entirely clear to the reviewer at what stage Dronesat got involved with the project or if there were beneficiaries of the work after the technical tasks were accomplished. The technology has a broad range of use. However, in this project the collaborations were rather limited and there was less emphasis on broadening the collaborations. The project team engaged interns in the effort, as evidenced by the illustrations.

Reviewer 2:

The project transitioned to a company collaborator looking at a specific application. The project did not have initial industrial participation. According to the reviewer, the project has lots of opportunity to transition to industry participation.

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 state project ended.

Reviewer 1:

The reviewer commented that the project has ended, but the team did transition to a new project with an industry collaborator.

Reviewer 2:

The reviewer said that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The DOE objectives of lowering embodied energy and increasing the life span of structures align with this effort. The overall effort has a broad range of applicability in structural health monitoring of wind blades, power plants, structures, buildings, aerospace, and automotive components as examples. This project had limited collaboration; however, the reviewer said that the technology can apply to these areas.

Reviewer 2:

The reviewer stated that real-time monitoring of damage in composite materials can improve processing evaluations, in-use composite performance measurements, and safety. This would reduce material waste and increase material component use without prematurely removing from the service.

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 ORNL team has all the resources to conduct this work within the organization, such as CF and coating technologies, mechanical testing, electronics and electrical measurements, and the microscopy and evaluation facilities.

Reviewer 2:

The reviewer asserted that the project was completed in a timely fashion with excellent results to show for the money spent.

Presentation Number: mat174
Presentation Title: Carbon-Fiber Technology Facility (CFTF)
Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

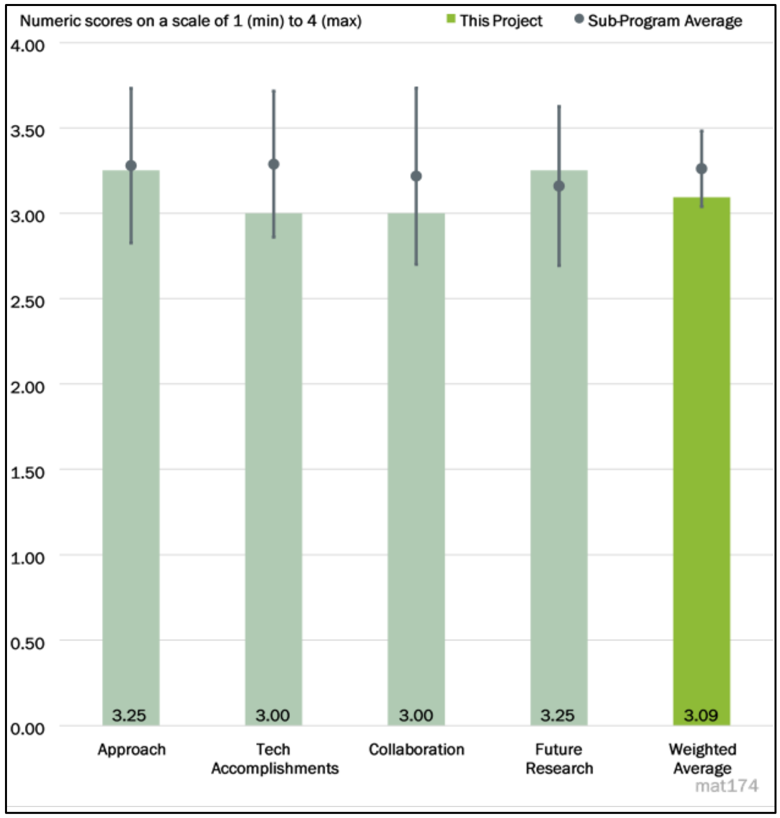


Figure 6-10 - Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

Presenter

Merlin Theodore, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the Carbon Fiber Technology Facility (CFTF) is a unique R&D facility that helps pilot-scale and industry-scale research. The approach includes low-cost conversion of polyacrylonitrile (PAN) and the development of alternative precursors. The projects are well designed and very feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the precursor fiber lines and conversion processes/lines are well designed and help reduce CF costs. Further, the reviewer stated that alternative precursors are promising toward meeting DOE targets.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration at CFTF has been excellent. The reviewer remarked that the team has been working on projects with universities and industry 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Several projects have been planned and are on track. The road maps and target metrics made sense to the reviewer. The decision points and barriers are well considered. It would be helpful if more CF companies are involved in the CFTF for their R&D.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The VTO project at CFTF supports the overall DOE objectives. The reviewer opined that low-cost CF is critical for EVs and low-C emissions.

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

Reviewer 1:

The CFTF has sufficient resources for lab-scale, pilot-scale, and industry-scale CF research. According to the reviewer, the VTO project at CFTF has achieved the stated milestones in a timely fashion.

Presentation Number: mat183
Presentation Title: High-Temperature Coatings for Valve Alloys
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

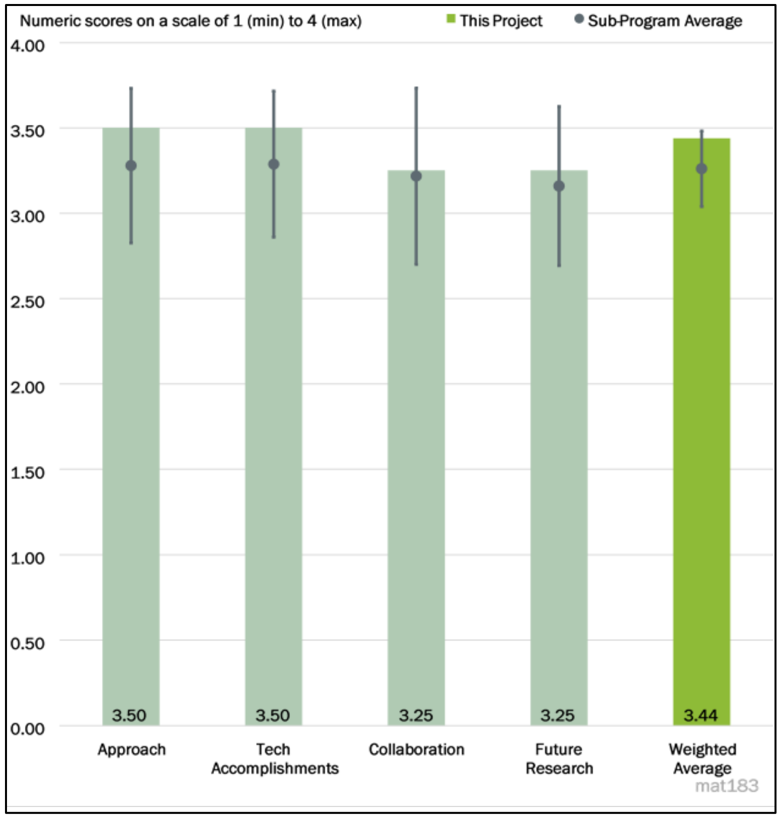


Figure 6-11 - Presentation Number: mat183 Presentation Title: High-Temperature Coatings for Valve Alloys Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer identified High-Temperature Coatings for Valve Alloys - Research Thrust Area 2A3: Cost Effective Higher Temperature Engine Alloys (with some additional funding provided by Subtask 4B – Advanced Computing) under the Powertrain Materials Core Program (PMCP). The approach used to investigate the impacts of many different materials for powertrain use in the Powertrain Materials Core Program (PMCP) is excellent, according to the reviewer.

This approach will be used to Improve elevated temperature oxidation resistance of high-strength valve alloys. The reviewer noted that this process will accelerate coating development time in a cost-effective manner that will ensure compatibility between the alloy substrate and the coating.

By developing and applying an oxidation-resistant alumina-forming coating on a chromia-forming substrate, the reviewer stated that there is an opportunity to place oxidation-resistant coatings on the highest temperature regions of valves, which could significantly improve component lifetime at temperatures greater than 850 degrees Celsius (°C). These high temperatures are common in newly developed, highly fuel-efficient internal combustion engines (ICEs).

Reviewer 2:

The reviewer found that the project efficiently identified a key ingredient (Ti) to prevent oxidation on Al alloys and successfully demonstrated it through tests.

Reviewer 3:

The project is an ideal test bed for the evaluation and transfer of technology that is proven in other applications (aerospace) to more broadly distributed applications in the automotive sector. The proposed approach and supporting micrography are what would be expected of ORNL work and are very supportive of the conclusions being drawn. A broader study using alloys that are expected to have different phase kinetics at the surface would have been extremely interesting to the reviewer, but the team seems to suggest that this gap will be addressed by developing the appropriate models (direct comparisons of alloys 31V to ORNL-1 are presented so there are some examples of different behaviors). The project budget is not exorbitantly large, so this may be one of the obstacles to a broader evaluation of substrates. The actual limited-scale evaluation of a valve would be extremely helpful, also. The interaction between the coating and a valve seat insert may present additional problems that will require some investigation.

Reviewer 4:

The reviewer commented that the approach is excellent. Using coatings on engine valves to improve the oxidation performance is a reasonable approach. Comparing the performance on multiple alloys is nice. No planned engine testing is a negative because the engine conditions will vary significantly from the laboratory testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researchers have proven to the reviewer that it is possible to coat these valves. Slurry coating significantly improved the oxidation behavior of alloys 31V and ORNL-1. However, 31V had a decrease in strength. Critical coating thickness was determined to be a 40 micrometer (µm) coating on ORNL-1 to achieve the higher operating temperature of 950°C. Optimization of the substrate and the coating will be critical to developing a commercially viable product. The ICME approach is an excellent approach to determining this optimization. Leveraging the coupled thermodynamic and kinetics model developed to optimize coatings and predict lifetime was done in PMCP Thrust 4b. The model and characterization have good parallels that can be applied to this project.

Reviewer 2:

The coating performance is encouraging. The impact of Ti on the coating performance was interesting to the reviewer, and the potential of optimizing an alloy to work with the coating is exciting.

Reviewer 3:

Microstructures, phase maps and profiles, and mechanical testing are all present. A case is clearly being made that the approaches are going to provide some level of benefit. The fatigue test results are less compelling to the reviewer than what would be expected. The resistance to oxidation would be a major benefit to fatigue crack prevention, and yet the actual fatigue performance bump is very modest. Is the benefit being offset to some extent by a higher propensity for mechanical cracking on the coated surface?

Reviewer 4:

The project has almost accomplished its initial goals. It would have been better if the project explored more of the modeling and optimization aspect, according to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaboration with the alloy development team is a big plus for the project.

Reviewer 2:

The collaborations are appropriate for the project (there are facilities that provide the actual coating services). A broader contribution would have been interesting also, but is the reviewer understood that the capabilities of ORNL limit the need for additional assistance.

Reviewer 3:

This reviewer noted that the program lead laboratory is ORNL, and partners include Flame Spray Inc. and Stony Brook University. There is active collaboration with Thrust 2, Tasks 2A1 and 2A4; Thrust 4A Advanced Characterization; and Thrust 4B Thermodynamic and Kinetic Modeling.

Reviewer 4:

The reviewer was unable to determine this part of the question.

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 state project ended.

Reviewer 1:

In order to determine the acceptable Ti content and optimization, the reviewer asserted that it would be necessary to have a good predictive model. Also, it would be necessary to test the surface property (including wear) of the coating.

Reviewer 2:

The proposed future research is appropriate if not overly ambitious. A broader study demonstrating the manufacturability and robustness across different materials and approach combinations is likely more appropriate than optimizing an ORNL-1 alloy combination. The reviewer said that actual valve testing is needed also, as lab-scale mechanical testing has long been proven to be inadequate as an absolute substitute.

Reviewer 3:

The reviewer reported that future research under this project will focus on the following four activities:

- Determine acceptable Ti content in substrate for excellent coating oxidation resistance at 900°–950°C—optimizing the Ti content in the substrate is critical to keeping costs down.
- Determine optimum substrate and coating combination. The fatigue life is similar to the coated ORNL-1 alloy sample with superior oxidation resistance.
- Conduct fatigue testing in corrosive environment to demonstrate coating benefit.
- Investigate coating homogeneity on an actual valve.

The reviewer suggested that the researchers should consider testing a coated valve in an engine (currently outside the scope of the current project). This would be a good next step for this project.

Reviewer 4:

According to the reviewer, the plans are reasonable and address the remaining barriers.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 2:

The reviewer said that the work is highly relevant.

Reviewer 3:

High-temperature coatings would support the overall DOE objectives, according to the reviewer.

Reviewer 4:

The project has broader implications than vehicle components, although the reviewer opined that engine valves provide an ideal test bed for components subjected to demanding conditions that are prone to failure in fatigue. Coatings, if they can enhance the performance of materials that are lower in cost, would be attractive in other areas as well.

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

Reviewer 1:

The period of performance is October 2018 until September 2023. The reviewer commented that 50% of the project is complete, and it is on schedule. The FY 2020 budget was $170,000, and the FY 2021 budget was $160,000. The reviewer further reported that the project is on schedule, and the funding appeared sufficient to complete all current and future objectives.

Reviewer 2:

The reviewer noted that the project progress demonstrates that the resources are sufficient for the stated goals, as milestones are being achieved.

Reviewer 3:

It appeared to the reviewer that the provided resources are sufficient for the project.

Reviewer 4:

The reviewer said that resources are sufficient.

Presentation Number: mat184
Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys
Principal Investigator: Yuki Yamamoto (Oak Ridge National Laboratory)

Presenter

Yuki Yamamoto, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

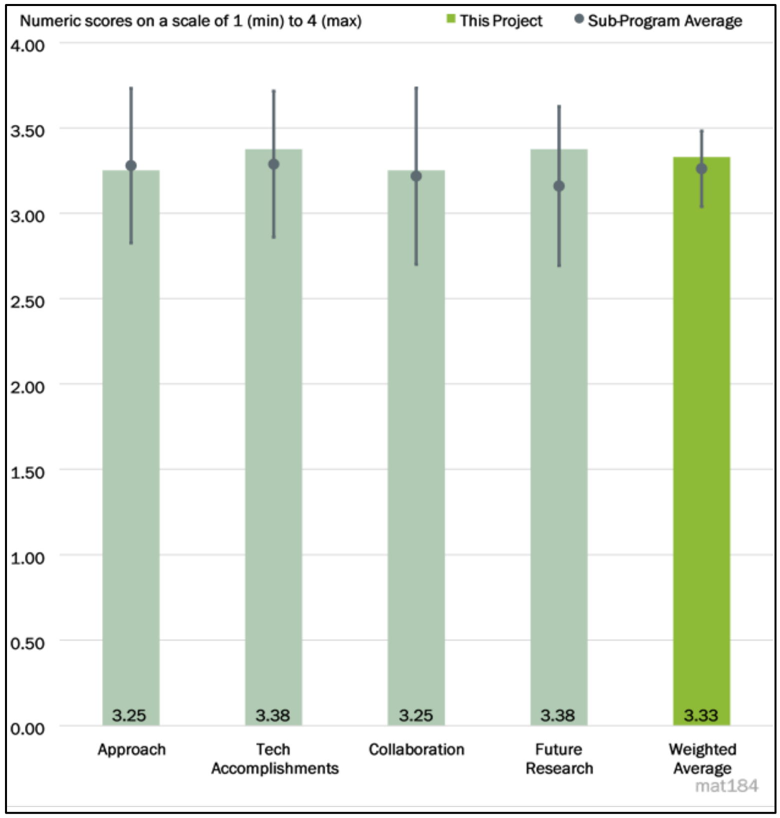


Figure 6-12 - Presentation Number: mat184 Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys Principal Investigator: Yuki Yamamoto (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is solid, with work this year focusing on process development and optimization to improve the alloys and push toward the technical targets of greater than 900°C. The team is doing a nice job exploring unexpected findings as they arise and exploring root causes. It was helpful to the reviewer that the project team specified the quantitative performance targets this year. Some additional statistical work would be helpful to interpret the results with confidence levels.

Reviewer 2:

The reviewer liked the approach. The use of modeling to accelerate the alloy design is a nice touch. It is also very good that the research team is moving beyond the laboratory scale to industrial heat.

Reviewer 3:

In general, developing a new alloy that pushes the current limitation requires a lot of effort. The project focuses on developing Fe-based alloys that have oxidation resistance at high temperatures, increased strength and creep resistance, and low cost. This is a challenging task, as expected. Without fully understanding metallurgy, it would be difficult to overcome several limitations. Also, the reviewer noted that the project may need a clear target goal to determine its success.

Reviewer 4:

Referencing Research Thrust Area 2B1 – Development of Cast, Higher Temperature Austenitic Alloys under the Powertrain Materials Core Program (PMCP), the reviewer stated that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic for leveraging limited resources and investigating several potential solutions.

The reviewer highlighted the following regarding the Utilized ICME Type Approach to Minimize Iteration slide: alloy design; assessment with laboratory-developed tools; validation on a laboratory scale; and industrial scale up.

The approach to accomplish this project used the ICME stepwise process, which this reviewer listed as follows:

- Cast alumina-forming austenitic alloys that will provide better protection than chromia scale.
- Use ICME (CALPHAD databases) to minimize alloy selection during the iteration process.
- Validate material physical properties in the laboratory via experimentation using 1 pound or less of material.
- Evaluate production feasibility with trial industrial scale-up heats using 50 pounds or greater of material.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Overall, the reviewer found the progress to be excellent. The variation in the creep stress is one issue, but the findings that it is impacted by the yttrium (Y) composition is a necessary initial step to overcoming this.

Reviewer 2:

At the laboratory scale, it seemed to the reviewer that the achievement is significant, albeit too much variation for industry-level applications. It would be necessary to investigate the cause of large variation and identify key factors for quality control.

Reviewer 3:

Based on Slide 5, the reviewer said that one of the four quarterly milestones for FY 2021 has been completed to date with the others still somewhat delayed. The Y findings are some of the most interesting outcomes to the reviewer from the FY 2021 work thus far, so it is good that the team plans to investigate further the role of Y (positive or negative) in the alumina-forming austenitic (AFA) alloys, which will likely involve tradeoffs between oxidation performance and creep performance.

The high-temperature performance results are promising. The reviewer was curious if the project team has explored statistical significance and repeatability for the results provided (e.g., Slides 7, 9, and 14). How many samples were tested of each type to draw conclusions?

Reviewer 4:

This reviewer reported that the objective for this project was to develop Fe-based alloys for vehicle applications (exhaust manifolds and turbo housing)—greater than or equal to 800°-900°C and greater than 260 bar for heavy duty; and greater than or equal to 950°-1,000°C and greater than 103 bar for light duty.

By using alumina (Al_2O_3) scale formation (AFA alloys), improved oxidation resistance can be achieved.

A lab-scale heat of newly developed ORNL-AFA (AFA5, Fe-22Ni-17Cr-4Al base) achieved the balanced properties of oxidation resistance, creep rupture property, and inexpensive raw material cost (comparable to the benchmark steel) and will be moved toward scale-up through the industrial metal process. The reviewer stated that centrifugally cast AFA ingots (in another project under the Advanced Research Projects Agency-Energy [ARPA-E]) exhibited more consistent mechanical properties (good quality cast AFA type alloy is possible).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration seemed good to the reviewer between multiple national laboratories and industry.

Reviewer 2:

The collaboration seemed reasonable to the reviewer, and the research team seems to be coordinating the work between collaborators.

Reviewer 3:

The reviewer stated that the program lead laboratory is ORNL and partners include the Advanced Photon Source (APS) at Argonne National Laboratory (ANL) and the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest National Laboratory (PNNL). The industry partner, MetalTek International (materials supplier subcontractor), is working closely with Thrust 4B researchers. An example of laboratory-to-laboratory collaborations was ORNL working with PNNL on "Microstructure Characterization to Understand Improved Creep Performance in Lab-scale Cast AFA5." The reviewer indicated that there is no interface with universities for this project.

Reviewer 4:

Partnerships are in place through the PMCP, though it was a bit unclear how closely knit the collaborations were in this specific project because all the external partners seem to be working under Thrust 4 while this project falls under Thrust 2. There was one mention of a PNNL collaboration and no mention at all of ANL, though both are listed as contributors to this project. The reviewer wanted to see more detail on the inter-thrust collaborations. Industrial partner MetalTek produced the cast ingots and seems to have had some good collaboration with ORNL in process optimization for AFA alloy casting.

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 state project ended.

Reviewer 1:

The future plans are good and address the observed barriers and issues. The reviewer noted that the investigation into alternatives to Y is especially important.

Reviewer 2:

Proposed future work seemed appropriate and valid to the reviewer. A major focus should be on the September go/no-go decision to initiate scale-up of cast AFA for exhaust components.

Reviewer 3:

The reviewer opined that it would be better if the future research focuses more on understanding the metallurgy and parameter study to identify dominant factors for quality control.

Reviewer 4:

The reviewer suggested that quality improvement of commercially cast components is still needed, including melt temperature, pouring technique, mold design, and others requiring improvement for manufacturing processes, and alloy design modification and compositional optimization for material characteristics.

The reviewer commented that downselected cast AFA5 moved to scale up through industrial melt processes and led to excellent oxidation resistance at 950°C comparable to the laboratory-scale heat. The observed variation of creep-rupture performance was due possibly to inhomogeneous defect formation and/or local high Y level impacts.

Investigating the source of the creep-performance variation led to relatively high Y contents in industrial heats, researchers considering the combined effect of aluminum oxide and the mold size, and proposing both allow and process optimization, which are currently in progress.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles. It was noted that alumina-formers may also offer enhanced resistance of attack from alternative fuels, such as natural gas, biofuel, or hydrogen.

Reviewer 2:

The reviewer stated that the work is highly relevant.

Reviewer 3:

The project is closely related to the overall DOE objectives, according to the reviewer.

Reviewer 4:

The reviewer said that this project supports DOE objectives related to lightweighting and high-temperature materials performance.

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

Reviewer 1:

Several milestones were delayed because of restricted access to the laboratory during the COVID-19 pandemic. Although this project’s schedule has slipped, the reviewer commented that resources remain adequate as activity was delayed and funding should be sufficient.

Reviewer 2:

It seemed to the reviewer that the project team has enough resources to develop the new alloy.

Reviewer 3:

Resources appeared to be sufficient to the reviewer for this effort.

Reviewer 4:

The reviewer said that resources are sufficient.

Presentation Number: mat185
Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

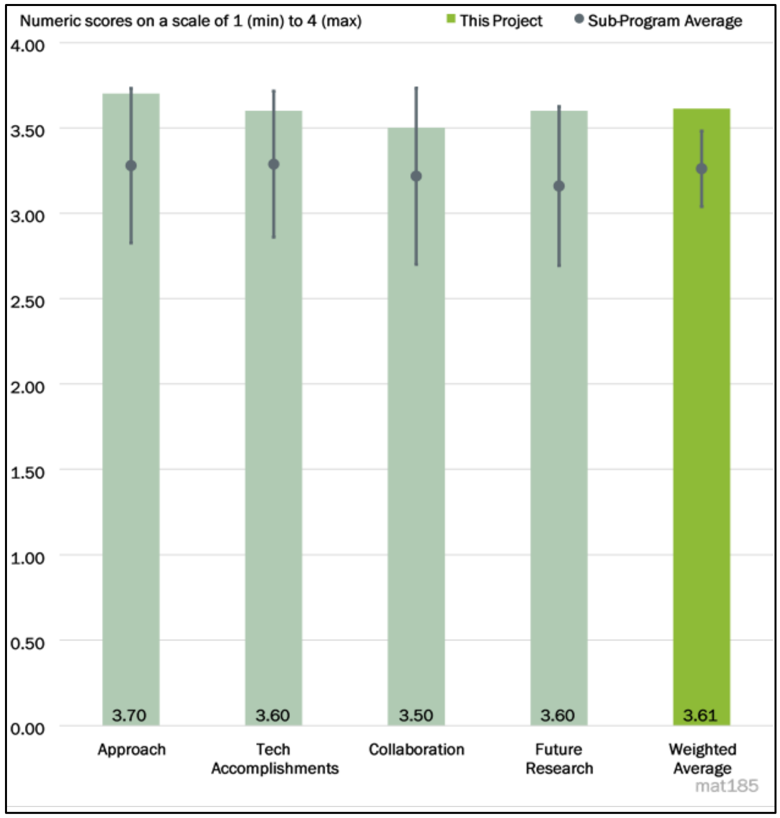


Figure 6-13 - Presentation Number: mat185 Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach addresses a method that enables accessing new material properties with conventional alloys using an additively manufactured reinforcement and preform process and a vacuum melt infiltration method to address two of the technical barriers that are identified in the presentation. Advanced materials characterization, tensile testing, and modeling of the results are described that address the ability of the new materials to withstand the high-energy impact forces experienced by pistons in a combustion engine. The reviewer affirmed that this is an outstanding technical approach to solve the problems with high-temperature engine environments.

Reviewer 2:

The reviewer remarked that this is a great project that is well balanced between modeling and experimental work. This is essentially an extension of composite material in three-dimensional (3-D) printing. The real impact can be expected if the feature size of a 3-D printed structure is further reduced, and infiltration can reduce the size and number of pores. It was especially great that the PI explored the possibility of damage de-localization, which can be a major issue in material performance.

Reviewer 3:

The project aims to address piston failure from knock and stochastic pre-ignition (SPI) rouge cycles in excess of 300 bar, abnormal (knock) events. These knock events can be catastrophic failures, even for a single event. Additive manufacturing (AM) processes can create heterogenous materials that provide target material characteristics. This allows the researchers to locally tailor the material to the preferred mechanical properties for the material. The reviewer stated that this is a direct approach to produce multi-metallic components while enabling opportunities for lightweighting. Researchers are also investigating micro features with digital image correlation. By using finite element analysis (FEA) modeling, researchers can "see" into the material.

Reviewer 4:

The project is well designed and well planned. According to the reviewer, the technical barriers have been addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

A significant technical accomplishment was the demonstration that a change in the volume fraction of 316L stainless steel will significantly increase the energy to fracture a composite material test sample. This finding was supported by FEA that showed that damage and failure occurred in a single localized location in the material and that the increased volume fraction helped to distribute the load that was applied. The analysis also showed a significant finding of the effect of a bending load on the lattice structure at the node junctions, and these findings were supported with microscopic analyses. According to the reviewer, another significant technical accomplishment was the use of hot isostatic pressing (HIP) to close the pore structures in the Al alloy and the composite 316L/A355 material, thereby reduces debonding at the composite interface. This interface bonding was shown to affect the mechanical performance for strength and ductility when the interface is removed but reduces energy adsorption potential when the bonding is strong. These are all outstanding technical accomplishments.

Reviewer 2:

The reviewer asserted that the project shows top-notch research on designing, building, and testing an AM composite that can show damage delocalization. This is really a boundary between AM and conventional composite materials. The research is well balanced by modeling and simulation and testing.

Reviewer 3:

Special focus is given to the interface and shock modeling was also developed. This aligns with the researchers' attempts to delocalize damage enabled by dramatic energy to fracture improvements (by five times). This provides high damage absorption potential for extreme conditions. Also, the researchers found that bonding is critical in energy adsorption. Other applications that require energy adsorption material properties can use these materials. The reviewer commented that progress has been made to develop high damage tolerance materials with a novel early stage, bi-metallic system.

Reviewer 4:

The reviewer said that the team presented the combination of digital image correlation (DIC) measurements and FEA model analyses that revealed the mechanism by which the PrintCast composites' energy absorption property transitioned under uniaxial tension. The team investigated the role of interface between constituents and characterized the interface systematically. The team produced one journal paper, and two manuscripts are under preparation.

The post-processing of HIP effectively closed the interface gap. However, the HIP is not an efficient process to be applied in industrial manufacturing. The reviewer encouraged the project team to develop a method to replace the HIP post-process for industrial applications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is an excellent team for collaboration on this project, which included two universities (for early-stage vacuum casting development), a large service company, a Department of Defense laboratory, and internal coordination with test facilities and other project Principal Investigators at ORNL. The reviewer said that the only improvement could be the inclusion of an OEM from the automotive industry. Close coordination during the planning phase is evident.

Reviewer 2:

This reviewer described collaboration with the university, Air Force Research Laboratory (AFRL), and industry as excellent.

Reviewer 3:

The reviewer remarked that the ORNL team—in collaboration with Rice University and the Massachusetts Institute of Technology (MIT)—is well organized and has progressed the tasks effectively.

Reviewer 4:

Partners on this project include ORNL (leading laboratory), MIT, AFRL, Rice University, Quintus Technologies, and Bechtel (broader Advanced Materials Intelligent Processing Center [AMIPC] work). The team is also working closely with Task 3B1 researchers in the development of lattice material. The reviewer noted that there is good coordination among partners and a balanced team of national laboratories, university participants, and an industry 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The future research described is consistent with the approach and strategy to address the DOE VTO technical targets and barriers that will allow acceptance of the technology and models by the end-user. The next steps in this research project were logical to the reviewer and will continue to address the challenges using the new alloy systems developed at ORNL. The future work also includes a scale-up demonstration, which will be valuable for transitioning of the technology being developed.

Reviewer 2:

The future plan of studying coatings is good as it is related to many other DOE project activities. Applying the current technology to other alloys already shows some progress. Fatigue is of the utmost important performance; therefore, the reviewer said that it is important to investigate the fatigue performance.

Reviewer 3:

The reviewer stated that the researchers' next steps will be evolutionary developments toward full-scale demonstration solutions. Future work focuses on lattice geometry effects on shock loading and scale-up to component level problems.

Reviewer 4:

Future work focuses on lattice geometry effects on shock loading and scale-up to component-level problems. The reviewer asserted that it will be better to include a good post-processing method applicable to industrial manufacturing.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project directly supports the overall DOE VTO technical targets and U.S. DRIVE roadmap (which includes DOE) goals for material development and predictive modeling and simulation of high-performance materials used in internal combustion engines.

Reviewer 2:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 3:

The reviewer said that that the scope of work is well aligned with the overall DOE objectives.

Reviewer 4:

The reviewer noted that the project is closely related 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 funding is about $200,000 per year which is sufficient for the composite material development, the characterization and analysis of the new alloy compositions, the software development for failure analysis, and the scale-up demonstration. According to the reviewer, the number of researchers and collaborators are adequate for each technical area being addressed.

Reviewer 2:

This project is on schedule and the funding appeared to the reviewer to be sufficient (FY 2020 was $205,000 from AMIPC and FY 2021 was $190,000 from AMIPC) because all stated milestones have been completed on time (to date). The project is 50% complete with 50% of the schedule to go.

Reviewer 3:

The reviewer commented that the team has sufficient resources to carry out the planned tasks.

Reviewer 4:

It seemed to the reviewer that the project is progressing well with the current support.

Presentation Number: mat186
Presentation Title: Modeling of Light-Duty Engines
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

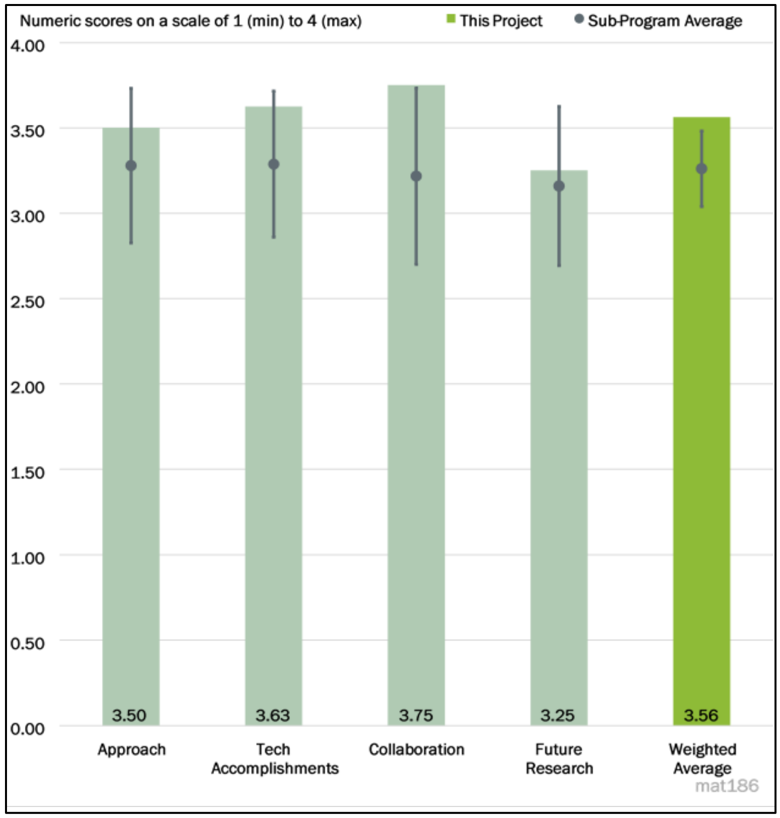


Figure 6-14 - Presentation Number: mat186 Presentation Title: Modeling of Light-Duty Engines Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the project is focused on engine modeling for light-duty vehicles. The specific outcomes are determining the engine operating conditions under various engine power densities and determining the required material properties for the engine components that will perform reliably. The project is using computational fluid dynamics (CFD) and thermal modeling to address these barriers. In addition, the project is leveraging other DOE VTO materials development projects, specifically within the PMCP, to define the material properties that would be needed for higher efficiency engines.

Reviewer 2:

This project represents a collaboration between combustion and materials scientists aimed at the development of improved computational models to assess the impact of new materials development on engine performance. The reviewer remarked that the approach involves co-simulation of combustion and materials' thermal properties that are measured for the new alloys being developed under VTO programs. It includes validation efforts together with efforts to measure relevant materials properties required as the input.

Reviewer 3:

The reviewer stated that the approach addresses defined technical barriers and is feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is a 2-year project. The team has made excellent progress in the modeling of the engine using low- and high-dimensional models to establish the engine performance and the target material properties. The reviewer said that the project in on track in terms of progress.

Reviewer 2:

The reviewer noted that good progress was documented in simulations to explore the impact of new materials on higher specific output.

Reviewer 3:

The reviewer indicated that the project is progressing relative to performance indicators and milestones.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is a relatively modest effort that nevertheless mentions sharing of methods and materials properties with a much broader engine modeling community. Explicit mention was made of the partnership with five different PMCP tasks and the Partnership for Advanced Combustion Engines (PACE) program for property inputs and validation data. It also involves collaborations with Convergent Science, Inc., in the area of model development and validation. The reviewer asserted that this is an impressive level of collaboration and partnership.

Reviewer 2:

The project team is collaborating with the other teams working on other materials development and in advanced characterization and computation thrust areas as part of the PMCP. In addition, there is external collaboration with Convergent Science, Inc., in the area of engine simulations and PACE. As evidenced by the progress, the collaboration across the various partners and collaborators appeared to be quite fruitful to the reviewer

Reviewer 3:

Collaboration and coordination are appropriate for this project, according to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The project has identified plans for future work related to light-duty and hybrid EV operation. It also mentions three other efforts, including efforts for medium- and heavy-duty vehicles. It was difficult for the reviewer to assess the degree to which these different proposed efforts are synergistic and whether more focused plans might be desirable, given the modest size of this effort.

Reviewer 2:

The reviewer said that the proposed future work is logical and appropriate.

Reviewer 3:

The future work entails further refining the models and establishing the full operating map for the engine to leverage new materials and alloys being developed and/or to guide the development of new alloys. Further, application of this effort for hybrid EVs and medium- and heavy-duty vehicles will be explored. The reviewer opined that it would be nice to have input and collaboration with an OEM to further the applicability of the modeling effort and the validation for the use of the identified engine materials.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that the project supports the large VTO investment in materials development by providing predictive models to understand the impact of these new materials on engine performance.

Reviewer 2:

The reviewer stated that this project adequately meets the DOE objectives for minimizing fuel consumption by designing and producing engines with higher efficiencies and lightweighting.

Reviewer 3:

According to the reviewer, this project is relevant to modeling powertrain performance with different materials.

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

Reviewer 1:

The resources available appeared adequate to the reviewer to support this well-focused effort.

Reviewer 2:

The reviewer commented that resources have been appropriate to address project barriers and support the approach.

Reviewer 3:

It appeared to the reviewer that the resources are sufficient to complete the work in a timely manner.

Presentation Number: mat187
Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

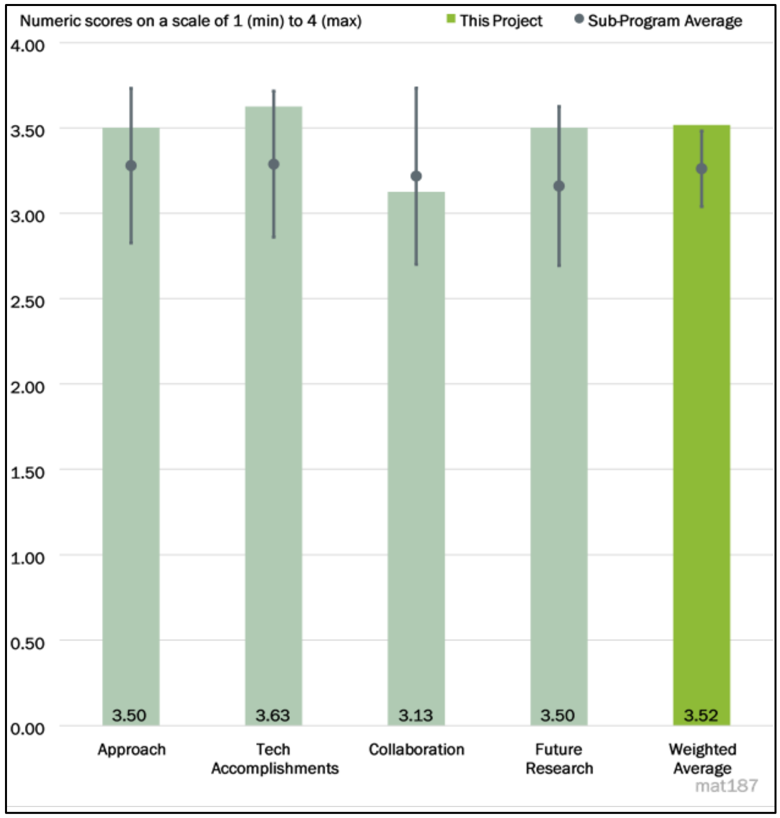


Figure 6-15 - Presentation Number: mat187 Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The researcher has a good approach to this basic research goal of understanding complex precipitation pathways in lightweight alloys. The DFT investigation of hypothesized phase transformation pathways between θ''-Al_3Cu and θ'-Al_2Cu was very interesting to the reviewer. The supercell approach for the Al matrix and Al_3Ni using high performance computing (HPC) is also a good approach.

Reviewer 2:

The reviewer found this to be an interesting opportunity to increase the temperature ranges that Al alloys are available for designs and will allow further increases in temperatures and pressures over time as these are deployed. The ability to use these alloys in components that have traditionally been cast iron is an advantage to engineers, allowing improved vehicle efficiency and safe operation.

Reviewer 3:

According to the reviewer, the project is well designed to address long-standing barriers to increasing the temperature limit of Al alloys in automotive applications. The barriers addressed include the lack of understanding associated with precipitation mechanisms and kinetics in Al alloys.

Reviewer 4:

The reviewer asserted that this is an excellent approach to identify alloys that segregate to the precipitate interface to delay transformation of theta prime to theta.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work using the DFT database of solute partitioning in Al-copper (Cu) (A206) precipitates and DFT solute segregation database at the interface between an Al matrix and Al_3Ni has shown to be very useful to the reviewer.

Reviewer 2:

The increases in temperature for Al-Cu alloys has direct application and is a major accomplishment. The reviewer remarked that this is well planned and well executed.

The Al-Ni alloys hold promise for a large array of applications if the spheroidization is overcome. This work indicated to the reviewer that that it is possible.

Reviewer 3:

The reviewer commented that this project has completed, or is on track to deliver, all milestones in characterization and modeling of precipitation pathways.

Reviewer 4:

The reviewer observed excellent accomplishments to identify solutes that segregate to the semi-coherent interfaces to stabilize theta prime in the Al-Cu system and identify zirconium (Zr) enrichment at Al/Al_3Ni to retard coarsening in that system. What was not clear to the reviewer is how those alloying additions were identified or if it were done by DFT. It is not clear if these additives have been tried by experimentalists or if this is a first.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Good collaboration and coordination appeared evident to the reviewer, based on the quality of work presented while meeting timing milestones.

Reviewer 2:

There is good collaboration between the various national laboratories, according to the reviewer.

Reviewer 3:

The reviewer said that evidence of work between PNNL, ANL, and ORNL was presented.

Reviewer 4:

The researchers have assembled a collaboration between different national laboratories (ORNL, ANL, and PNNL) and with some industry (Fiat-Chrysler Automobiles [FCA] and Nemak), but collaboration with academia (Worcester Polytechnic Institute [WPI], etc.) on this type of basic research—such as the interface between an Al matrix and Al_3Ni—could require a Big Data (industry 4.0) type of approach. The reviewer asserted that collaboration with a data scientist on this type of basic research could help to achieve the goal in a timely manner.

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 state project ended.

Reviewer 1:

Understanding the evolution of Al and Al_3Ni is a great direction. Also, the reviewer said that the idea of solute segregation at the interface has a lot of promise. Nice work has been done by the team to define the actual accomplishments and then use those to map out the next set of required data.

Reviewer 2:

The work on the construction of a DFT solute segregation database at the interface between an Al matrix and Al_3Ni is very interesting. The research team is going to determine if it is possible to mitigate detrimental spheroidization of Al_3Ni microfiber via solute segregation. The reviewer was looking forward to reading the paper on neutron diffraction analysis of deformation in a thermally stable Al alloy at room and elevated temperature.

Reviewer 3:

According to the reviewer, the project's future plan is well aligned to address barriers in lightweight alloy development with reasonable next steps building on previous accomplishments.

Reviewer 4:

It was not clear to the reviewer if the multiple solute segregation effects can be successfully handled by DFT.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project work in characterizing, modeling, and applying the fundamentals of precipitation kinetics to engineer new alloys is critical to DOE objectives for accelerating the development of lightweight alloys for automotive applications.

Reviewer 2:

The reviewer affirmed that, yes, either higher temperature engines or Al lightweight brake calipers will allow for more efficiency and will lower the carbon footprint of a vehicle.

Reviewer 3:

According to the reviewer, lower mass always improves vehicle efficiency, and this also has improvements in thermal conductivity.

Reviewer 4:

The reviewer found good work driving the lightweighting research.

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 more resources could speed knowledge, and this is a great area to add additional resources due to its high impact.

Reviewer 2:

The reviewer stated that the project is sufficiently funded to deliver the plan.

Reviewer 3:

The reviewer noted that this type of basic research takes a lot of resources, and the project team has three national laboratories working with the team on this subject. Again, a university data scientist might be an additional resource to help arrive at the goal in a more timely manner.

Reviewer 4:

It was unclear to the reviewer whether all the work being comprehended is contributing to the outcome.

Presentation Number: mat188
Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

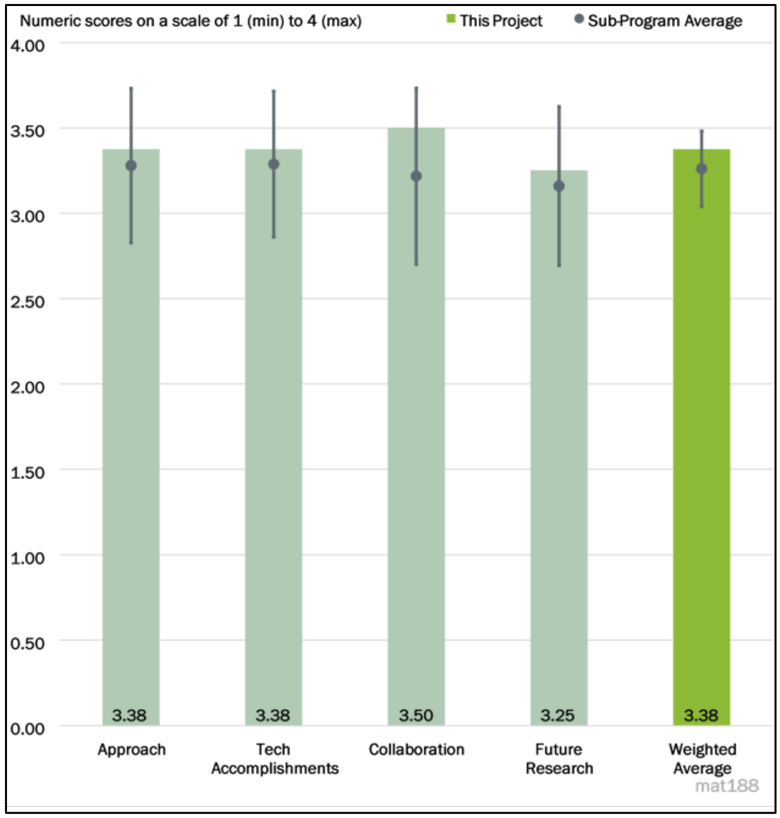


Figure 6-16 - Presentation Number: mat188 Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The premise is sound and the impact on the market would be sizeable. The reviewer opined that this is an area where changes would significantly impact the fuel efficiency of vehicles, both passenger cars as well as medium-duty commercial vehicles.

Reviewer 2:

The reviewer said that the approach has been to relate material properties of Al-Cu-Mn-Zr (ACMZ) alloys for automotive powertrain applications to the fundamental barriers of understanding microstructure kinetics.

Reviewer 3:

It is a well-designed and well-planned project, and the reviewer said that the technical barriers are addressed.

Reviewer 4:

Considering that the overall alloy system is defined, the work to understand the influence of processing on microstructure—the heart of commercialization—was not clear to the reviewer. The effect of particles and ductility is known, and the effect of porosity on fatigue is also known. How to optimize between chemistry and process is not known. It is also not clear whether solidification modeling is a part of the ICME approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It is a great process to assess the microstructure options with an eye toward commercialization. This allows alloys to be well defined with all the necessary properties to be available to designers, making adaptation much quicker. According to the reviewer, the ability of the team to focus on the specific materials properties that are not yet optimized creates a strong data set for designers.

Reviewer 2:

Good accomplishments have been made to understand microstructure influence on properties, especially the work on correlating macro-strain with a theta phase lattice strain. Also, the reviewer commented that there is good work on understanding the influence of chemistry and microstructure on creep behavior.

Reviewer 3:

The reviewer remarked that the team studied properties of cast Al alloys and understood how grain boundary and strengthening precipitates affect the mechanical properties and corrosion of a series of ACMZ alloy compositions. The team produced multiple journal papers, including four in 2021 and two in 2020.

Reviewer 4:

The reviewer said that project milestones have been completed in ACMZ alloys studies in thermal stability, thermal conductivity, and creep as a function of differing compositions of alloying elements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Project collaboration by lead and partner organizations was presented as effective and positive, according to the reviewer.

Reviewer 2:

The reviewer said that there is good collaboration between the various national laboratories and Industry.

Reviewer 3:

Three national laboratories are actively participating in the planned tasks led by ORNL in partnership with ANL and PNNL. In addition, the reviewer stated that there is collaboration with GM and Northwestern University.

Reviewer 4:

The reviewer commented that the presentation explained the collaboration between ORNL, PNNL, Northwestern University, and General Motors.

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 state project ended.

Reviewer 1:

The reviewer noted that the corrosion data will be very useful, and the ability to use these alloys in EV applications is great. The materials property data sets are of great value to both ICE and EV platforms.

Reviewer 2:

Future project attention on alloy development for EV applications is appropriate, according to the reviewer.

Reviewer 3:

Future work focuses on microstructure and thermal and electrical conductivity relationships to be co-optimized with mechanical properties. As the thermal conductivity of the alloy is often much lower than that of pure metal, the relationships between the thermal conductivity of Al and contents of alloying elements, as well as temperature, need to be studied systematically. Therefore, the reviewer asserted that the ways to achieve the optimal compromise between the strength and electrical and thermal conductivity need to be studied systematically.

Reviewer 4:

Key issues for correlating casting processing to microstructure appears generalized under the term “commercialization.” The other application for EVs appears incomplete in terms of what these new alloys will provide. The application on brakes includes composites, and the reviewer was not sure how these connect.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

As stated, the reviewer found that this is an excellent advancement in materials that will lead to more efficient vehicles due to reduced mass and longer lives.

Reviewer 2:

The reviewer commented that accelerating alloy development with ICME to deliver targeted, in-service performance metrics is a definitive need for the automotive industry.

Reviewer 3:

According to the reviewer, the project is well aligned with the overall DOE objectives as it plans to develop more robust engine materials that can withstand higher temperatures and combustion pressures, and thus enable higher efficiency powertrains.

Reviewer 4:

The reviewer said that improving elevated temperature and fatigue properties of Al is a good goal.

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

Reviewer 1:

Progress seems to be moving at a good pace and all seem to be contributing. The reviewer emphasized this is nice work.

Reviewer 2:

The reviewer observed that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

Resources appeared to the reviewer to be aligned with milestone objectives.

Reviewer 4:

The reviewer was not clear if all the work being comprehended is focused on commercializing.

Presentation Number: mat189
Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing
Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

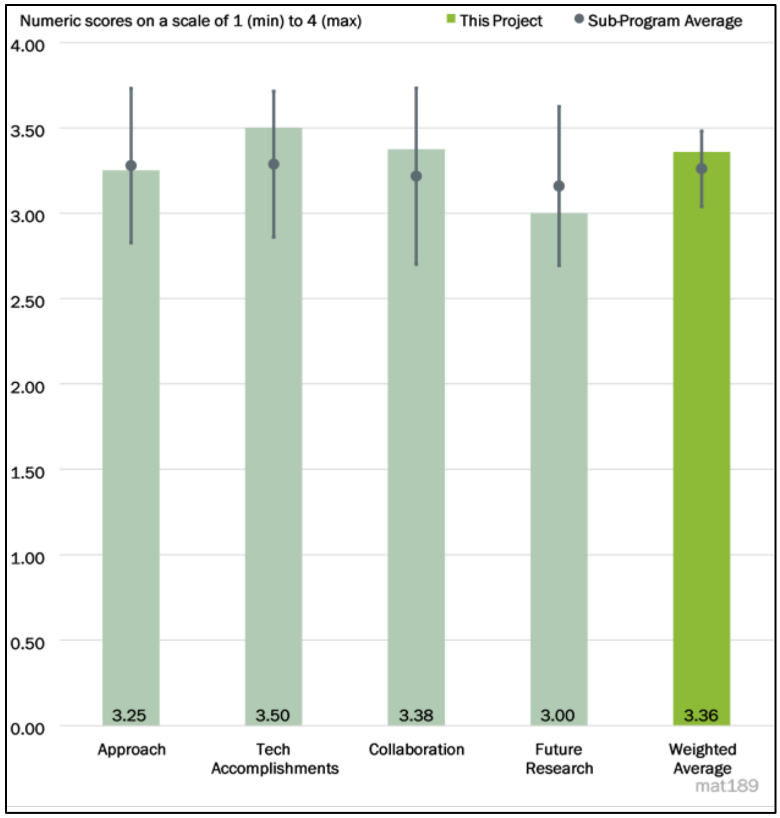


Figure 6-17 - Presentation Number: mat189 Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

Presenter

Alex Plotkowski, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the approach taken here is well thought out. The combination of thermodynamic modeling with high throughput testing of different printing parameters is great.

Reviewer 2:

The reviewer said that the approach leverages ICME methods, advanced characterization, and property testing to accelerate the design of new Al alloys for AM. The alloy design is being guided by the needs to address manufacturing challenges and property requirements associated with higher power density engines. The property targets are driven by specific applications and industry partners. The effort is considering multiple alloy systems in parallel with an approach that has demonstrated feasibility.

Reviewer 3:

Excellent structures approach combining ICME, computational thermodynamics, and process testing to guide the alloy development. However, the reviewer had a concern that the lack of demonstration on shaped parts that emulate a prototype powertrain component leaves the project vulnerable to unfortunate surprises in the last year.

Reviewer 4:

The reviewer was impressed with the fast pace of the work combining different expertise in the study of a novel process and novel structures. This is an important scientific study. The points below are for consideration:

- The property requirements are not well described in this study. It may be that they are application driven but development of an alloy for better creep, fatigue, etc., will not go far toward a performance AM alloy for commercialization. At least it needs to be identified whether the application is an engine block or a cylinder head; these have different service conditions, and the requirements for fatigue are different (low cycle versus high cycle). The reviewer thought that the PI and the collaborators should have a discussion on these.
- AM microstructures are heterogeneous. A good study on the heterogeneity of the structure (grain, texture, and microstructure) needs to be included (not just the good things about the microstructure but its limitations as well).
- The creep test with a step-change in stress may not give a good indication of creep mechanisms. The microstructure evolves in the previous step. The creep mechanisms are likely dislocation creep in the service conditions studied (they would not be always influenced by grain size but would be with prolonged holding under stress, which may not be representative of the service cycles). The creep mechanisms need to be studied (activation energy determination followed by transmission electron microscopy [TEM] studies), perhaps with academia.
- There are so many alloys being developed. The reviewer suggested an ML-based study into all these data (with supervised knowledge and with training data) to optimize the alloy compositions (even with the Zr-bearing alloy) before embarking on extensive studies on AM.
- Finally, the application of these alloys is shrinking with the electrification of the vehicles. They are still important for some applications, but these continuing applications need to be explained in the study.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work appeared to be on target to the reviewer. The key performance indicators were not defined in detail, but new alloys with improved properties for the intended applications have been developed. These alloys have demonstrated improved properties relative to current SOA.

Reviewer 2:

This reviewer observed strong efforts on AlCuCeZr and AlCeNiMn. The focus on mechanical properties, heat treatment to modify the microstructure, creep resistance, and fatigue capacity all address the critical needs for the project.

Reviewer 3:

The success in this project is quite impressive. The performance of the new alloys after printing is excellent. The reviewer suggested that one thing the project team should keep in mind for future presentations is that the good fatigue performance is only after surface machining. The team should test the fatigue performance of as-printed surfaces.

Reviewer 4:

Two of the milestones have been completed, and the third (AM structure study) is underway. The progress is normal, but the reviewer would have liked to see more in-depth study of the AM microstructures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project leverages an extensive number of collaborations, spanning academic groups to industry. The former brings enhanced capabilities in microstructure characterization and creep testing. The latter includes a cooperative research and development agreement (CRADA) with GM for applications in medium-duty truck piston design, as well as key partnerships for feedstock production.

Reviewer 2:

The collaborations are directly contributing to the success of the project, and the coordination seemed good to the reviewer.

Reviewer 3:

The strong accomplishments indicate good coordination and cooperation across the project participants and contributors. The reviewer would have liked to see a chart or table illuminating the typical interactions (i.e., weekly, monthly, and/or quarterly) and a clear list of roles and responsibilities, plus a "gives and gets" table showing the interactions as the project continues.

Reviewer 4:

The tasks of the various parties are mentioned but a description of the nature of the collaboration (virtual meetings, their frequency, and a perhaps a short summary input from the collaborators) would have been interesting to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The work to date has demonstrated opportunities for achieving improved properties through the production of novel, non-equilibrium microstructures produced by AM. The reviewer said that to fully exploit these opportunities, an effort will be devoted to understanding more fully these non-equilibrium microstructures. Advancing fundamental understanding along these lines will be key to guiding alloy design to exploit such opportunities going forward.

Reviewer 2:

The plans are reasonable to the reviewer and address the remaining barriers.

Reviewer 3:

The reviewer said that some of the comments in the answer to Question 1 should be considered as a response to this question.

Reviewer 4:

The proposed work culminates in a prototype component. The reviewer had concerns that a shaped component has not been attempted or at least reported to date. The development, demonstration, and testing of a prototype part is a critical portion to have these new materials accepted by industry. Also, the lack of a powder supplier to address any powder production challenges might be a hole in getting these new materials into automotive parts.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The project supports the development of new alloys that can be produced by AM. This approach provides new design opportunities for improving engine performance and fuel economy. The unique microstructures produced by this processing route provide opportunities for producing materials with improved properties and performance. The reviewer noted that several challenges exist in the application of existing commercial alloys that this project is addressing through new alloy design.

Reviewer 2:

Better materials for powertrain components can improve efficiency and thus reduce energy consumption. According to the reviewer, the use of these new materials in 3-D printing and AM can enable unique designs to further improve high-temperature efficiency.

Reviewer 3:

The reviewer found the work to be highly relevant.

Reviewer 4:

This reviewer stated yes, and referenced prior comments that should be addressed to better evaluate relevance.

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

Reviewer 1:

The resources appeared to the reviewer to be sufficient, as the project is productive and on track.

Reviewer 2:

Resources are sufficient, but the reviewer suggested that some allocation should be made to further the study of creep mechanisms and an ML-based optimization of the alloys.

Reviewer 3:

The reviewer found that the funding is sufficient.

Reviewer 4:

The resources are sufficient for the project scope, according to the reviewer.

Presentation Number: mat190
Presentation Title: Oxidation Resistant Valve Alloys
Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

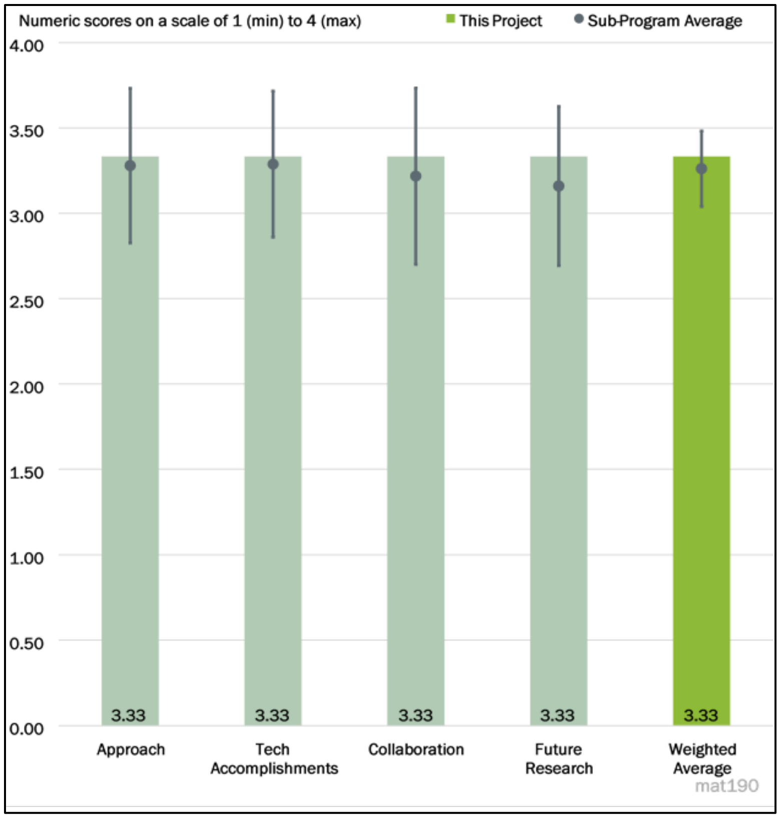


Figure 6-18 - Presentation Number: mat190 Presentation Title: Oxidation Resistant Valve Alloys Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Presenter

G. Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the team’s overall approach is excellent, and the researchers are addressing important barriers.

Reviewer 2:

The project shows a well-organized plan to evaluate high-temperature performance of newly developed chromia-forming and alumina-forming alloys. The reviewer found that the proposed tasks are adequate to address the barriers.

Reviewer 3:

Generally, the researchers present a structured and concise approach to performing and achieving the project targets. The reviewer suggested that some further explanation of the exact property requirements for valve alloys could be made and the link to the work performed could be more clearly drawn. Additionally, a detailed justification of the alloy choice for scale-up would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress is excellent. The performance of the researchers' latest alloy is very impressive. The reviewer was very happy to see that the team plans to create an actual valve and test it in an engine.

Reviewer 2:

Based on the technical objectives outlined, the reviewer commented that there is good agreement with the results obtained.

Reviewer 3:

Alloy 6B-alumina shows promising results (high-temperature strength and superior oxidation resistance). The high-temperature fatigue test is planned to evaluate its performance. The reviewer suggested that detailed microstructure characterization, specifically for precipitates, should be included to understand why it performs better when compared with others.

Most results shown are heavy on performance indexes, which is understandable. The reviewer was not sure if they were from a single heat or multiple heats. The properties should be verified after scale-up production. It is also not clear if the alloys can be used in the as-cast condition or if additional heat treatment is needed to achieve the desirable microstructure.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, collaboration among project team members is well coordinated.

Reviewer 2:

The reviewer noted that there does seem to be good collaboration among the team.

Reviewer 3:

From the presentation, it seemed to the reviewer that the majority of the work is being done at ORNL and that the collaborations are on the periphery and are not part of the main work 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer observed that the proposed future work is reasonable and directly addresses the remaining barriers.

Reviewer 2:

The reviewer indicated that the proposed future tasks are adequate to finish the proposed project.

Reviewer 3:

The proposed upscaling strategy appears to be sound in itself. The reviewer asserted that a clear rationale for the exact choice of alloy compositions should be given.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that this project certainly supports the objective for energy efficiency in transportation.

Reviewer 2:

The project directly addresses DOE goals and objectives, according to the reviewer.

Reviewer 3:

Development of high-temperature alloys has been important in improving the efficiency of the engine, especially for vehicles equipped with ICEs. The reviewer opined that the focus may shift away in the years to come as the nation moves toward 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 the resources for the project are sufficient.

Reviewer 2:

No shortage of resources was communicated to the reviewer.

Reviewer 3:

The funding is reasonable to the reviewer.

Presentation Number: mat191
Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program
Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

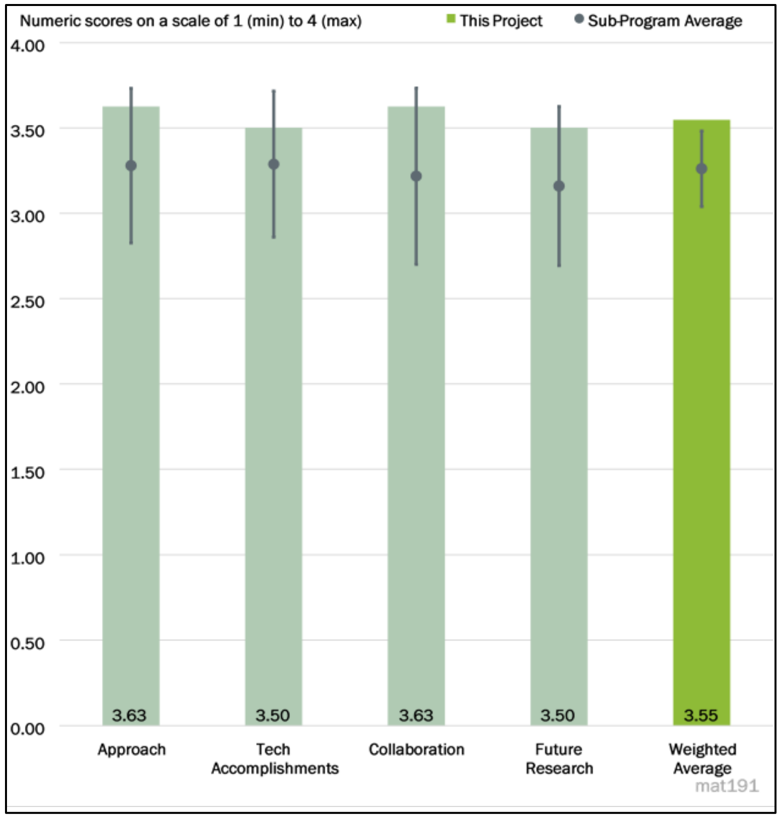


Figure 6-19 - Presentation Number: mat191 Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

Presenter

Tom Watkins, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The details provided by the presenter showed an excellent insight into the characterization techniques utilized in this program. State-of-the-art microscopy was presented that provided a valuable source of information to interpret various results collected as part of this project. In particular, the reviewer found that the atom probe tomography (APT) of oxidation along grain boundaries was particularly impressive.

Reviewer 2:

This reviewer identified Research Thrust Area 4A – Advanced Characterization within the Powertrain Materials Core Program under the Powertrain Materials Core Program (PMCP). The reviewer said that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions. This project provides the characterization of 24 different projects. The consolidated approach leverages synergies between projects.

Reviewer 3:

The approach makes use of SOA characterization tools available in the DOE scientific user facilities to advance understanding of microstructure of materials being developed across the three thrusts of the PMCP. The tools are expertly used, and important insights have been gained to support material development efforts.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the task start was October 2018, and the task end is September 2023. The project is on target for completion in September 2023 and is 50% complete. The budget in FY 2020 was $1.05 million, and the budget in FY 2021 was $1.02 million. This averages out to approximately $45,000 per year for each project.

The reviewer highlighted several excellent results below:

- Cast ACMZ alloys for engine heads: Properties are controlled by precipitates. Theta prime is beneficial, but theta is deleterious in cast structure. It was determined that (AM of the same alloy produces a unique, fine microstructure where properties of AM are much better than that of cast. This is an excellent result. Also, dispersed fine theta precipitates were stronger and stiffer than theta prime, which both strengthens and increases ductility in the ACMZ alloys. This is another excellent result.
- Regarding investigation of new alloys that can work within the increasing operating temperatures and pressures of advanced ICEs, new alloys are needed because existing alloys have poor strength and corrosion resistance at higher temperatures (greater than 870°C). The research team was able to identify a unique outcome that will enable key future studies of oxygen solubility in more complex alloys using electron backscatter diffraction (EBSD), an excellent result.

Reviewer 2:

The reviewer found that good progress was demonstrated across the different thrusts. New insights were derived using advanced characterization techniques related to structure-property links in AM lightweight alloys, high-temperature oxidation processes, and microstructure in advanced high-strength steels.

Reviewer 3:

The reviewer said that the work is very good; in particular, the atom probe was utilized in a very effective way.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that materials characterization within such a project always serves a multidisciplinary role. As apparent from the presentation, there is excellent collaboration among the team.

Reviewer 2:

Laboratory personnel (ORNL, PNNL, and ANL) leverage specialty equipment to efficiently assess and characterize materials. Microscopy and modelers also work closely together. The reviewer remarked that coordination with ICME includes weekly meetings and discussion of the latest results.

Reviewer 3:

This project involves three national laboratory partners, and evidence was shown of coordination across these laboratories in response to last year's reviewer comments. It was difficult for the reviewer to assess the degree to which there is direct collaboration and coordination between the efforts of this project and the extensive characterization efforts taking place within the different Thrust 1-3 PMCP projects, many of which demonstrated in presentations detailed characterization work in the context of alloy design. Also, it was unclear if there is coordination across techniques (e.g., advancing correlated characterization approaches in this context).

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 state project ended.

Reviewer 1:

The outlined future work seemed appropriate to the reviewer.

Reviewer 2:

The project supports a wide breadth of research spanning the different thrusts in the PMCP program. Hence, it would be helpful to the reviewer to understand how the priorities for future work are selected. Presumably, these priorities are set by key bottlenecks in materials development efforts that require insight into structure-property links beyond what can be derived from more routine characterization efforts already included in Thrusts 1-3 projects. Time on the user facilities is limited so prioritization of the most impactful areas where advanced characterization is needed seems important. More discussion of how these priorities are set would be helpful for future reviews.

Reviewer 3:

This reviewer reported the study of microstructural features to understand the co-optimization of material properties, and observed a cost-effective approach to develop materials properties quickly. Also, the reviewer listed plans to use the equipment in a manner that will produce the intended results. Planned activities include STEM and APT at nano scale and atomic scale at ORNL and PNNL--structure, composition, shape, size, and size distributions; high-strength Ni-based super alloys; carbides in AM austenitic steel; and AFA alloys—as well as diffraction, small angle x-ray scattering bulk view at nano scale via ANL Synchrotron—phase, distribution, sizes; Ni-based alloys; AFA alloys; and in situ coarsening behavior in advanced martensitic steels. The reviewer also highlighted electrical and thermal measurements for EV materials and neutron in situ creep of precipitate strengthened ACMZ alloys at ORNL.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles. Also, it involves researching materials to improve electric-powered vehicles.

Reviewer 2:

The reviewer commented that project supports materials development efforts across PMCP thrusts.

Reviewer 3:

According to the reviewer, the overall objectives of the project help to improve fuel efficiency in transportation vehicles.

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

Reviewer 1:

This project has substantial resources, and the work appears to be on track. The reviewer said that it is impressive to see the progress made even in the face of the pandemic, which must have severely limited access time to the user facilities.

Reviewer 2:

The reviewer observed that this project is on schedule and the funding appears to be sufficient because all the stated milestones have been completed on time (to date).

Reviewer 3:

The reviewer noted that no shortages in the budget were reported.

Presentation Number: mat192
Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

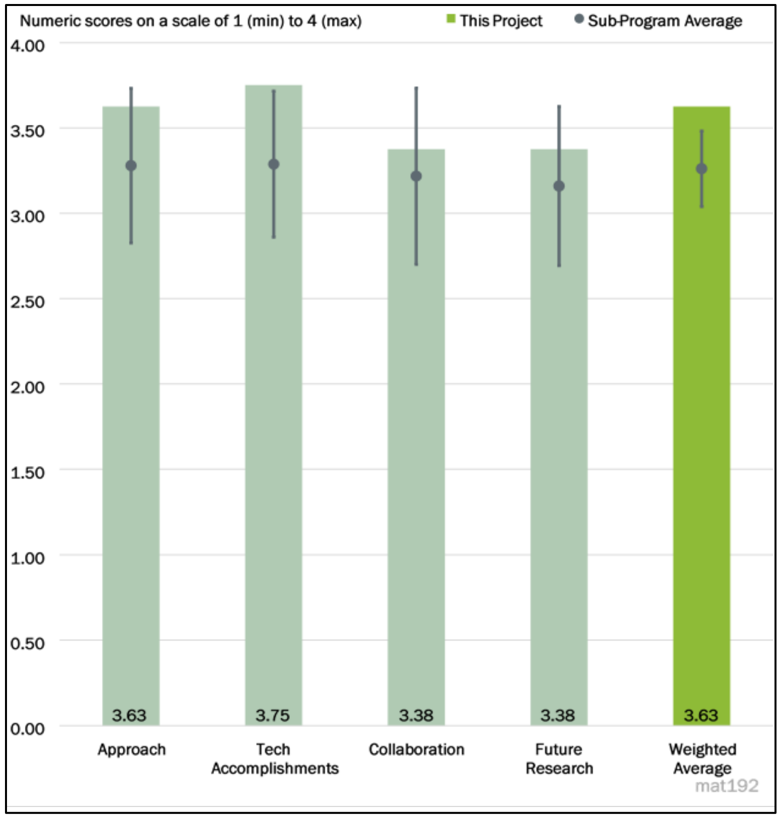


Figure 6-20 - Presentation Number: mat192 Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this work couples state-of-the-art modeling techniques with novel processing routes (AM here) to develop new, high-performance alloy systems. Both the topic as well as the approach are therefore outstanding. The project is thoroughly carried out. Due to the excellent results achieved, an expansion of the application could be anticipated.

Reviewer 2:

The reviewer asserted that the approach fully supports and addresses the technical barriers identified in the beginning of the presentation. These are specific technical targets in the DOE VTO Propulsion Materials area and are part of the U.S. DRIVE roadmap strategy. The approach is consistent with routine materials development projects that start with commercial metals or fully developed metals and looks at using AM to optimize their fabrication. It also includes advanced characterization of structures and physical property testing.

Reviewer 3:

It is a well-designed and well-planned project, and the technical barriers are addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that technical accomplishments for FY 2021 focus on a laser powder bed fusion (LPBF)method for fabricating austenitic steels, which was demonstrated to provide superior strength over commercial alloys. It also provided similar oxidation resistance because their unique and specific cellular structure was fabricated with AM. Analysis of the microstructure confirmed the strengthening feature for two different alloys. These are excellent results for the materials being characterized. Good results for stress reduction were also obtained from the annealing experiments and for the predicted microstructure that was validated with experimental results. Although the project began in FY 2019, only the FY 2021 milestones are addressed and are shown to be completed or on track to complete. The reviewer praised this research as outstanding for the resources involved.

Reviewer 2:

The reviewer emphasized that the results collected so far are excellent.

Reviewer 3:

The reviewer noted that the team conducted tensile testing at a range of temperatures on the CF8C+ steel fabricated by LPBF and demonstrated that carbonitride nanoscale precipitates at less than 100 nanometers (nm) in size. The team produced three journal papers, including two under submission.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination are primarily between two national laboratories for the materials preparation and characterization. One university and an AM developer are the other partners, which rounds out the team for early-stage research support and for advanced development assistance once the technology is mature. There is not a materials supplier or OEM involved, so the reviewer warned that technology transfer will only occur to the AM developer who would then be a Tier 1 supplier.

Reviewer 2:

The collaboration within the project team appeared good to the reviewer.

Reviewer 3:

The reviewer said that the team is led by ORNL and is partnering with PNNL, Pennsylvania State University, and Siemens.

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 state project ended.

Reviewer 1:

The reviewer indicated that the team plans to develop, produce, characterize AM-specific high-temperature high-strength alloys. Additionally, the team plans to do in situ testing, crystal plasticity, and finite element method (FEM) modeling by using advanced characterization and data analytics to improve understanding of the formation, role, and stability of cell structure.

Reviewer 2:

The proposed future research appears to be an extension of the existing research, i.e., to develop and characterize more alloys and to perform advanced characterization and data analytics. The “new” research is to conduct testing and modeling to better understand the formation, role, and stability of the cell structure. The reviewer asserted that this has the potential to optimize the alloy structure and optimize the AM method for these materials.

Reviewer 3:

The reviewer has no objections to the proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project directly supports the overall DOE VTO technical targets for materials development and the U.S. DRIVE roadmap strategy for advanced material development of high-performance materials used at elevated temperatures in automotive powertrains fabricated with advanced manufacturing process methods.

Reviewer 2:

The reviewer noted that high-performance alloys allow higher efficiencies in transportation applications.

Reviewer 3:

The reviewer said that the proposed tasks are well aligned with 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:

The funding is about $200,000 per year, which is sufficient for material development, characterization, analysis of the new alloy compositions fabricated by additive manufacturing, and the modeling effort. The reviewer found that the number of researchers and collaborators are adequate for each technical area being addressed.

Reviewer 2:

The reviewer stated that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

No insufficiency was reported by the reviewer.

Presentation Number: mat193
Presentation Title: Higher Temperature Heavy-Duty Piston Alloys
Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

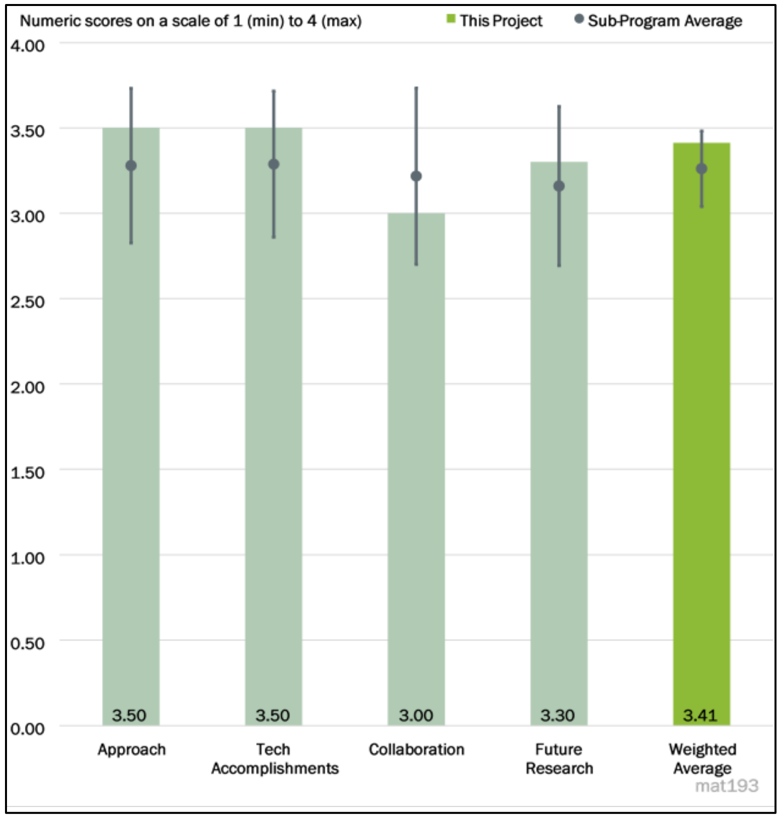


Figure 6-21 - Presentation Number: mat193 Presentation Title: Higher Temperature Heavy-Duty Piston Alloys Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

Presenter

Dean Pierce, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The results were presented in a very clear fashion. The approach taken in this project appeared sound to the reviewer, who suggested that it would be wise to also include creep resistance and fatigue testing.

Reviewer 2:

The reviewer said that the approach is reasonable and would lead to reaching milestones and objectives of the project.

Reviewer 3:

The reviewer stated that this project has a good approach. The use of the commercial alloys to quantify the improvements from the given alloys is a great part of the approach. Also, the development of three different alloys (with different Cr compositions) is very nice, as it allows the team to provide a range of possibilities for future pistons. The presenter mentioned that the team hoped to make prototype valves from the alloys, but that depends on finding an industry partner. The reviewer emphasized that making prototype pistons is very important in proving that the alloys can be applied, so this should be strongly prioritized.

Reviewer 4:

The reviewer identified Research Thrust Area 2A2 – HD Diesel piston materials under the Powertrain Materials Core Program (PMCP) and stated that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions. This project is assessing higher temperature heavy duty piston alloys for compression ignition engines.

According to the reviewer, ORNL is investigating three martensitic steel concepts for piston material in heavy-duty vehicle applications. The baseline are three alloys—4140 alloy plus two 12 Cr martensitic steels. Development alloys are low Cr (0-3 wt.%), medium Cr (3-8 wt.%), and high (8-15 wt.%). The increase in Cr is linked to oxidation resistance. Researchers are targeting high-performance, low material cost, and high manufacturability. The reviewer also noted significantly accelerated alloy development time using reasonably priced raw materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that the performance of the three ORNL alloys is very impressive. The research team has achieved goals very effectively.

Reviewer 2:

The reviewer noted that the alloys being tested show promise, although cost-benefit analyses are lacking at this point. The reviewer presumed that will come soon as the project enters its final half.

Reviewer 3:

The reviewer said that there appears to be excellent progress in meeting the objectives of the project.

Reviewer 4:

The reviewer listed the achievements of this project regarding Cr alloys:

- ORNL low-Cr developmental alloys have a100% Increase in strength at 600°C and a 10% increase in thermal conductivity versus the alloy 4140.
- Medium-Cr alloys achieve an oxidation resistance similar to 12Cr steels at lower costs. A 200°C increase in oxidation for ORNL-D is a very low mass change. There is a slightly higher cost, but oxidation improvement is exceptional.
- High-Cr alloys overcome the tradeoff between strength, thermal conductivity, and oxidation. Significant increases in peak surface temperature occur above the strength limit of the alloy. High-Cr alloys result in lower thermal conductivity (25°–30°C in surface temperature) and improved durability of the piston. This results in a decrease of oil cooling loads and parasitic losses for engine efficiency.
- Results after 150 and 422 hours significantly increase oxidation masking. New ORNL G and H alloys performed very well up to 700 hours, successfully decoupling the performance criteria from the Cr weight percentage.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, there is excellent collaboration within the project team.

Reviewer 2:

The reviewer found that the collaborations outside the laboratory are complex and well positioned to validate the results.

Reviewer 3:

The researchers are partnering with ANL under Thrust 4A: Advanced Characterization, Advanced Photon Source. The project is loosely associated with the U.S. Army Ground Vehicles Systems Center (GVSC). The reviewer remarked that the team is still exploring potential industry partnerships to commercialize the 600°–650°C piston material.

Reviewer 4:

Collaborations were briefly mentioned but none of the presented results seemed to the reviewer to use any of the capabilities from 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that future work is reasonable and will contribute toward meeting milestones and goals. Cost-benefit analyses, which the PIs say are going on in other thrusts, will be essential for a successful drive toward commercialization.

Reviewer 2:

The reviewer said that the proposed future work meets the reviewer´s agreement.

Reviewer 3:

This reviewer reported accelerating alloy development time and improving the balance of elevated – interesting co optimization problem. Planned end date remains September 2023.

The reviewer commented that proposed future research for FY 2022 and beyond includes performing remaining optimization of developmental alloys prior to scale up (6–12 months); initiating partnerships to scale up material for prototype piston manufacturing with supplier; and identifying opportunities in the EV space for application.

Reviewer 4:

The future plans were reasonable to the reviewer. The reviewer's one worry is the lack of a definitive plan for the creation of prototype pistons. The prototype is a critical part of proving the successful of these alloys targeted at a specific application.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 2:

Higher temperature alloys would lead to higher operating engine temperatures. The reviewer asserted that this would lead to higher efficiency and more durable engines.

Reviewer 3:

According to the reviewer, the measures investigated provide means to improve the fuel efficiency of vehicles.

Reviewer 4:

The work is highly relevant 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:

This project is on schedule and the funding appears to be sufficient because all the stated milestones have been completed on time (to date). Through collaboration, the reviewer noted that the team avoided duplicate research and additional cost.

Reviewer 2:

The team seemed to the reviewer to have sufficient resources. Data on spend rate (ratio of amount of work done to dollar spent) would be a helpful gauge to help determine whether money is sufficient or not.

Reviewer 3:

The reviewer indicated that resources are sufficient.

Reviewer 4:

The reviewer said that no lack of resources was reported.

Presentation Number: mat195
Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks
Principal Investigator: Brian Knouff (Oak Ridge National Laboratory)

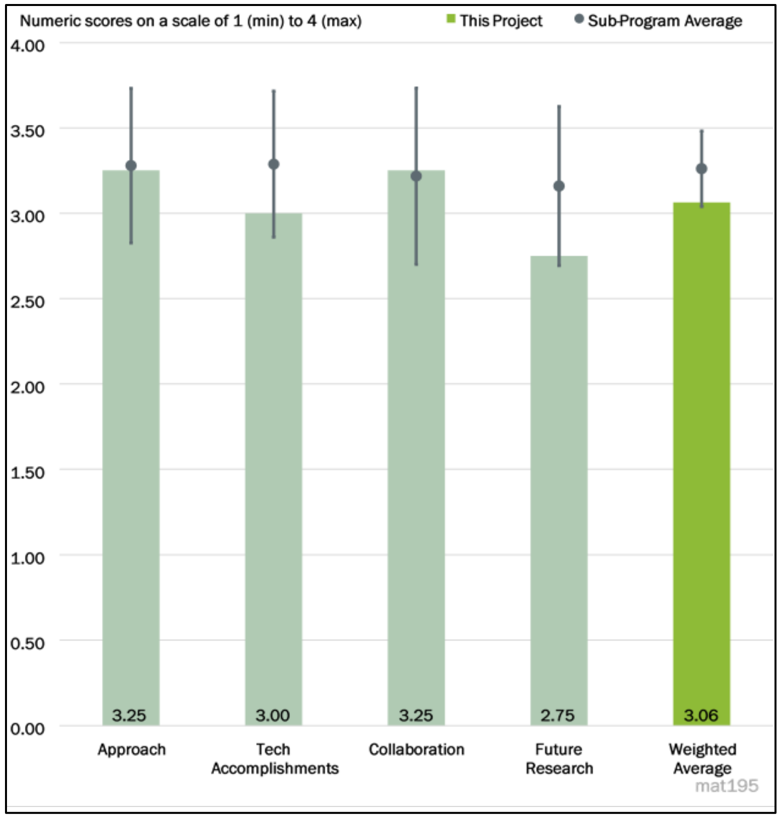


Figure 6-22 - Presentation Number: mat195 Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks Principal Investigator: Brian Knouff (Oak Ridge National Laboratory)

Presenter

Brian Knouff, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approach is solid, but the project is behind due to a laboratory shutdown. The work will be extended 6 months for the environmental testing. The proposed Year 2 change to develop AM tooling seems out of scope for the original work. It seemed to the reviewer that there could be additional work to improve the wheel performance and material process controls for improved quality.

Reviewer 2:

The project is considering a tailored fiber placement (TFP) process for the carbon wheels application. The team is witnessing reduced in-plane tensile strength due to the stitching process. The project is devised around a test matrix to characterize the properties at room and elevated temperatures. Researchers are looking at a printed metal AM tool and resin infusion with layup of TFP layers. Overall, the approach to performing the work was reasonable to the reviewer. Some of the process aspects of the AM tool and anticipated issues in maintaining the geometric tolerance may pose a challenge, but the project may provide answers as it proceeds. The 6-month delay due to COVID-19 has put the project behind.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team has made great progress considering the limitations and challenges with laboratory shutdowns. The team identified stitching as the key contributor to the tensile strength and is working to address alternative ways to deal with that impact. The reviewer stated that there is nice work on the TFP work for setting up the panel testing for tensile and flexural data.

Reviewer 2:

It appears that the 6-month delay due to COVID-19 has impacted the technical deliverables. The current phase of the project pointed to making some TFP laminates and conducting flex and ILSS tests. A significant amount of characterization work needs to happen prior to the next steps of design and prototype development. It was not clear to the reviewer from Slides 13–15 if this were prior work at ESE Carbon that the current material systems will progress toward. Also, the additional information in terms of modeling and tooling development was not clear about whether that was current work or building from past work. The project needs to align carefully with the technical milestones that were proposed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the team work on the material testing, wheel design, and evaluation was great. A significant weight reduction was achieved over an Al wheel.

Reviewer 2:

ORNL is collaborating with ESE Carbon. That was clear from the briefing. The slides titled “Collaborator” (Slides 13–15) gave the information on the ESE Carbon technology but did not provide any insight into the specific nature of the collaboration. Hence, it was not possible for the reviewer to assess the specifics of the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Despite the team’s progress, the reviewer stated that the testing is lagging due to issues at the beginning of the project beyond the team’s control. The proposed work is addressing the barriers and the environmental testing that still need to be completed.

Reviewer 2:

The proposed “Future Research” on Slide 17 was somewhat vague and not fully thought through. Future research points to only metal AM tooling aspects. Without any early work on the AM tool, how can the team start making improvements on future work? For example, the ideas to allow fluid channels, eliminate the computer numerical control (CNC) roughing step, eliminate the hole drilling step, reduce parts by 50%, and achieve time savings of 50% are overarching, broad brush statements that really do not convey anything specific. The reviewer stated that no mention of tooling materials, composition, response to temperature, etc., has been considered.

Also, future work should have included the team’s outlook on materials response, optimization of the TFP preform, what the current shortcomings are, how they will be overcome, etc. The work thus far has limited scientific backing. The reviewer asserted that some deeper science backing the rationale for the study and the mechanics and mechanisms would have helped.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The weight reduction of 40% as well as increased wheel performance is a win-win, and the reviewer asserted that the team should receive kudos for the demonstration.

Reviewer 2:

Lightweighting technologies directly benefit weight- and energy-saving goals. The reviewer indicated that the use of a domestic CF supply will advance the U.S. position in advanced materials and manufacturing.

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 team has demonstrated and performed well, despite the challenges, and has met milestones and targets.

Reviewer 2:

The reviewer stated that the team has the necessary resources. AM metal printing is advanced technology at ORNL, and ESE Carbon has the wheel technology.

Presentation Number: mat196
Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

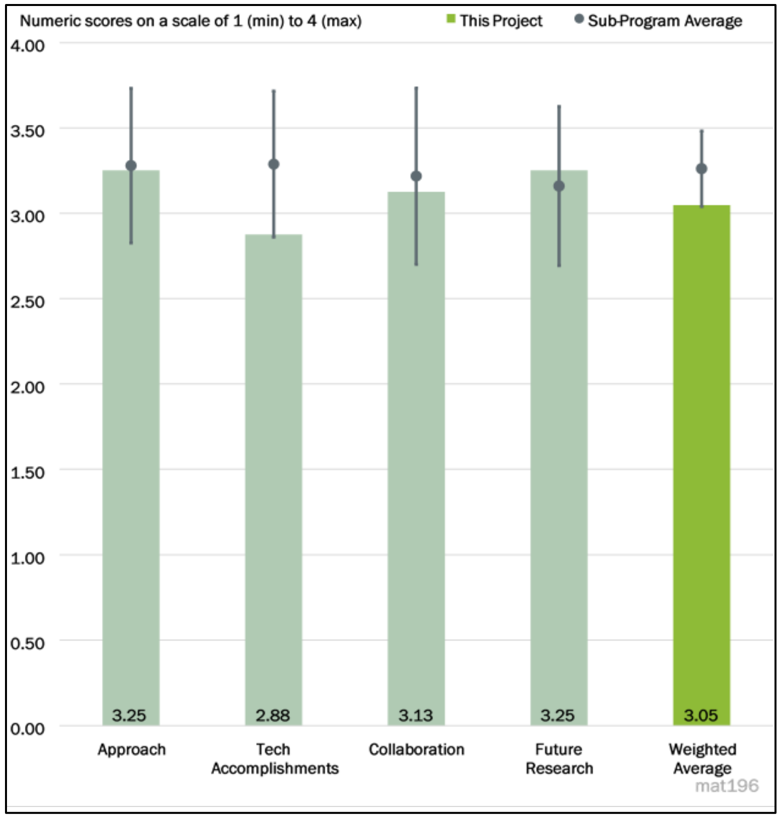


Figure 6-23 - Presentation Number: mat196 Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the development of the two-stage, high-temperature carbonization procedure to reduce the energy and therefore the cost of producing CF is the logical next step in this long journey to increase the use of CF in the automotive industry. The strategic approach to develop a process that directly coupled energy from a source to the fiber through electromagnetic coupling is creative and possibly a 5% cost reduction.

Reviewer 2:

The approach seems generally sound. The work is still in its early stages, and the reviewer stated that how the approach is executed as well as the ensuing results will go a long way in validating the approach.

Reviewer 3:

The technical barrier was limited on the low-temperature carbonization (LTC) and this project is moving to a high-temperature (HTC) process and has utilized modeling to design the parameters needed for success. The approach was practical and feasible to the reviewer.

Reviewer 4:

The reviewer stated that this project deals with HTC via dielectric heating. The team approaches it in that the dielectric heating is faster and more efficient than conventional and can be conducted at atmospheric pressure. In the team's prior work, researchers focused on LTC with the current technology. In this work, the team is focused on HTC. The scientific approach seemed reasonable to the reviewer. The emphasis is on energy savings, although the relation of the technical approach to how energy savings would be achieved was not entirely clear from the briefing beyond the fact that density differences occur with a short versus long process. How that impacts energy was not clear to this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The technical and project management accomplishments are excellent, especially through the COVID-19 challenges of 2020 and early 2021. The design of the equipment is based on solid physics. The reviewer said that the initiation of procurement of the long lead time equipment is wise to keep the project on track for success.

Reviewer 2:

Progress on the project is good, considering that the COVID-19 global pandemic caused a slowdown in the work. The September 30 go/no-go decision point is fast approaching, and the reviewer wondered whether the PIs will be able to meet this deadline due to the time lost to COVID-19.

Reviewer 3:

The project has some long lead times and has had difficulty in getting contracts in place. The modeling aspect is complete, but the milestone was not met. Lots of work in building capability and modifying the former LTC system is needed. The project has only been in place for 6 months at the time of the presentation and 4 months when presentations were submitted. The reviewer would not have expected a lot of technical accomplishments other than modeling, which was completed. The project will be a year before fiber gets put through the system.

Reviewer 4:

This project is in its early stages, so it was hard for the reviewer to assess its progress yet. It was obvious that the research team was going to expand on the lessons learned in the LTC work toward the HTC development. Also, the team proposes to use composite epoxy material (CEM) to establish the design methodology (by the way, CEM was never expanded in the slides). Slide 8 on the CEM is an important one, but it did not comprehensively convey to the reviewer the interpretation of the "Reflection" study for a given design (parameter sweep) and its relevance to the energy-savings metrics.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

ORNL is continuing to collaborate with 4XTechnologies, building upon their work on the LTC developments. The reviewer commented that this is a logical collaboration.

Reviewer 2:

The roles and responsibilities of ORNL and 4XTechnologies are clear. This reviewer would have liked to see a chart of typical interactions (i.e., weekly, monthly, and/or quarterly). The installation and commissioning of the new equipment should be explained in more detail.

Reviewer 3:

The reviewer noted that there seems to be synergy between ORNL and 4X Technologies. The PIs mention joint development including equipment construction and experimental work performed on the 4XTechnologies site. However, the relative amount of work being carried out by each organization was not explained in more detail. This would be nice for future presentations (please mention the specific contributions made).

Reviewer 4:

The presenter needs to better communicate the role and importance of 4XTechnologies. It was not clear to the reviewer how much is ORNL's and the collaborator's portion for the respective levels of effort.

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 state project ended.

Reviewer 1:

The research team's immediate future work will focus on design, construction, and testing. A large amount of effort will focus on completing the CEM modeling study for an optimized design, parts upgrade, and setting up for the fiber production. Overall, the reviewer said that the future research is along logical lines.

Reviewer 2:

The FY 2021 efforts on the design of the process and equipment and then the building, installation, commissioning, and start of operations is a great plan. The reviewer warned that it might be aggressive against the proposed timing.

Reviewer 3:

The proposed work is consistent with meeting the milestone. The speed at which the work can be completed in order to meet the September 30 go/no-go decision point was more of a concern to the reviewer. Perhaps that decision point needs to be postponed.

Reviewer 4:

The proposed future research is a lot of design and build. The reviewer asserted that there are no clear decision points to measure progress of the design and build to make sure it is on track to meet milestones and commissioning.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Lowering the amount of energy used in CF production will lead to low embodied energy of CF composites, which the reviewer said aligns directly with DOE goals.

Reviewer 2:

The cost of CF is one of the barriers to adoption in high-volume automotive parts. The reviewer asserted that reducing the material cost by 5% is a required improvement on the cost for CF.

Reviewer 3:

Reduction in energy consumption translates to a reduction in the price of CF. If the processing time can be reduced, this will further reduce the cost. The reviewer indicated that CF cost is a major barrier to wider adoption in vehicles for lightweighting.

Reviewer 4:

The goal is to reduce CF costs; however, the HTC stage is only projected to be a 5% cost reduction in the overall production of CF, which seems very small to the reviewer for the cost and level of the effort.

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

Reviewer 1:

Comparing the budget to the cost savings, it seemed to the reviewer to be pretty high for the return on investment. The project is building out a significant capability with a speculation of 5% energy savings.

Reviewer 2:

The reviewer said that the team of ORNL and 4XTechnologies combined have the necessary resources.

Reviewer 3:

The remaining funds in FY 2021 and FY 2022 appeared sufficient to the reviewer for the project plans.

Reviewer 4:

It is difficult to tell at this point if the funds are sufficient to carry out this project. The ratio of work done to money spent has not been presented. The reviewer can only assume adequacy of funding because the PIs have not said otherwise.

Presentation Number: mat197
Presentation Title: Multi-Functional Smart Structures for Smart Vehicles
Principal Investigator: Patrick Blanchard (Ford Motor Company)

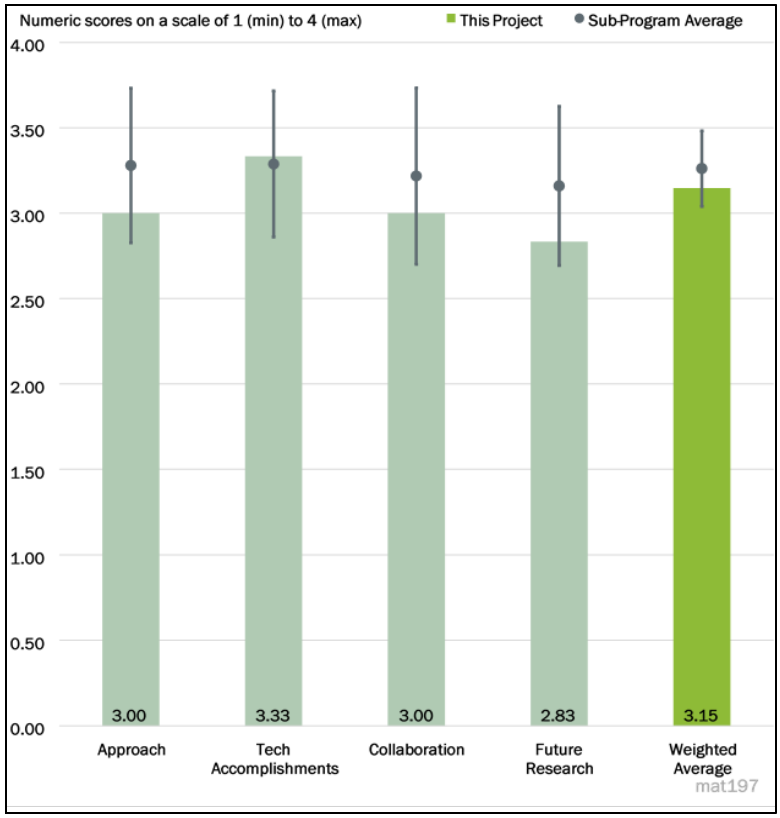


Figure 6-24 - Presentation Number: mat197 Presentation Title: Multi-Functional Smart Structures for Smart Vehicles Principal Investigator: Patrick Blanchard (Ford Motor Company)

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the project is in its early stages but has been well laid out. The research team is focusing on a concept instrument panel, cross car beam with advances in materials, functionality, and process innovations. The task layout structure on Slide 6 and Slide 7 is excellent and provides a clear thought process starting from design through the various process elements.

Reviewer 2:

The composite materials under development could meet the structural requirement and also provide multifunctionality. How to control the distribution and dispersion of the conductive nanofillers in the composites was not very clear to the reviewer, which is an important factor in determining the conductivity of the composites. The high processing temperature of the polymer resin, which makes it hard for electronics component integration, represents one challenge that needs to be overcome.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project is in its early stages; however, all aspects are being addressed in a very comprehensive manner. Specifically, the initial concept of the cross beam is detailed with vision. The reviewer noted that the team has made progress along the lines of early screening of material concepts that have progressed well. Water injection molding and tow placement technologies, sensor integration, joining and attachment, and AM segmented tooling are examples of the progress.

Reviewer 2:

The reviewer said that good progress has been made in terms of component design, water-assist injection-molding testing, composite tape production, the preliminary sensor integration study, evaluation of the manufacturing concept, tooling development, etc.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration and roles across the team were well laid out and clear to the reviewer. The team is comprised of Ford, Michigan State University (MSU), ORNL, Purdue, and Yanfeng Global Automotive Interiors is logical and will strengthen the project plan.

Reviewer 2:

The collaborators seem to work closely with one another. The research is well integrated. The reviewer remarked that the role of MSU is not as clear as that of the other parties.

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 state project ended.

Reviewer 1:

The reviewer indicated that the proposed future research and remaining barriers on Slide 16 and Slide 17 are logical and well thought through. Sensor integrity through the process would be interesting to see in future stages of the work. The dimensional tolerances of the part via water injection molding and tape placement would also be interesting for future designers.

Reviewer 2:

The proposed future research seems reasonable. The reviewer highly recommended that there be more discussions on how to address the pain point (e.g., high processing temperature of polymer resins).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Multifunctional design, integration of sensors, cost reduction in manufacturing, and complex shapes are all leading to lower energy and advancements in automation and EV technologies of the future. The reviewer said that the project has high relevance to DOE objectives.

Reviewer 2:

The reviewer commented that this project, targeting the development of lightweight, multifunctional composite materials, supports the DOE objectives in terms of improving energy efficiency and 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 said that the team has comprehensive resources to address all aspects of this work.

Reviewer 2:

According to the reviewer, the research team has access to all the necessary facilities and resources.

Presentation Number: mat198
Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure
Principal Investigator: Venkat Aitharaju (General Motors, LLC)

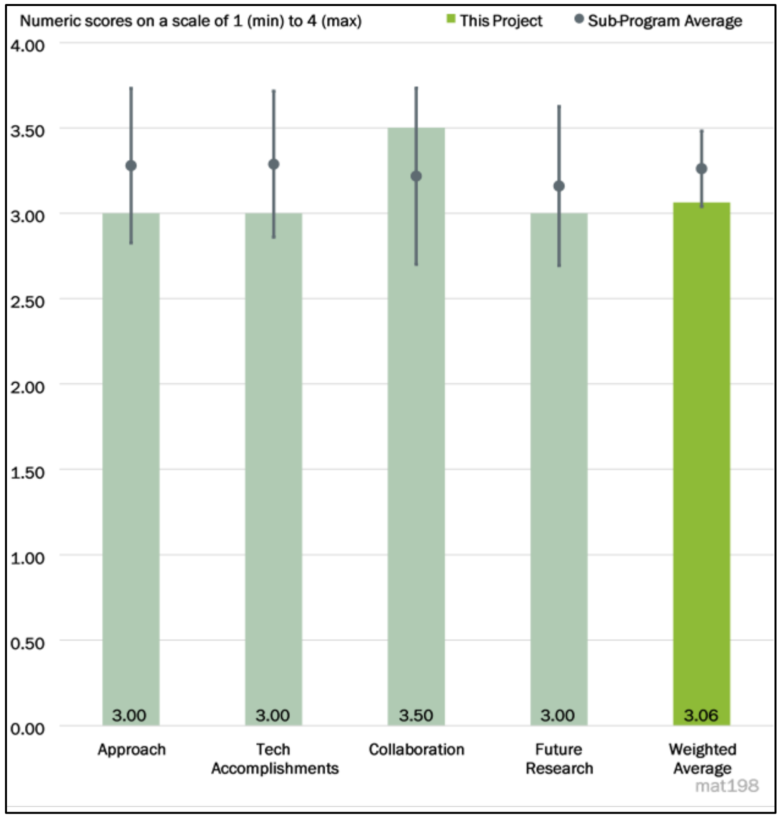


Figure 6-25 - Presentation Number: mat198 Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure Principal Investigator: Venkat Aitharaju (General Motors, LLC)

Presenter

Venkat Aitharaju, General Motors, LLC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team has an excellent approach to create multifunctional structural battery enclosures. By investigating different routes to make the enclosure multifunctional (i.e., self-health monitoring, fire-retardant, and electromagnetic compatibility), the reviewer believed the probability of success is high for finding a value proposition for these new enclosures. In the next AMR, the reviewer said that it would be good to clarify if all the added functionalities are planned to be integrated into the same enclosure or if different enclosures are being designed to have different functionalities. Also, because this application is highly dependent on cost, a more robust cost analysis of the composite composition would be useful. For example, it was mentioned that E-glass fiber and PX35 Zoltek CF were selected as the fibers, but a lot of different grades of fiberglass and CF are available at different cost points and with different performance properties. A little more discussion on how the team arrived at those specific fibers would be useful in future AMRs. Overall, it was an excellent approach to the battery enclosure problem that will become more prevalent as EV adoption increases.

Reviewer 2:

The project targets reducing the cost and achieving reduced vehicle weight. Probably due to being a large project, the detailed approach was not communicated. It was not clear to the reviewer how novel these approaches are and why the research team thinks this scope can be a gamechanger for vehicle technologies. Also, it seems these are completely separate tasks, and it was not clear what the synergies of each task are in the project.

Reviewer 3:

The proposed hybrid CF- and GG-based system could provide high-performance multifunctional composite materials. However, the reviewer asserted that the compatibility of these two different types of fibers, particularly for the co-mingling in a tow (e.g., different thermal expansion, weak interfacial interaction, etc.), needs to be addressed.

Reviewer 4:

The approach is broadly interesting from the perspective of hybridizing CF and GF to optimize the cost-to-strength benefit ratio for the target application. However, the approach to that optimization of properties and its execution is lacking in detail and appears to be heavily experimental and somewhat iterative. The reviewer suggested that the project could really benefit from some attempt to rationally model or otherwise approach the optimization in a less Edisonian manner.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Due to the late start of the project, it is hard for the reviewer to compare the progress of this project to other projects that started on time. Despite not having significant technical accomplishments and progress so far, the team did provide a great outline of the plan to accomplish the goals moving forward. With the size of the team on this project, it would be expected that significant progress can be made before the next AMR.

Reviewer 2:

The project started late, but the reviewer indicated that some decent progress has been made in terms of model and experiment design, process evaluation, and instrument setup.

Reviewer 3:

The project is 2% complete; however, initial progress appeared to be encouraging to the reviewer.

Reviewer 4:

The research team has just started the project. Considering the timing, the researchers seem to have made reasonable progress, although it is hard for the reviewer to evaluate because the detailed strategy was not clearly discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

With GM having six partners and collaborators as part of the team, the reviewer saw this as a very strong team that was created. There was a great slide outlining the general tasks and expertise of each team member, so overall the coordination across the project team seems very well organized. With the project being only 2 months in, it is hard to determine how well the project team members performed together thus far, but the team and plan established seems well thought out from the start.

Reviewer 2:

The reviewer noted that the team has a broad range of collaborators who appear to bring unique capabilities and resources together for the benefit of the project.

Reviewer 3:

The reviewer said that the collaborators have complementary expertise and the research is well integrated.

Reviewer 4:

The project has a large team, and many institutes are contributing to this project. The project takes advantage of the strength of each team member. The reviewer's one minor comment is that it was not perfectly clear how synergistic all the capabilities are, partly because some of the tasks may not be correlated.

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 state project ended.

Reviewer 1:

In line with the Approach comments, the reviewer said that it would be beneficial to look at incorporating a rational design and molding approach to the optimization of properties versus relying solely on iterative methods.

Reviewer 2:

With numerous functionalities proposed for the battery enclosure, this enhances the risk mitigation. If one functionality does not perform as desired, then there are other functionalities that can be leveraged to meet the value proposition. However, the reviewer would have liked to have more specifics about the metrics established to determine whether the added functionality is successful. For example, what are the specific values targeted for the self-monitoring electronics, fire-retardant, and electromagnetic compatibility and how do those compare to the properties of current battery enclosures?

Reviewer 3:

The reviewer opined that the proposed future research is fairly general and does not really target any specific issues, which is likely due to the short period that this project has been going on.

Reviewer 4:

The proposed future work is too generic, and it was hard for the reviewer to tell what the actual plans are. Also, the research team did not disclose the detail of the composite battery enclosure. What performance does the team need for the composite battery enclosure and why is the study unique? In terms of the CF and GF study, researchers should calculate what mechanical properties are expected based on the ratio and what the target performance is. Then, the team should be able to estimate the cost benefit versus composite performance. In a sense, what is the acceptable range of properties and cost? Also, the cost estimate and performance estimate should include different kinds of resin choices because that will also impact the expected cost and performance.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project supports DOE objectives of vehicle lightweighting by targeting the weight and functionality of the battery enclosure at a cost of no more than $5 per pound (lb) saved. The use of a hybrid fiber structure will help meet the performance and cost targets set by DOE. If the goals of this project are achieved, then the reviewer asserted that it will provide a significant step forward in meeting DOE's objectives of vehicle lightweighting with the integration of added functionalities.

Reviewer 2:

The reviewer stated that the project could lead to novel lightweight composite materials for vehicle manufacturing with reduced cost. It could also contribute to fuel economy.

Reviewer 3:

According to the reviewer, the project is clearly attempting to address improvements in the cost-benefit ratio of lightweight non-metallic battery enclosures in line with the DOE's identified barriers and needs in the 2017 U.S. DRIVE Roadmap Report, Section 4.

Reviewer 4:

The reviewer said that the project supports DOE objectives toward meeting some of the targets described in the U.S. DRIVE report. However, the proposed direction includes incremental advancement, and the benefit to DOE is relatively limited. The technical advancement may end up being limited to themselves. Considering the large investment by DOE, the reviewer suggested that it would be better that it invests in truly impactful research for vehicle technologies rather than small incremental improvements.

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

Reviewer 1:

Initially, the budget for this project seemed excessive to the reviewer, but when looking at the size of the project team and all the tasks proposed, the funds are sufficient to deliver on the proposed goals. With the large budget and size of the team, significant accomplishments should be expected in the future years of this project.

Reviewer 2:

The project has an ambitious series of milestones and multiple collaborators. The resources appear—as far as this review can determine—to be sufficient to achieve those goals.

Reviewer 3:

The reviewer indicated that the research team has good resources as well as a significant cost-share commitment to meet milestones in a timely manner.

Reviewer 4:

The research team has access to all the resources needed, according to the reviewer.

Presentation Number: mat199
Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)
Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

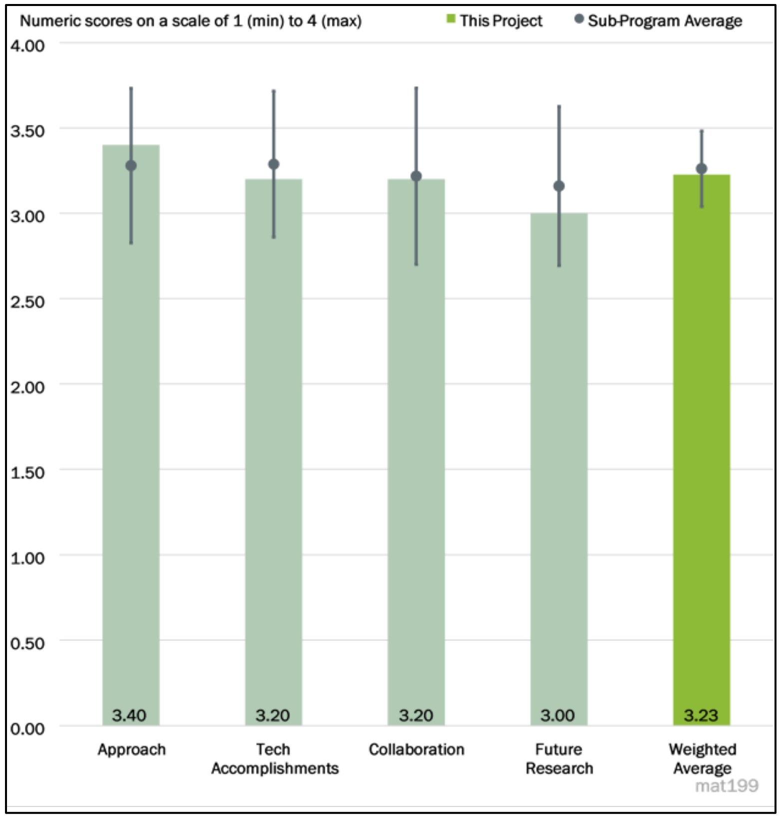


Figure 6-26 - Presentation Number: mat199 Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project) Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

Presenter

Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The target of this project is to develop a high-strength and high-modulus composite material. The researchers proposed polymer fiber and polymer matrix composites with two approaches of development. One is for developing high-strength and high-modulus polymer fibers (strengths greater than 500 megapascals [MPa]), and the other is for developing composite manufacturing processes. The project is split between ORNL (polymer fiber development) and PNNL (manufacturing process development) based on specialties. Overall, the reviewer commented that the project is well designed and the team has shown the feasibility by providing preliminary results.

Reviewer 2:

According to the reviewer, the proposed thermoplastic polymer matrix and polymer fiber composite could provide lightweight materials for manufacturing of vehicles with significantly reduced weight as well as increased recyclability.

Reviewer 3:

The reviewer noted that this is an interesting approach to developing a materials and processing technology that could potentially allow industry to access relatively novel, low-cost, lightweight composite systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress made to date indicates that the team is making a coordinated and effective effort to meet the technical goals. The reviewer found that fabrication of both materials and samples are proceeding effectively, and the materials characterization effort is yielding results of interest and relevance. The approach is methodical, and the initial data show promise.

Reviewer 2:

Very good research progress has been made in terms of fiber development, composite fabrication and physical characterization, and mechanical property studies. The reviewer highly recommended more studies on such materials' recyclability.

Reviewer 3:

As a preliminary result from the manufacturing process development side, the team demonstrated polymer panels by film stacking with low void and showed mechanical data from polymer fiber and polymer matrix composites. However, the research team did not show how far (or how close) the current results are from the target performance. The team showed an improved adhesion by plasma treatment. From the fiber development side, the team showed processing temperature (T) range for crystallinity. The reviewer indicated that the progress provided in the presentation is reasonable for 8 months of work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project is divided into polymer fiber manufacturing (ORNL) and composite process manufacturing (PNNL). The reviewer opined that both ORNL and PNNL teams have expertise in the assigned tasks and the collaboration of the two teams will provide synergetic benefits to the project.

Reviewer 2:

The reviewer noted that the collaborators have complementary expertise (PNNL focused on commercial fiber characterization, surface modification, and processing parameters while ORNL focused on fiber development and characterization, etc.). The research is well integrated.

Reviewer 3:

As far as the reviewer can determine, both laboratories in this collaboration appear to be equally and effectively collaborating for the benefit 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. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the proposed path of future research is well defined and logical.

Reviewer 2:

Detailed future research has been proposed with milestones clearly stated. It would have been more helpful to the reviewer if some experiments targeting specific challenges the project is facing now were discussed more.

Reviewer 3:

The reviewer commented that the Proposed Future Research slide does not show specific timelines associated with ORNL's milestones. In the Technical Accomplishments slides, high crystallinity is mentioned to increase mechanical performance of the fibers. However, in the Proposed Future Research slide, a plan about how to achieve high crystallinity is not mentioned. Overall, the Proposed Future Research slide shows some of the milestones without how to achieve them.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project supports the overall DOE objectives. CF manufacturing is an energy-intensive process, and manufacturing of CF-reinforced thermoplastics is another energy-intensive process. The proposed project is targeting replacing CFs with polymer fibers in composites, which will bring down the overall manufacturing cost and also carbon footprint.

Reviewer 2:

The reviewer said that the stated goals of this project meet DOE requirements for new solutions addressing low-cost, high-volume manufacturing, low-cost fiber reinforcements, and recyclability.

Reviewer 3:

According to the reviewer, the project could lead to thermoplastics-only composite materials that could provide lightweight materials for manufacturing of vehicles with significantly reduced weight. It could also contribute to 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 funding amount is sufficient to develop the technologies.

Reviewer 2:

The cost model for this project would appear to be sufficient to meet the stated milestones to schedule.

Reviewer 3:

The research team has access to all of the resources needed.

Presentation Number: mat200
Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications
Principal Investigator: Seokpum Kim (Oak Ridge National Laboratory)

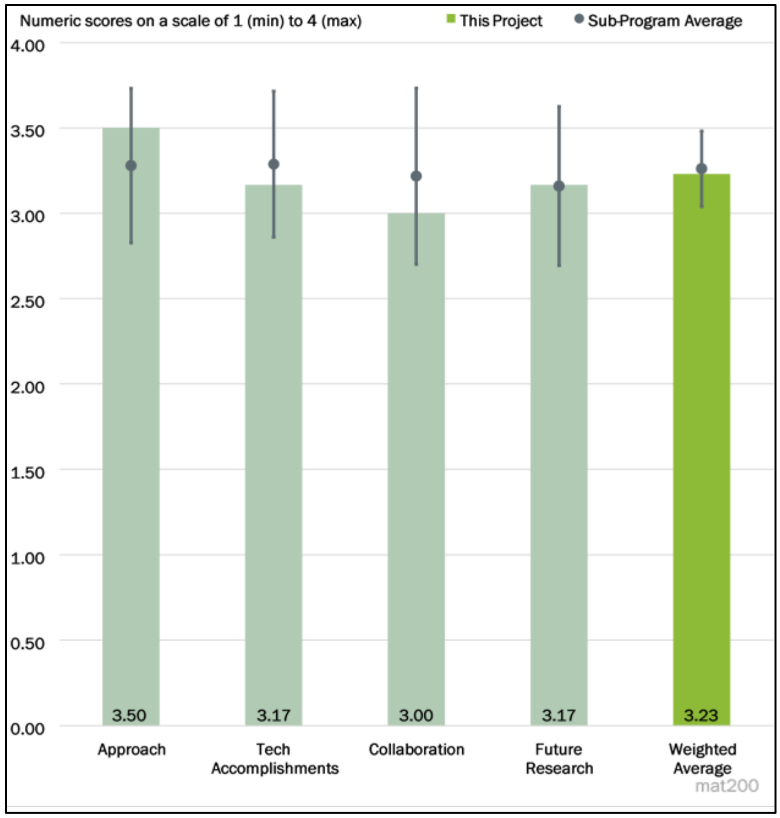


Figure 6-27 - Presentation Number: mat200 Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications Principal Investigator: Seokpum Kim (Oak Ridge National Laboratory)

Presenter

Seokpum Kim, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project started in October 2020 and has made significant progress. The approach is innovative and feasible. The reviewer found the cellular structure design according to stress distribution to be smart.

Reviewer 2:

The reviewer noted that the project has clearly identified the technical barriers and identified technical targets. The project layout is well organized.

Reviewer 3:

This reviewer stated that the work is a good combination of materials development but is mainly focused on design. The project approach toward the goals is clear to the reviewer, and progress made is commensurate with the project team's timeline.

The reviewer identified a number of points and questions that can be addressed:

- Because the interest is on lightweighting with a high strength-to-weight ratio, what are the unique testing methods beyond standardized testing that have been employed?

- There are a number of opportunities for materials development. What is the correlation between specific materials development approaches and the team's optimization simultaneous with design?
- What artificial intelligence (AI) methods employed can be specific to lightweighting and will include materials and design development?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Overall, the reviewer commented that the technical accomplishments are matched with the key performance indicators. The demonstrated printable materials and design are what has been proposed. The barriers of the project have been identified. There is a chance to develop new testing protocols that are relevant, including what is unique with multi-axis printing.

Reviewer 2:

The project is on track and has made progress toward the overall objectives. The stress analysis and experimental testing made sense to the reviewer. It would be great if mechanical testing can be in conjunction with DIC. The team may do in situ characterization during printing, if possible.

Reviewer 3:

The presentation was not clear to the reviewer about what accomplishments had been completed. Some of the information presented was from previous years. There are some modeling aspects that the project team indicated were done, but it is not clear what the results were or what the issue was. This was more of a description of what each task was about and not what was accomplished to date.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The ORNL team is teamed up with UCLA. The reviewer found the collaboration to be excellent.

Reviewer 2:

The reviewer suggested that the project team start a more collaborative effort with possible external partners. The armrest demonstration is a good example, although the role and contribution of an external partner can be elaborated more in terms of actual testing and parameters that will see the performance requirements.

Reviewer 3:

It is not very clear to the reviewer which collaborator was responsible for which part of the project. The Collaborations slide, while mentioning the industrial partner and university subcontractor, does not explicitly tell who is doing what task or subtask 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The direction toward future research was clear to the reviewer and has been stated in the presentation well. It is possible that a new direction toward unique mechanical testing and environmental testing methods can be employed. There is a need for more clarification on the direction of multi-materials printing. Is this based on a gradient approach or is it designed to achieving strength only where it is needed?

Reviewer 2:

According to the reviewer, the future work has been well planned by considering the technical barriers, risk mitigation, and alternative pathways.

Reviewer 3:

It seemed to the reviewer that there has not been much work started. The proposed future work is some of the same work that should have been completed or in progress and demonstrated during this presentation. The project has been in progress for 6 months without much to show about it. The order of the proposed tasks and the work to be completed is logical.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project is relevant to the mission of the DOE Energy Efficiency and Renewable Energy (EERE) VTO office. It also addresses the challenges of the specific Technology Readiness Level (TRL) level that is mentioned in the phased project timeline. It is important now to define the pathway toward higher TRL levels and identify key collaborations.

Reviewer 2:

According to the reviewer, the project directly supports the overall DOE objectives. The lightweight AM cellular structures are critical for EVs and lowering carbon emissions.

Reviewer 3:

The proposed work could meet the DOE weight reduction objectives. It was not clear to the reviewer whether it meets the industrial collaborators cost and production rates for implementation.

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

Reviewer 1:

ORNL and UCLA have sufficient resources and expertise for the project. The project is on track toward the stated milestones in a timely manner. The reviewer indicated that industry involvement helps a lot.

Reviewer 2:

The reviewer affirmed that, yes, the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been clearly identified.

Reviewer 3:

The milestones are timely with sufficient resources; however, it looked to the reviewer like the project is behind, based on no milestone progress for the review.

Presentation Number: mat201
Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage
Principal Investigator: James Lewicki (Lawrence Livermore National Laboratory)

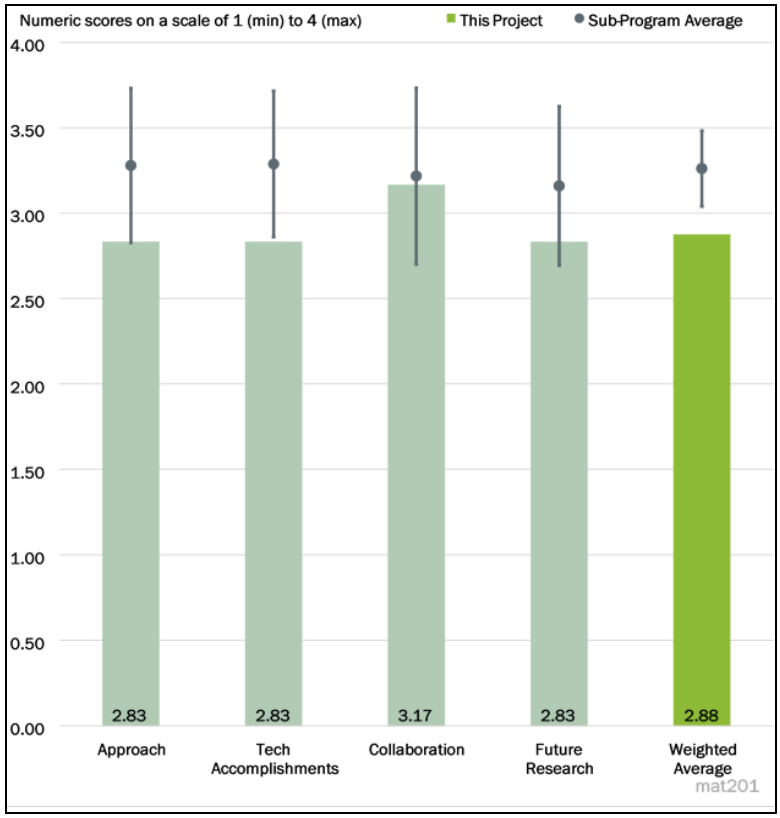


Figure 6-28 - Presentation Number: mat201 Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage Principal Investigator: James Lewicki (Lawrence Livermore National Laboratory)

Presenter

James Lewicki, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to the work is clearly defined. However, how the measured improvements in resin properties relate to overall compressed natural gas (CNG) tank performance was not fully addressed, according to the reviewer. Based on the presentation, there should be more effort directed at understanding system-level benefits of using these additives. The team should also include an assessment of the hurdles to high-volume manufacturing, should this approach be proven effective.

Reviewer 2:

Using direct ink writing (DIW) to print multiscale nano-micro reinforced composites for CNG tanks is innovative and of great interest to the reviewer. The new resin with graphene oxide and carbon nanotubes (CNTs) has shown promising results. The team presents a thoughtful pathway (nano reinforcements, short fibers, and long fibers) to overcoming the barriers.

Reviewer 3:

The project is focused on enhancing matrix properties and using AM to reduce compressed gas storage (CGS) costs. The project does not address the primary cost driver, which is high-strength CF. According to the reviewer, the project premise is not sound and would most likely—and in the best of circumstances—result in increased tank costs for CNG applications. The CGS tank industry is highly developed and efficient with filament winding of five tanks at a time. The AM extrusion process is prone to have many defects and has a much slower manufacturing rate. However, the approach toward enhancing the matrix may have some merit for cryo-hydrogen storage to reduce micro-cracks and enhance toughness.

The reviewer strongly urged the team to interact with a CGS tank manufacturer that understands tank certification requirements, SOA materials, and manufacturing methods. The work may result in improved matrices for more extreme environments. The team should be aware that nano-enhanced matrix resins have been developed for tanks in the past 10 years and are kept proprietary. Another chief concern is that tank volume and weight are critical design issues. The current approach using low-performance, chopped CF will seriously reduce tank volume and increase tank weight.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The research team presented clear evidence that improvements in resin performance are possible with the incorporation of nanofillers. This aligns with the July 2021 milestone for this project. Furthermore, the reviewer stated that scalable methods are being investigated for incorporation of high aspect ratio nanofillers into the resin.

Reviewer 2:

The project is on track and has demonstrated progress toward the overall objectives. The preliminary mechanical testing results are encouraging. It would be better if the team could do theoretical calculations (using the rule of mixture) to predict the mechanical performance of the composites. Another one is characterization of the defects in DIW composites during printing. The reviewer asserted that a table is needed to show the costs of graphene oxide and CNTs with reference to conventional CF tanks.

Reviewer 3:

The team was able to compound several formulations and print test coupons. According to the reviewer, the technology may ultimately have value for AM but is very unlikely to be used in CGS tanks.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration has been excellent. Lawrence Livermore National Laboratory (LLNL) is teamed up with MSC Materials Sciences, LLC, to scale up the composite design and process. The X-ray Computed Tomography XCT Facility at the University of Texas and mechanical testing at the University of Illinois at Urbana-Champaign (UIUC) are essential and helpful, according to the reviewer.

Reviewer 2:

The reviewer indicated that the roles and responsibilities for the project partners are clearly defined with good communication across the team.

Reviewer 3:

Collaborator roles are defined. The reviewer suggested consulting with an actual tank manufacturer to determine if the technology has value. The reviewer also suggested evaluating the DOE Hydrogen and Fuel Cell Technologies Office CGS tank cost 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The future research is well planned with appropriate decision points and risk mitigation plans. The reviewer opined that it will be necessary for the project to down-select a nano-reinforcement recipe and optimize the DIW process to get fewer defects at low cost.

Reviewer 2:

The proposed work plan addresses most of the key technical hurdles. However, further attention should be placed on the system-level performance of this hybridized design. In addition, the reviewer said that the potential negative effects of tank charging and discharging and resultant fatigue life need to be determined.

Reviewer 3:

The primary focus is on improving strength and stiffness of the AM printing resin. The current performance is far below current practice and not expected to meet requirements. The reviewer suggested that the team seeks guidance from a tank manufacturer to see where the technology could have value.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the work being performed supports the DOE goals for improved energy efficiency through the use of lower cost CNG energy storage.

Reviewer 2:

The project directly supports the overall DOE objectives. The reviewer commented that lightweight, low-cost CNG composites are critical for lightweighting vehicles and lowering carbon emissions.

Reviewer 3:

The reviewer stated that the technology premise is flawed as described above but may have some value in cryo-hydrogen storage.

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

Reviewer 1:

LLNL, MSC Materials Sciences, the University of Texas XCT Facility, and UIUC have sufficient resources and expertise toward the stated milestones. The reviewer found that the project is on track and is progressing in a timely manner.

Reviewer 2:

According to the reviewer, the milestones to develop a formulation and print with it are on track.

Reviewer 3:

Based upon the stated progress against objectives, the reviewer indicated that the project remains on track to meet the stated milestones.

Presentation Number: mat202
Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles
Principal Investigator: Rigoberto Advincula (Oak Ridge National Laboratory)

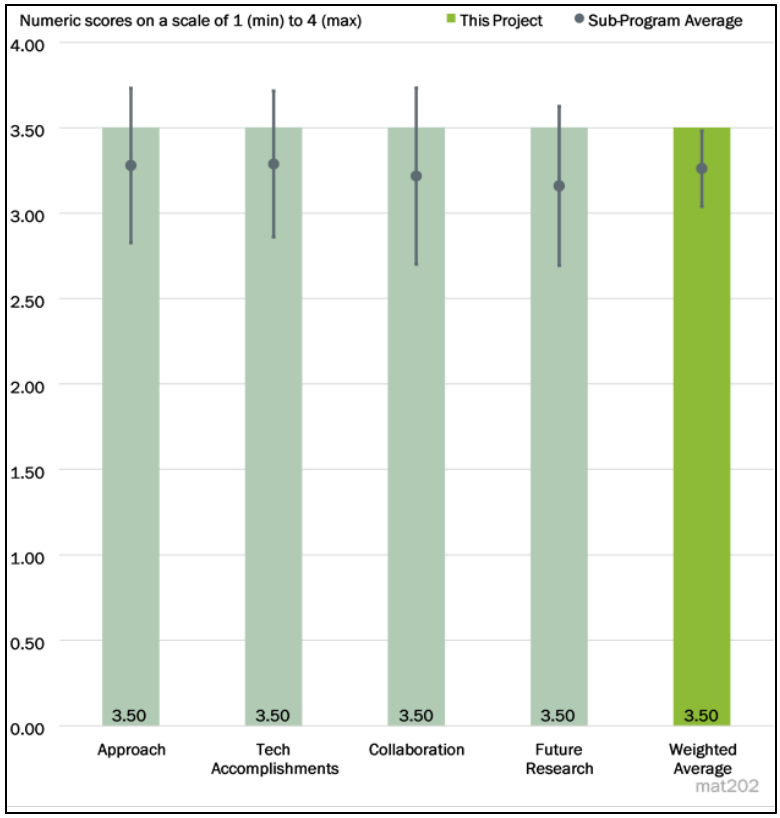


Figure 6-29 - Presentation Number: mat202 Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles Principal Investigator: Rigoberto Advincula (Oak Ridge National Laboratory)

Presenter

Rigoberto Advincula, Oak Ridge National Laboratory

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer observed an excellent breakdown of key tasks and a logical approach to the technical work plan.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted a very nice overview of the key accomplishment by project partners.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer described collaboration with project partners as fully clear and in line with project team 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. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer asserted that future proposed research supports key project learning.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the project supports the DOE objectives in supporting and overcoming key manufacturing barriers.

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 resources were sufficiently deployed.

Presentation Number: mat203
Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

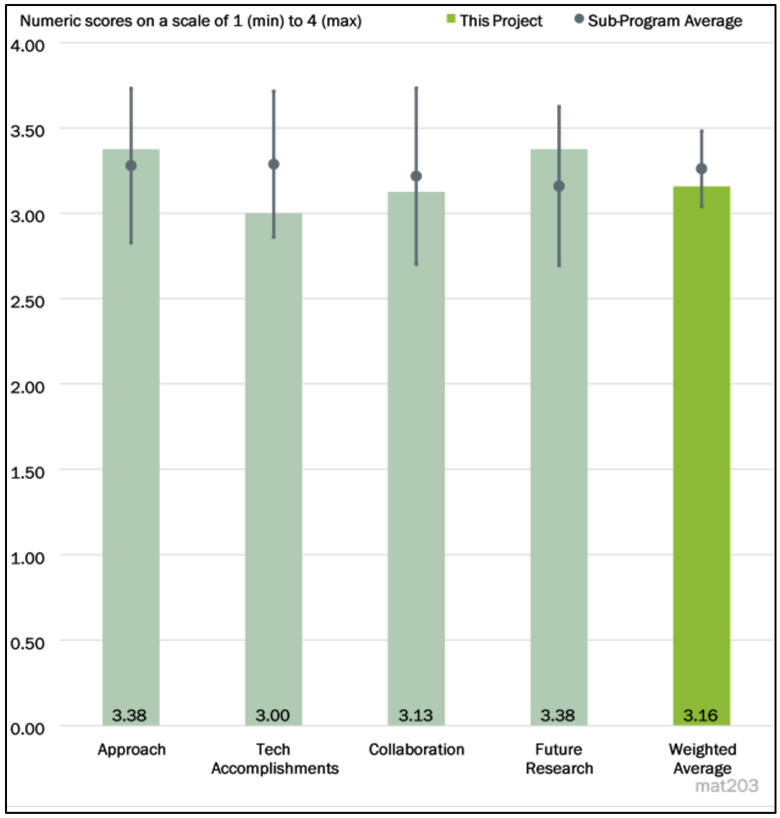


Figure 6-30 - Presentation Number: mat203 Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is innovative. Large-diameter PAN CFs are very challenging. Using low-cost textile PAN is of great interest to lowering the CF cost. Drying, spinning, and plasma oxidation are promising. The reviewer opined that the PI’s work with 4XTechnologies helps the technology transfer.

Reviewer 2:

The project intends to meet DOE goals for CF cost and performance using melt-spun PAN with larger effective diameters. The project plan covers key requirements for fiber production. According to the reviewer, potential issues for composite performance should be addressed as well, including fiber shape effect on packing density and mechanical properties. Dog-bone shaped CF and other shapes were explored in 1970s. The key difference was an aerospace focus on tensile strength versus a DOE focus on modulus.

The reviewer said that the key issue is oxygen stabilization for larger diameter fibers. In fact, the minor diameter of the fiber is actually less than conventional fiber diameters, so diffusion rate should not be an issue.

Reviewer 3:

The reviewer commented that the team has the necessary expertise to process large-diameter textile PAN fibers. The project team is fully aware that the oxidation will be challenging, and it plans to use plasma oxidation to accelerate the oxidation step. How large the textile PAN fiber diameter and cost savings can be for the precursor fibers was not perfectly clear to this reviewer. If the cost savings of the precursor fiber are not significant or people can produce dry-spun textile PAN with much smaller diameters, tackling to process large-diameter PAN fibers for CF production may not have a large benefit. The reviewer suggested considering clarifying the diameter and cost benefit of dry-spun textile PAN fibers and why dry-spun textile PAN fibers cannot be produced in smaller diameters. Is there a technical limitation or a cost reason?

Reviewer 4:

There is interest in low-cost CF as the demand for composites increases. This work is a good combination of materials development but also improvements in the process design. The approach taken by the project team toward the goals were clear to the reviewer and the progress made is commensurate with the timeline.

The reviewer had a number of points and questions to be addressed:

- There is interest in low costs with high strength ratios. What are the unique parameters for evaluating this goal as compared to other fiber fabrication methods? Is it availability, transportation of raw materials, and/or cost of the machine?
- There are a number of opportunities for materials development. What is the correlation between specific materials development approaches and their optimization in an actual composite design? Is there a need to develop a new thermoset chemistry with these fibers?
- What AI methods may be employed that can be specific to improved fiber materials and process design development?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project started on October1, 2020, and is on track. The initial precursor for fiber targeted at 25% larger in effective diameter was delivered. The alternative treatment is also ready for treatment. It was not clear to the reviewer if dog-bone-shaped precursor fibers can be converted to circular CFs.

Reviewer 2:

Overall, the reviewer found that the technical accomplishments are matched with the key performance indicators. The demonstrated low-cost fiber materials and process design proposed are on target. The barriers of the project have been identified.

There is a chance to develop new environmental testing protocols that are relevant for this class of fibers (chopped or winding filament). The reviewer wanted to know whether it is relevant to develop this independent of the thermoset matrix used.

Reviewer 3:

The reviewer said that the project technical goals are well defined. The project is really just getting started. Work thus far is updating the facility.

Reviewer 4:

The delay of the project is understandable due to the COVID-19 situation. However, the project progress is significantly behind schedule. The projected milestone completion is crunched into the last 4 months of FY 2021. The reviewer was not sure if that is a realistic schedule.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the collaboration has been excellent. The project has teamed up with 4XTechnologies, providing fast technology transfer to industry.

Reviewer 2:

The capability of 4XTechnologies is highly complementary. Textile PAN precursor will be provided by Dralon GmbH. This may be due to the limitation of manufacturers, but the reviewer noted that Dralon GmbH is not based in the United States, and it may be more beneficial to get textile PAN precursor from a U.S. company.

Reviewer 3:

The reviewer commented that the project team is comprised of the critical elements, including PAN fiber production, ozone stabilization, CF conversion, performance, and cost evaluation.

Reviewer 4:

The reviewer indicated that more details on collaborative effort with possible external partners can be stated.

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 state project ended.

Reviewer 1:

The future research is well planned and on track. The decision points and risk mitigating plans made sense to the reviewer. Alternative treatments have been considered.

Reviewer 2:

Future work is well defined with respect to CF production. The reviewer suggested that the research team should also consider composite manufacturing and performance. Fiber packing is likely to be complex.

Reviewer 3:

The direction of future research was clear to the reviewer and has been well stated in the presentation. Is it possible that a new direction toward more environmental testing can be employed, including exposure of fiber to more extreme conditions?

Reviewer 4:

The mechanical strength targets and cost-analysis plan are well mapped out, according to the reviewer. The project targets processing 25% larger effective diameter fiber in Year 1 and 50% larger diameter fiber in Year 2. Because the baseline diameter is not described, a 25% or 50% larger diameter is hard to evaluate. If the baseline diameter is already large, processing a 50% larger diameter and delivering high mechanical strength within reasonable processing time and energy use will be very challenging. While the general target is good, lack of a detailed strategy, other than process optimization, makes the plan relatively vague.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project is relevant to the mission of DOE EERE VTO. It also addresses the challenges of the specific TRL level that is mentioned in the phased project timeline.

Reviewer 2:

According to the reviewer, the project supports the overall DOE objectives, which are developing low-cost, high-strength CFs for lightweight vehicles. This is also critical for EVs and reducing carbon emissions.

Reviewer 3:

The reviewer affirmed that, yes, the project clearly addresses targets for DOE performance and cost.

Reviewer 4:

It is important to establish the process technology for CF production from low-cost precursors. The success of this project may translate to the other low-cost, large-diameter precursors. The reviewer suggested that it will be good to have an estimate of techno-economic analysis in the early stage. If processing dry-spun, large-diameter fiber does not provide significant cost benefit with increasing process costs, it may be rather good to look into investigating dry-spinning textile-grade PAN to reasonably small diameters by manipulating the spinning process and draw ratio.

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, yes, the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly.

Reviewer 2:

The project team (ORNL and 4XTechnologies) has sufficient resources for the project to achieve the proposed milestones. The reviewer found that the project is on track and expected to meet the milestones in Year 2.

Reviewer 3:

According to the reviewer, the resources are sufficient to conduct the proposed project.

Reviewer 4:

Resources are sufficient to conduct the research. The reviewer remarked that there is no guarantee that the resulting fiber will meet performance targets—at least no past data were presented.

Presentation Number: mat204
Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry
Principal Investigator: Tomonori Saito (Oak Ridge National Laboratory)

Presenter

Tomonori Saito, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

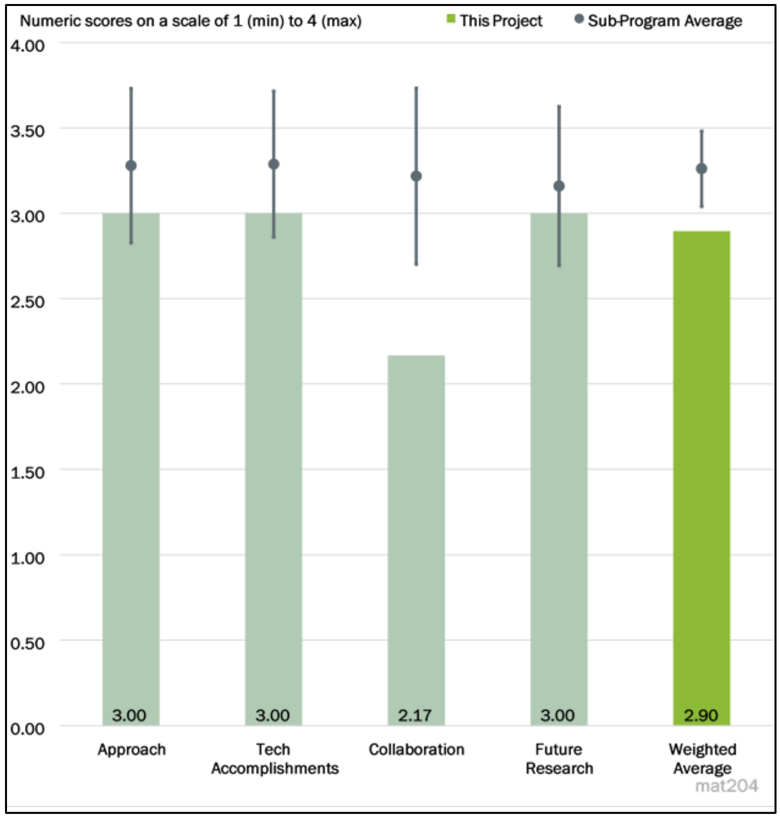


Figure 6-31 - Presentation Number: mat204 Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry Principal Investigator: Tomonori Saito (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has demonstrated the ability to produce vitrimers with properties of interest for advanced composites. Extensive characterization will be required for any safety critical applications, but for now this looked like an interesting technology to the reviewer.

Reviewer 2:

Given the unique reversible bonding nature of vitrimer, the proposed vitrimer-based carbon fiber reinforced composites (CFRCs) could realize the desired welding, repairing, and recycling features. Although the presentation did not show any chemical structures, the project seemed well designed to the reviewer, and the proposed experiments and tests seem feasible.

Reviewer 3:

The reviewer noted that the technical barriers targeted in this project are the lack of low-cost, high-volume manufacturing, joining and repair, and recycling options for current CFRPs. Vitrimer resins have the potential to overcome these barriers through reduced cycle time in production and the ability of them to be reformed and recovered. The targeted production of vitrimer from "commodity polymers" may enable competitive material costs and supply availability relative to vitrimer resins from novel, boutique polymers.

Development of novel modification strategies for CF is less directly applicable to the targeted goals. Dynamic chemistry between the resin and the fiber may enable recycling options, but the reviewer asserted that recovery of CFs from the CF and vitrimer system to demonstrate this advantage is not identified in the milestones or the future work. Custom fiber sizing increases interfacial bonding and composite performance but does not lower cost for high-volume manufacturing or enable joining or repair.

Part of the second-year scope of the project (the September 30, 2022, milestone) and the first-year accomplishments reported is demonstration of CFRP manufacturing by prepregs and stamping with conventional resins. While baselining the vitrimer resins is important, CFRP production using prepregs and stamping should be known technology by ORNL. Its demonstrations are not a meaningful milestone of this vitrimer resin project, according to the reviewer.

The feasibility of the vitrimer systems explored for overcoming the technical targets was difficult for the reviewer to assess as no information is provided regarding the chemical systems and approaches pursued.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Pretty good research progress has been made, including vitrimer synthesis, mechanical property studies, CF surface functionalization, as well as CFRC preparation. It seemed to the reviewer that the processing temperature of current vitrimers is a little bit low, but further optimization is definitely feasible.

Reviewer 2:

The reviewer said that two resins were developed, with strong progress toward meeting Year 1 milestones.

Reviewer 3:

According to the reviewer, no information is provided on chemical systems and approaches being pursued (only vitrimer resin 1, crosslinker-a, etc.). No information is provided on the nature of CF functionalization (only X-ray photoelectron spectroscopy [XPS] confirmed). Tensile strength targets appear to be successfully met for both resin 1 and resin 2.

Milestone progress appears to be on track, but other than the 25 MPa strength performance, most of the milestones involve accomplishments like designing, quantifying, and identifying with numerical targets and were therefore difficult for the reviewer to use to measure progress toward project goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

ORNL states collaborators will be selected at a later date to include fiber, resin, and OEMs. The reviewer said that this is a sound strategy.

Reviewer 2:

It seemed to the reviewer that there are no official collaborators or partners at the current stage, although the PI has reached out to some potential partners, and some of them might join the collaboration at a later stage toward commercialization.

Reviewer 3:

The reviewer reported that the project only has one participant, ORNL, and does not involve collaboration or coordination with other team members. However, collaboration partners are proposed to be pursued "As the project progresses, toward commercialization," but the reviewer indicated that the project would benefit from an early stage by communication with resin suppliers, compounders, molders, and OEMs to identify performance targets and commercial feasibility of approaches pursued.

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 state project ended.

Reviewer 1:

Future proposed research is appropriate. The reviewer suggested including existing commercial-sized CF as part of the evaluation to be less disruptive to the supply chain.

Reviewer 2:

The proposed research seems to align with the project aims very well. There are a lot of parameters the PI can play with. The reviewer suggested that a recyclability study should be one of the key research tasks.

Reviewer 3:

The reviewer indicated that decisions point at the end of the first year and the end of the second year involves resin mechanical performance (35 MPa tensile strength) and CF composite performance (500 MPa tensile strength). Verifying resin and composite mechanical performance is a reasonable strategy to compare the novel resin systems to current SOA automotive resins. The reviewer asserted that the inability to meet strength performance would be a significant barrier to realization of the proposed technology.

The target vitrimer resins are proposed, however, to address the CFRP barriers of high-cost, low-volume manufacturing, inability to join or repair, and the inability to recycle. None of these potential advantages of vitrimers that justify investment in vitrimer development is addressed by the project decision points or by the milestones and deliverables (at least the ones provided here that cover Year 1 and Year 2 of the project). These points are mentioned in the Remaining Challenges and Barriers, but details on strategies to measure progress toward them or address them are not described in the Proposed Future Research other than “optimizing the resin chemistry, fiber functionalization, and composite fabrication process.” Without details it was difficult for the reviewer to assess mitigation of risk through consideration of multiple development pathways. The development of vitrimer resin 1 and vitrimer resin 2, with two orders of magnitude difference in strain-to-break, may represent two distinct technology alternatives to mitigate risk if one is found not to be suitable.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the stated goals of the project— to decrease processing time, increase repairability, increase recyclability, and increase affordability— directly support overall DOE objectives.

Reviewer 2:

The reviewer commented that the proposed vitrimer-based composites could provide affordable CFRPs with re-processability, recyclability, and repairability, aligning well with the VTO goals for lightweight vehicles.

Reviewer 3:

The biggest advantage to the vitrimer technology is that it may provide a better pathway toward recycling while maintaining more of the virgin composite performance. The vitrimer technology should provide the best characteristics of thermosets and thermoplastics. The reviewer asserted that cost is critical and has not been discussed.

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

Reviewer 1:

Resources are sufficient to meet the project milestones. The reviewer stated that movement toward commercialization may be lengthy and extensive, depending on the vitrimer synthesis process and cost.

Reviewer 2:

The reviewer stated that the PI has access to all the necessary facilities and resources.

Reviewer 3:

According to the reviewer, the stated milestones are not ambitious but are vague and listed mostly as actions rather than measurable achievements. They will be easily met with remaining resources.

Presentation Number: mat205
Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites
Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

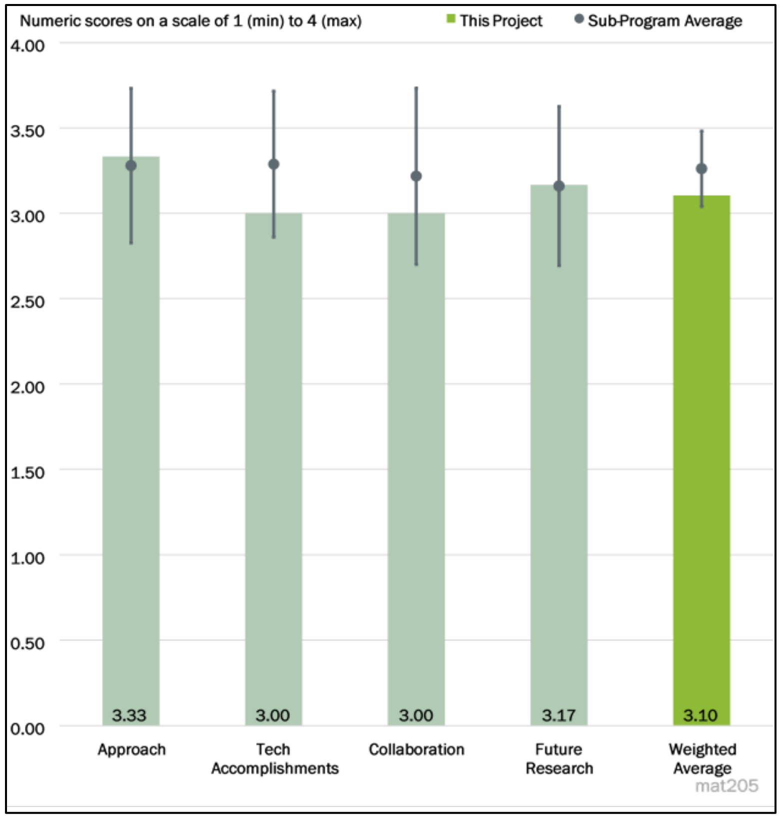


Figure 6-32 - Presentation Number: mat205 Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers felt that the project was relevant to current DOE objectives, 33% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that pros of the technical approach include use of commodity fibers instead of nanofibers and nanomaterials, and activating fiber surface for enhanced adhesion. The reviewer that it was unclear why polypropylene (PP) was chosen; polyethylene (PE) is the commodity polymer with larger market volume and lower resin pricing.

Reviewer 2:

Developing an optimum sizing chemistry for CF to use with thermoplastic resins is a challenging problem, and this reviewer indicated that it is nice to see the project address this hot topic. The reviewer suggested that sizing chemistry needs to be optimized from various performance requirements—strength, molding process, and loading type such as impact, fatigue, etc. The project is well designed and take into consideration the previously mentioned requirements. Additionally, the objectives set for the mechanical performance makes sense—strength between 0.8-1.4 Gpa, 50-100 Gpa for stiffness, etc.—with large tow continuous CF composites.

The reviewer remarked that it is not clear what the plans are in meeting the cost reduction object (30-50%?). Furthermore, the objective of meeting a 100 MPa tensile strength using discontinuous fiber materials is very low for a volume fraction around 30%. The reviewer explained that commercial thermoplastic materials already provide a strength around 200 MPa using discontinuous CF materials (1 in long) with 30% volume fraction. Can the project team elaborate on the metric?

Reviewer 3:

Given the number of DOE CF composite programs funded, this reviewer suggested that the project team develop a more specific list of barriers that would be relevant to the project. The barriers listed are too broad and there is not a clear link between project deliverables and listed barriers. The reviewer stated that notably more is understood regarding CF systems since the publication of February 2013 light-duty technical requirements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Milestones were met on time or ahead of time, which this reviewer described as commendable. The reviewer further reported that the first stage of the manufacturing approach was determined.

Reviewer 2:

The reviewer observed reasonable technical progress as the project plan was developed. However, the plan does not adequately describe the direct link to barriers.

Reviewer 3:

This reviewer pointed out that one of the AMR presentation figures showed that treated CF composite yields a strength of 138 MPa at a volume fraction close to 22%. Is this with the continuous or discontinuous fibers? What are the volume fractions?

Additionally, the reviewer noted that the unidirectional PP composite with CF showing improvement in the composite ductility was shown. What is the mechanism involved in achieving a ductility greater than 20%? The reviewer also asked why the stress versus strain curve is showing a change in slope at around 8% strain, and what phenomenon is involved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Good collaboration was established with a university, and the reviewer commented that it was great to see the project support a graduate student and aid in workforce development.

Reviewer 2:

The reviewer remarked that the level of progress is in line with the required collaboration and coordination.

Reviewer 3:

This reviewer indicated that it was good to see greater collaboration between the researchers inside ORNL. However, it was not clear what kind of collaboration exists between ORNL and the University of Tennessee, and the reviewer requested a description.

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 state project ended.

Reviewer 1:

The reviewer noted that detailed plans were provided for future work, and project success measures were established early in the form of milestones and go/no-go points.

Reviewer 2:

This reviewer observed very detailed and specific future work, with no clear indication of overcoming the barriers listed.

Reviewer 3:

The reviewer described proposed future work as well laid out and reported that the project goal is to work with large-tow fiber systems. It was not clear why work over the last year involved commercial, small-tow fiber systems.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project directly supports DOE objectives in developing cost-effective high-performance thermoplastic composite material systems for the U.S. industry.

Reviewer 2:

Developing lightweight automotive materials at low cost using commodity precursors was described by this reviewer as essential for reducing automotive weight and enhancing fuel efficiency while decreasing GHGs.

Reviewer 3:

Unfortunately, this reviewer did not understand how this project would help achieve DOE objectives. The barriers listed are too broad and not relevant to what has been understood about CF composite systems in vehicle body structures. Perhaps, it was the way the project was presented and reviewed, or this reviewer's lack of understanding regarding the key project 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 sufficient resource utilization.

Reviewer 2:

The reviewer asserted that the resources proposed to meet project deliverables are sufficient.

Reviewer 3:

Future plans seemed to align with the level of funding provided from this reviewer's perspective.

Presentation Number: mat206
Presentation Title: Soft Smart Tools Using Additive Manufacturing
Principal Investigator: Jay Gaillard (Savannah River National Laboratory)

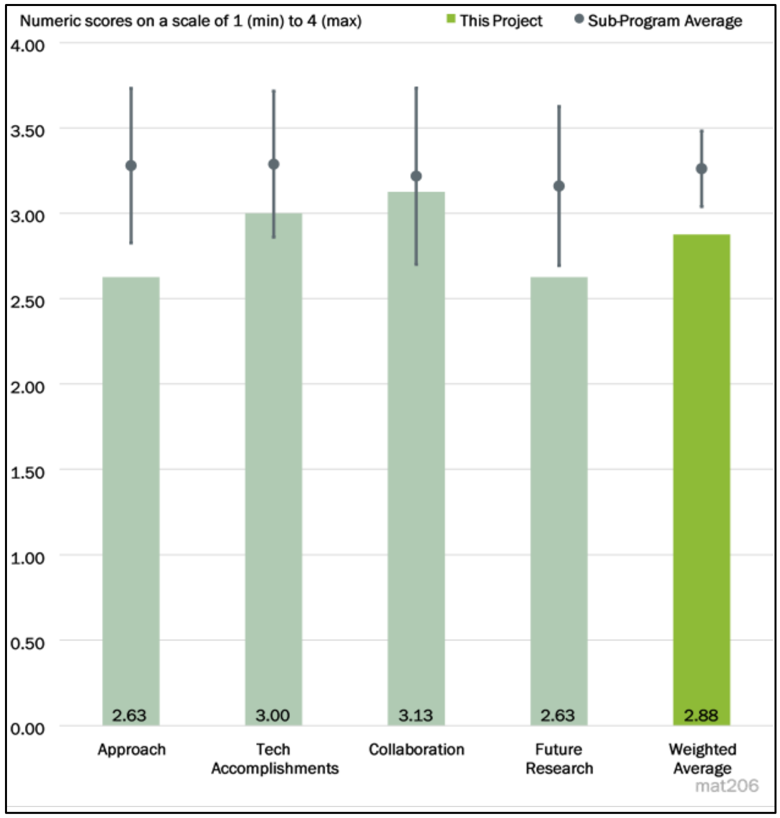


Figure 6-33 - Presentation Number: mat206 Presentation Title: Soft Smart Tools Using Additive Manufacturing Principal Investigator: Jay Gaillard (Savannah River National Laboratory)

Presenter

Jay Gaillard, Savannah River National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked the approach of using 3-D printing for tooling as opposed to using 3-D printing to directly fabricate parts. With the automotive industry needing high-volume parts, 3-D printing the tooling is a much more viable route to utilize 3-D printing in industry. The objectives are clearly laid out and the approach is excellent in targeting increased strength and increased thermal conductivity and integrating sensors into the 3-D printed tooling part. One aspect that could be added is quantifying the durability of these tooling parts compared to current industrial tooling parts. The use of electromagnetic (EM)-coupled heating compared to conventional heating is a great route to explore and could reveal significant improvements in industrial processing.

Reviewer 2:

The reviewer indicated that, generally, the project is well designed for the proposed tasks. Understanding how microwave heating affects various properties is an especially interesting approach. However, it is a little confusing how microwave heating is connecting to 3D printed sensor. While development of printable sensors itself is an important research subject, is EM-coupled heating critical for a sensing capability? The impact of the project seemed vague to the reviewer. The project aims to reduce tool cost and the curing cycle and lower thermal gradients. Are these parameters actually major issues in vehicle manufacturing?

Reviewer 3:

According to the reviewer, the project does not identify what type tooling or process it intends to support, and thus there are little criteria for success metrics. Polymer AM tooling has been demonstrated over the past decade and this project would appear to do little more than drive up the cost. With that being said, the TRL Level 2 effort could result in some technology like multifunctional structures that could be useful in some applications. America Makes funded a project about 6 or 7 years ago that demonstrated a higher level of embedded sensors and electronics.

Reviewer 4:

The project focus per title and project objective is soft tooling for automotive applications. The reviewer had several questions that were unanswered in the presentation or during the Q&A:

- What are the process and tooling technology that are being investigated?
- What is the target size of the tooling?
- What are the requirements on the tool (loads, temperatures, surface finish, etc.)?
- What is the expected life of the tooling?

Without answering at least some of these questions, investigation of AM with sensors is perhaps a worthwhile exercise but does not have a target or actual application.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Great progress has been made in evaluating the effectiveness of microwave heat treatment of the parts and in evaluating the best materials to be integrated into the parts to improve the microwave heating. The tensile strength results of the microwave-annealed parts are very promising, but the reviewer suggested including error bars in the tensile strength results to show the variability in part performance after the microwave heat treatment. The reviewer thought that the microwave heat treatment could also reduce the tensile strength result standard deviation over the baseline parts, which could serve as another reason to use that annealing process. The team has made great progress in evaluating different 3-D printed materials as well.

Reviewer 2:

Considering that this is the first year and especially during the COVID-19 pandemic, the reviewer stated that the team has made very good progress.

Reviewer 3:

This reviewer reported that the project just started and the researchers are investigating AM techniques with various fillers as well as direct-write techniques with conductive inks. Hyrel equipment is used for both efforts. Without targets, the reviewer asserted that this is exploratory work.

Reviewer 4:

The reviewer opined that the technical goal of using radiofrequency (RF) energy to anneal the tool seems misguided at best because a simple oven works fine. Ideally, the RF would be used to heat the tool during processing, such as curing a resin, but this is not the team's objective. Printing sensors on the tool might seem like a good idea; however, the tool typically requires machining after the print and any surface sensors would be lost.

The team was able to compound some AM feedstocks, print with them, and show some property improvements. Similar work had been accomplished 10 years ago. Conductive ink was applied to the tool surface to be used as a pressure sensor. Again, this was nothing new. The reviewer suggested that the EM susceptor microwave heating is the most novel accomplishment and should be applied in-process rather than in tool annealing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer commented that the project team consists of an excellent combination of partners that are tackling different tasks within the project, and the collaborator overview slide clearly defines the tasks for which each partner is responsible. One thing that could be clarified in the presentation is that when discussing the results, the collaborator and partner that performed the work could be mentioned on that specific slide. Overall, based on the progress made so far, it seemed to the reviewer that the project team is coordinating research activities very nicely.

Reviewer 2:

The team seems to be making ample use of collaborators; however, the reviewer suggested that having an end-use application for the tool technology would provide more focus and realism. In many cases, polymeric AM tooling has proven more expensive than CNC machine Al tooling and has a shorter service life.

Reviewer 3:

The research team has a synergistic collaboration for this research project. One suggestion is to plan for commercialization of the technology in the future. From looking at the roles, the reviewer commented that none of the institutes in the team will be the one to commercialize the technology.

Reviewer 4:

It appeared to the reviewer that collaboration is planned. Given the fact that this project just started, it would not be fair to judge the quality of 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed work is nicely described in a logical manner and the goals seem achievable in the project's timeframe. The proposed work also mentions more materials to evaluate so that greatly mitigates risks of some materials not performing as expected. One thing that can be considered for future work is discussing how the annealing process could be scaled up. The reviewer noted that some tooling parts can be very large, so discussing how the energy and time to anneal a part could change with the size of part would be valuable.

Reviewer 2:

The research focuses on annealing of parts and on printing with polyetherether ketone (PEEK) and polyetherketoneketone (PEKK) materials and continuous fiber. This is interesting academic work; however, the relation to tooling applications needs to be defined. What are the loads that this tooling needs to withstand? What are the tolerances and surface finish that need to be achieved? This is clearly low TRL level work; therefore, the reviewer asserted that questions about print speed to produce reasonably sized parts and about cost can be delayed. Techno-economic analyses should be performed in future years.

Reviewer 3:

The reviewer strongly suggested that the team evaluate similar technology that has already been developed and demonstrated. The team should consult with a potential end-user, like a resin transfer molding (RTM) fabricator, for example, to gauge merits and practicality of what is being sought. RF tool heating may have merit.

Reviewer 4:

In the proposed research tasks, the team has solid research plans, although it was not perfectly clear to the reviewer how the researchers plan to deliver Milestone 3.4 (25% reduction in energy consumption). In addition, is Milestone 3.3 supposed to be a test plan? If so, Milestone 3.3 is a strange milestone considering that is the final year of the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project supports DOE objectives by investigating routes to reduce tool cost, reduce cure cycle times with in-situ monitoring, improve part consistency, and increase tool durability. This would result in reducing overall cost of vehicle production, which meets DOE objectives.

Reviewer 2:

Smart sensing for tools is very important for vehicles and many other applications. The connection of EM heating for smart tooling was not clear to the reviewer, while EM heating is an interesting technique to investigate.

Reviewer 3:

This is a fundamental study of manufacturing and materials problems. The reviewer asserted that relevance to automotive tooling needs to be defined.

Reviewer 4:

It was not clear to the reviewer what DOE objectives are being met with this project. Polymer AM tooling was developed for rapid, low-cost, limited-life part demonstrations. This project would greatly increase tool cost and complexity. There may be some niche application, and the reviewer suggested that the team should consult with part fabricators to find some application pull to solve a problem without a conventional solution. Tool design taking advantage of RF heating is a missed opportunity.

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

Reviewer 1:

The resources appear to be sufficient to meet the milestones within the given timeline. The progress thus far shows that the team has used the current funds effectively, so the reviewer believed that the project team will continue to deliver within the budget and timeframe.

Reviewer 2:

Resources for the project are sufficient, according to the reviewer.

Reviewer 3:

The reviewer found the resources to be sufficient.

Reviewer 4:

Resources appear to be sufficient to meet milestones; however, the reviewer said that it would be best to add a tool demonstration that solves a real problem.

Presentation Number: mat207
Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures
Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

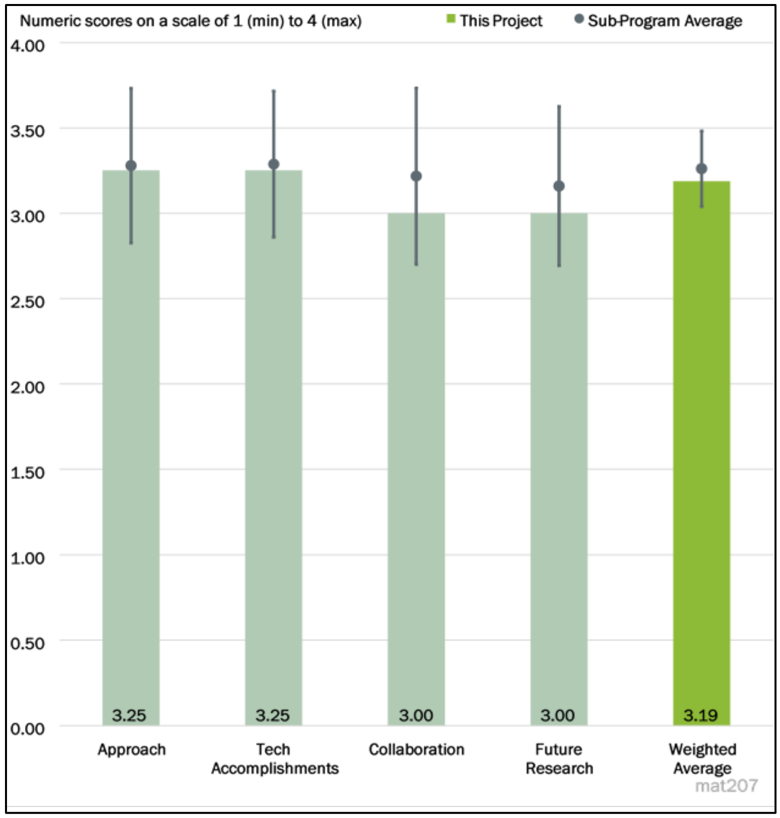


Figure 6-34 - Presentation Number: mat207 Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Presenter

Christopher Bowland, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of developing multifunctional composites for self-health monitoring by integrating ferroelectric particles on the surface of the fiber tows is very novel and innovative. The reviewer said that the project is well designed with important task breakdowns, milestones, and go/no-go decision points.

Reviewer 2:

The objective is to impart multifunctional performance into a composite without adding parasitic weight. The objective is met by improving composite shear strength and imparting apparent piezoelectric behavior to measure mechanical strain. A control sample was not discussed, but the reviewer opined that it could be the silver paint that is responding to strain rather than the coating with discrete particles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress on the project so far was promising to the reviewer. It is nice to see the relation between the applied excitation energy and the voltage measured on the composite material system. Additionally, the reviewer was glad to see that the mechanical performance is also improving after integrating the ferroelectric nano particles.

The reviewer suggested that it would be helpful to collect the data on a greater number of samples to determine the variance and also determine the efficiency of the manufacturing process of nanoparticle integration. The main assumption here seems to be that damage in the composite would result in a different amount of voltage for a given excitation. If so, the reviewer commented that this assumption should have been tested first by measuring the voltage with a different percentage amount of $BaTiO_3$ in the composite.

Reviewer 2:

A nano-coating was applied, and the data show marginal improvement compared to the sized fiber. The reviewer stated that discrete particles are unlikely to form a continuous electrical circuit for simple harmonic motion (SHM). A control sample for strain was not discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project seemed to the reviewer to have good coordination between ORNL and Columbia University.

Reviewer 2:

The reviewer said that the collaboration effort with Columbia University has yet to begin.

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 state project ended.

Reviewer 1:

Proposed future work will be sufficient once the baseline is validated against the silver paint. The reviewer suggested also looking at the state sensor at rest after some damage is imparted rather than when the structure is under strain and vibration during car driving. The data acquisition package is likely too expensive for automotive applications.

Reviewer 2:

The reviewer would have liked to see the sensing and energy harvesting data captured on more samples to determine the performance variation. The reviewer did not see any update from Columbia University and would have liked to see some preliminary work conducted at Columbia University in the last year to get them onboard with the entire project. This would keep both ORNL and Columbia University on the same page.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports overall DOE objectives in developing novel multifunctional composites to make a strong business case. The development of multifunctional capability explored in this project (self-sensing) is very important and will enable implementation of more lightweighting applications in the industry.

Reviewer 2:

Composite structural integrity was a concern to the reviewer and a barrier toward broad application in the automotive sector, primarily in the area of barely visible damage. The approach could have merits but is still at TRL Level 1-2.

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 proposed in the project to achieve the stated milestones are sufficient.

Reviewer 2:

Resources appeared to the reviewer to be adequate for the proposed milestones.

Presentation Number: mat208
Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste
Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

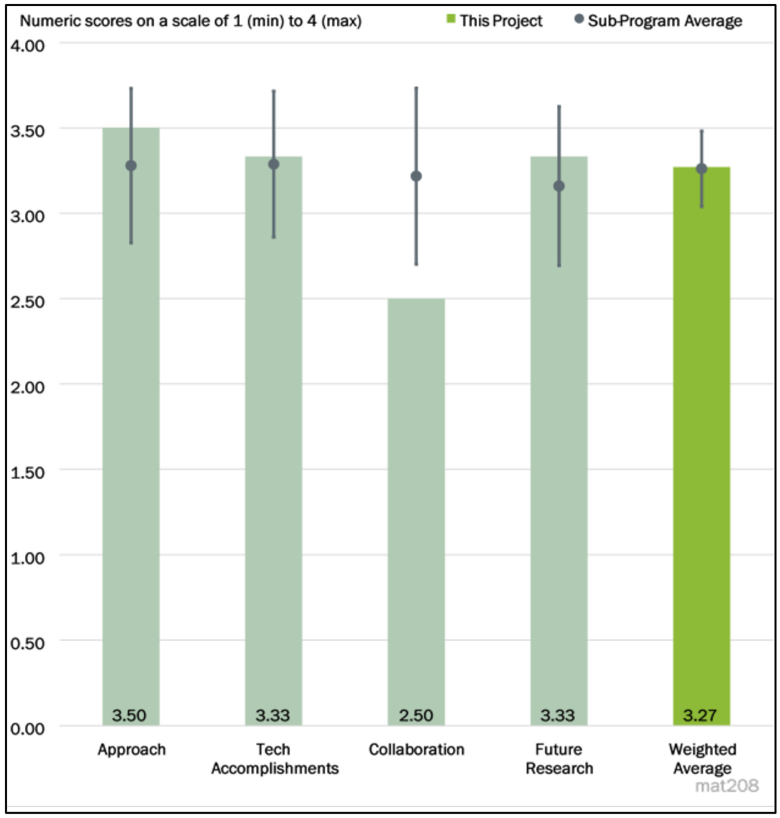


Figure 6-35 - Presentation Number: mat208 Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

Presenter

Lelia Cosimbescu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has an excellent approach to creating aramid fibers from a recycled starting material. This is a unique approach that could result in methods to generate cheaper aramid fibers while also reducing plastic waste and could help aramid fibers see more use in vehicles. The project is designed well in the logical progression of optimizing the synthesis process with the end goal of producing fibers that can be demonstrated in bulk composites. One of the biggest barriers the reviewer saw is producing the fiber. Aramid fiber spinning is not a trivial task, and the project team has identified collaborators and partners to approach to assist with that barrier.

Reviewer 2:

The reviewer commented that the approach is well outlined, and barriers already encountered, such as dissolvability of polyethylene terephthalate (PET) in practical solvents, have been addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project has met the milestone of demonstrating PET deconstruction with a yield of at least 85%. Overall, the project has made very good progress with the deconstruction of PET from a mixed waste stream. There are some residual PET particles after deconstruction, but the reviewer did not see that as much of an issue as long as the yield of at least 85% is still met. The team has also made good progress with preparing four polymers via the traditional route.

Reviewer 2:

According to the reviewer, the project just started, and the researcher has already identified and addressed some key issues.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There were no collaborators in the first stages of the project. For the initial stages, the team had the expertise to perform all the deconstruction and polymerization work so collaborators were not needed. Suggestions were made for establishing a collaboration with the University of Tennessee and the University of Washington for fiber production. The reviewer advised the project team to establish a partner for fiber production as soon as possible because fiber spinning can have a big learning curve to produce good fibers with consistent diameters and consistent geometries along the length of the fiber.

Reviewer 2:

The reviewer remarked that this appears to be a small project in its infancy. Possible project partners have been identified.

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 state project ended.

Reviewer 1:

The proposed future research was planned well. Good risk mitigation was established by proposing different routes to improve the solubility of the polymer in order to determine the molecular weight. In terms of scale-up, the reviewer suggested having plans to be able to produce numerous 20- gram (g) batches of the polymer due to the amount that will be required to perform the fiber spinning. The techno-economic analysis is vital for this project, and the project team has discussed that as a goal in the final year of the project.

Reviewer 2:

The reviewer noted that the PI has identified issues and proposed feasible ways of attaining aramid chemistry. Spinning of fibers needs to be addressed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project supports DOE objectives. While other projects are investigating ways to reduce the cost of CF, other fibers are needed to replace CF for different composite applications. By reducing the cost barrier for aramid fibers, the reviewer asserted that the team could see more use in vehicle composites that were not previously deemed cost effective and could reduce the vehicle’s overall weight.

Reviewer 2:

Upcycling of PET into Kevlar®-like fibers would be a breakthrough, according 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 said that the resources are sufficient to meet the stated milestones. As long as the project team finds a good collaborator with fiber-spinning capabilities, then the project should have sufficient funds.

Reviewer 2:

The initial research can be performed on the current budget; however, if successful, the reviewer stated that the budget and scope should increase. Collaboration with partners with a strong background in spinning fibers and composite research should be established.

**Presentation Number: mat209
Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling
Principal Investigator: Gregg Beckham (National Renewable Energy Laboratory)**

Presenter

Gregg Beckham, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

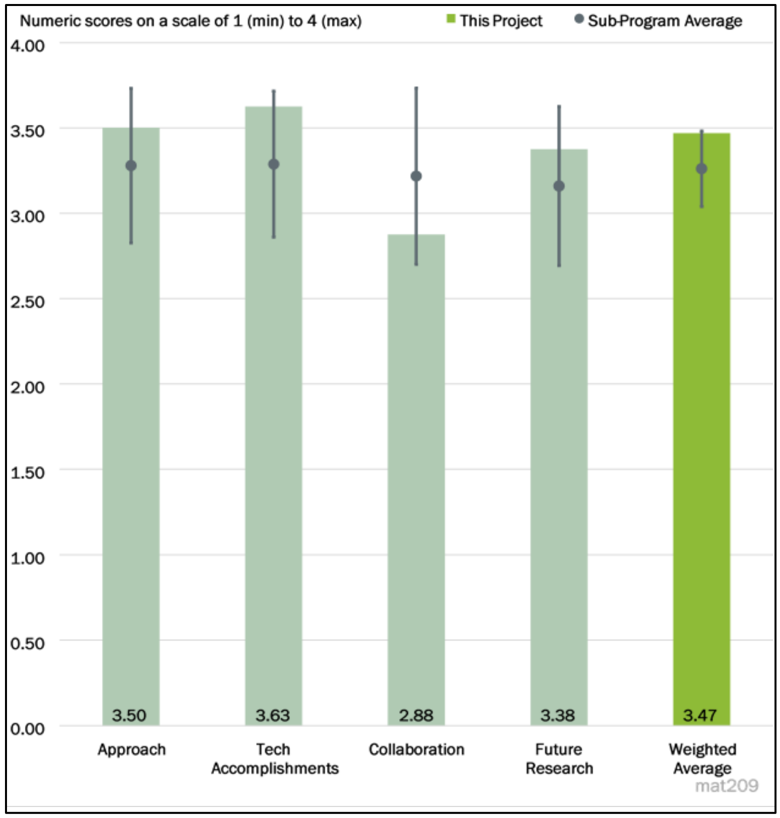


Figure 6-36 - Presentation Number: mat209 Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling Principal Investigator: Gregg Beckham (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project explicitly addresses two of the five critical challenges for carbon fiber (CF) composite materials—low-cost fibers (achieved here through fiber reuse) and recycling. The investigators demonstrated within the first quarter of the project that bio-based, covalently adaptable network resin system has a similar storage modulus and a glass transition temperature (Tg) as a standard epoxy-amine system and moved on to addressing the focus of the work—carbon fiber reinformed polymer (CFRP) recycling.

Low-temperature and low catalyst demonstrations of recycling were pursued, with acknowledgment of potential trade-offs between facile recycling and mechanical performance. The reviewer appropriately appreciated the need for maintained performance in subsequent generations of recycled material.

The project is well designed to identify multiple chemical paths to target resins, to quickly move to scale-up of candidate resins for processing and property demonstration, and to identify alternative strategies to mitigate risk if the target system does not meet required performance.

The reviewer asserted that the project approach is also strong in leveraging collaboration with other DOE investments (National Wind Technology Center, BOTTLE™ [Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment], and Renewable Carbon Fiber Consortium) and in considering techno- economic analysis (TEA) and Materials Flow through Industry (MFI) models relative to existing materials from the beginning of the project.

Reviewer 2:

The project addresses the problem with recycling CF composites by developing a recyclable epoxy-anhydride covalently adaptable network using bio-derived precursors. The reviewer called this a great approach to creating recyclable CF composites to recover both the matrix and the fibers without degrading the fiber integrity. From the start, the project team is keeping in mind life-cycle analysis (LCA) and TEA for this approach, which is great to see especially from the onset of the project. If this approach is successful, then the reviewer believed that this work could significantly reduce the cost of CF composites, especially after multiple cycles of recover and re-use.

Reviewer 3:

This project is in initial stages, but it clearly leverages Principal Investigators (PIs) ongoing efforts in this area. The reviewer said that the project is well structured and included projected costs estimates.

Reviewer 4:

The reviewer noted that the proposed CF reinforced composites based on bio-based precursors could lead to re-processible and recyclable light-weight composites for vehicle manufacturing. By maintaining fiber integrity across multiple cycles, the average cost of the fiber can be reduced.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, first-year milestones focused on points key to the project goal to facilitate CFRP recycling: feasibility comparison with mechanical performance of an epoxy-base resin completed right away, transition to demonstration and development of recycling commenced. The reviewer also found the progress in synthesis, validation, scale-up, and analysis tasks to be impressive and on track.

Reviewer 2:

The reviewer stated that this project clearly leverages other efforts, and the team delivered outstanding results in the first year.

Reviewer 3:

The reviewer’s comment was that good research progress has made in terms of bio-derived resin development, carbon fiber reinforced composite (CFRC) fabrication, a CF recycling study, and initial techno-economic analysis.

Reviewer 4:

The project team has made great progress in synthesizing and demonstrating the concept of the new matrix and its capability to be recycled. The reviewer remarked that the team effectively demonstrated the recycling of a CF composite that shows promising results.

The presentation states that the depolymerization at room temperature takes less than 2 days but can be faster at elevated temperatures. For future commercialization, the reaction would need to be much faster than a day to be attractive to composite recycling companies. After the depolymerization, the reviewer was curious about how the project team envisions the resulting fibers will be reused. For example, if a woven fabric is recovered, the reviewer asked if the weave would remain in its current state as a tight weave or whether it would start to fall apart during the solution process. It will be hard to recover continuous tows of fibers for re-use as a continuous tow since fiber weavers and filament winders typically use spools of fiber that are thousands of feet long, but not that much continuous fiber will be covered from a weave during a batch process. The reviewer wanted to know if the project team could include in the next Annual Merit Review the mechanical testing results to show that the mechanical strength of the fibers is maintained instead of simply stating the integrity is maintained.

The project team offered a good initial TEA and LCA. These analyses are vital to determine the success of this project, so it is great that the project team is already performing the TEA and LCA.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaborators have complementary expertise, with particular focus on redesign, formulation, and recycling area.

Reviewer 2:

The reviewer noted that the project has no partners other than the National Renewable Energy Laboratory (NREL), but the team is collaborating well with other U.S. Department of Energy (DOE) consortia and with wind technology resources at NREL.

Reviewer 3:

This project is in the first year and collaborations have not been established. A list of possible collaborators has been identified. The background of the team in chemistry is impressive. The reviewer encouraged collaboration with organizations having a strong background in composites manufacturing, and technology transition to the industry should be established.

Reviewer 4:

The reviewer remarked that no partners currently exist for the project. However, there are some companies listed that are engaged through the Renewable Carbon Fiber Consortium so there is the potential to add partners throughout the course 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed next focus on fiber reuse directly supports the project goals to reduce the effective cost of CF and enable recycling. Future focus on fiber sizing for increased durability was reasonable to the reviewer in terms of pursuing that goal, and demonstration and development of production processes, such as thermo-forming, are key to technology realization. The proposed pivot options of consideration of alternative resins if the current focus resin does not meet requirement helps to strengthen the project potential and mitigate risk.

Reviewer 2:

The reviewer indicated that future work is proposed in a logical manner and includes technical work relevant to the VTO mission as well as analysis of costs, energy, and carbon impact.

Reviewer 3:

The reviewer noted that detailed future research has been proposed with a particular focus on fiber reuse, sizing, and thermo-forming process, as well as scale-up of composite fabrication.

Reviewer 4:

The reviewer asserted that the proposed future research is laid out in a very logical manner and consists of good milestones for scale up, which are an important aspect for demonstration. Additional pathways were mentioned to improve the price and/or greenhouse gas (GHG) emissions, and alternative chemical pathways were presented, which all contribute to the risk mitigation plan for this project. For future work, the reviewer suggested that it would be a good idea to compare to existing composite recycling techniques, such as pyrolysis, which are able to maintain the fiber integrity and recover useful chemicals that decompose during pyrolysis.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that this project supports overall DOE objectives. Specifically, this work could help reduce the cost of CF composites by enabling recycling using a bio-derived matrix. This could help further accelerate the adoption of CF composites in vehicles, thus leading to vehicle lightweighting.

Reviewer 2:

This project clearly addresses key DOE-recognized Critical Challenges identified by seeking to reduce the overall cost of CF through recovery and reuse and by seeking to enable recycling. The developed technology will also address the needs for repair. The reviewer noted that the focus to increase the use of bio-based materials and reduce GHG emissions for vehicle materials, though not identified as critical CFC technology challenges, also supports overall DOE objectives.

Reviewer 3:

The reviewer observed that this work is relevant to the VTO mission and can provide important contribution to the composites community if successful.

Reviewer 4:

According to the reviewer, the project could lead to novel lightweight composite materials for manufacturing of vehicles with lower cost (recyclability) and 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 resources are sufficient for the project team to meet the milestones in a timely fashion. The team has already shown great progress so far with this year's funds and has a good outline for the future work. So, the reviewer believed the team has the necessary resources to deliver on the rest of the milestones.

Reviewer 2:

Judging from the relatively early point in the project and the significant progress already made, the reviewer commented that this project is on track to achieve its future stated milestones.

Reviewer 3:

The reviewer indicated that the research team has access to all the resources needed to achieve the milestones in a timely fashion.

Reviewer 4:

Resources for this project appeared sufficient to the reviewer.

Presentation Number: mat210
Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite
Principal Investigator: Patrick Blanchard (Ford Motor Company)

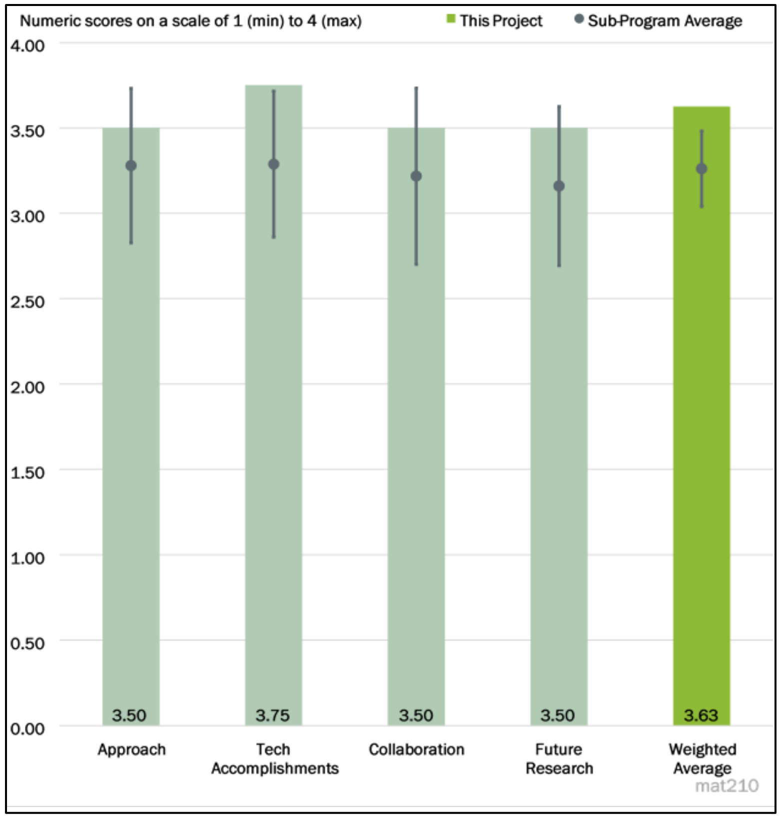


Figure 6-37 - Presentation Number: mat210 Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite Principal Investigator: Patrick Blanchard (Ford Motor Company)

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called additive manufacturing (AM) of CF composites with metal inserts for lightweight seats innovative. The project addresses the barriers and makes excellent progress.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the team did an excellent job in seat design with boundary condition inputs. The design optimization made sense and the project is progressing toward the overall objectives. The metal inserts are necessary. The reviewer inquired whether it is possible to add more CFs in the high stress area to replace metal inserts as this may further reduce the cost and weight.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer noted that collaboration between Oak Ridge National Laboratory (ORNL) and Ford has been excellent. The project is on track to progress toward the stated milestones.

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 state project ended.

Reviewer 1:

The reviewer stated that the future work is well planned with appropriate decision points, risk mitigation plans, and pathways to achieving the milestones.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer asserted that the project directly supports the overall DOE objectives. The success of the project will reduce vehicle weight and carbon emission. The reviewer mentioned that such lightweight seats may find applications in electric vehicles (EVs).

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, ORNL and Ford have sufficient resources and expertise for the project to achieve the stated milestones in a timely manner.

Presentation Number: mat211
Presentation Title: Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles
Principal Investigator: Masato Mizuta (Newport Sensors, Inc.)

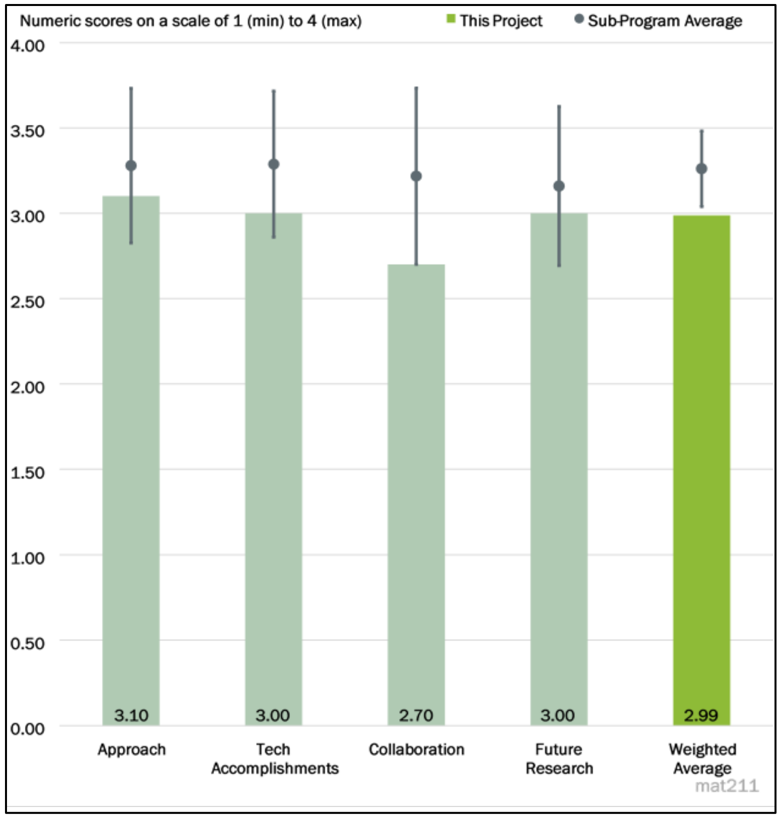


Figure 6-38 - Presentation Number: mat211 Presentation Title: Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles Principal Investigator: Masato Mizuta (Newport Sensors, Inc.)

Presenter

Masato Mizuta, Newport Sensors, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Self-sensing structure often requires external energy for generating the impact signal. This project proposes to develop a self-powered, self-sensing structure in CFRP composites. The idea is to place polyvinylidene fluoride (PVDF) piezoelectric material between CF layers and to use CF layers as an electrode. The sensing and energy harvesting are done simultaneously by including the capacitor circuit and pass filter circuit. The reviewer remarked that the idea is novel, and the approach is appropriate.

Reviewer 2:

The approach addressed the issue of how to integrate sensing functionality into a CFRC. It was demonstrated that the composite could serve as a damage detection device as well as an energy harvester. A circuit was developed that could function as both a sensor and energy harvester. However, the reviewer commented that this was a fairly rudimentary approach to integrating a sensor into a composite since just a layer of PVDF was placed between layers of CF fabric.

Reviewer 3:

The reviewer praised the approach described for developing a multifunctional polymer composite material as excellent because it includes a proven sensor technology but uses the conductive CF as electrodes to transform the sensor output to a damage detection output. The components are commercially available, which reduces costs and the risk of developing a system that does not meet the technical barriers. The development sequence and the circuit layout are well designed and very feasible for successfully addressing the technical barrier of real-time damage identification. The technical barrier for high fiber cost was not addressed during Phase I but is specified as part of the Phase II effort, if funded.

Reviewer 4:

The experimental test program appeared to the reviewer to validate feasibility of the technical approach with impact detected using the integrated piezoelectric sensor. Several questions remain regarding connectivity to the sensors and compatibility of the techniques with automotive production processes. However, this is out of scope for the current project.

Reviewer 5:

The reviewer stated that this project seeks to reduce damage inspection difficulty for CFRP. The project demonstrated that CF fabrics could be assembled into a laminate composite that produces an electric signal when it experiences an impact. The reviewer asserted that the translation of this demonstration to CFRP components used on vehicles or of the impact detection to condition monitoring methods was not provided in this early-stage exploratory research.

CF, though expensive and energy intensive to produce, is of interest for lightweighting automotive parts because of its excellent mechanical properties. Use of CF as electrodes in the demonstrated impact sensor is disconnected from use of CF as mechanical reinforcement in automotive components. The impact or other damage sensing needs to be demonstrated using an automotive CFRP to be relevant or, alternatively, the sensing technology could be pursued as a coating or thin layer to be applied to automotive composites to track impact. In that case, it does not need to be composed of CF itself, as CF on the vehicle is for mechanical reinforcement, not for use as electrodes. The reviewer opined that the project might have been better designed if it considered or at least better communicated how the CF-PVDF sensors would be incorporated in a vehicle to meet DOE non-destructive evaluation (NDE) targets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the presentation showed clear evidence of feasibility for impact, damage detection, and energy harvesting.

Reviewer 2:

For the very short period of performance (about 9 months), this reviewer observed significant technical accomplishments because the project team demonstrated that the sensor, which was integrated into the CFRP material, could detect shock and vibration and generate an electric signal with different frequency characteristics for shock and vibration. However, the charged power storage (energy harvesting feature) was unable to trigger the damage-detection circuit although the ambient vibration signal was sufficient to power the circuit, so this is a very positive result. The reviewer suggested that more research will be needed to select a sensor with the sensitivity and output to perform this function.

Reviewer 3:

The reviewer remarked that the project successfully met its stated objectives of designing and demonstrating a sensor that detects impact. The objective of energy harvesting was demonstrated, but it was not clear whether sufficient energy is harvested to enable the impact sensing or over what time period it is active. This reviewer also reported that “multifunctional CFRP composite including circuitry hardware and software” targeted was demonstrated as a laminated of CF weave and PVDF with externally applied laboratory signal sensing.

Additionally, the reviewer commented that the PVDF composite was multifunctional in the sense that it both produced a voltage from repetitive low-level mechanical stimuli (energy harvesting) and from discreet, higher level mechanical stimuli (impact detection). The functions of energy harvesting and sensing are valuable for on onboard sensor, but the role of CF on a vehicle is mechanical reinforcement and the reviewer would have expected a multifunctional CFRP composite to provide a mechanical (structural) function as well as other useful functions, such as energy storage or sensing.

Reviewer 4:

The reviewer indicated that the team fabricated the composites with PVDF piezoelectric materials and showed the impact-sensing signals with self-power generation. It was not clear to the reviewer if the sensing is a damage detection or an impact detection. The reviewer asked about how the signals differ between an impact without causing damage and an impact with damage. Also, it is not clear if the capacitor circuit and the high pass filter circuit are embedded in the composite structure or they are separate from the composite, since the team mentioned "… fabricate the multifunctional CFRP composites including circuitry hardware.…" Overall, the objectives were achieved in this project.

Reviewer 5:

This reviewer reported that all milestones were met. The team demonstrated the multifunctional composite fabrication as well as the energy harvesting and damage detection functionalities. While the milestones were met, the results reported were not exceptional compared to other sensors that have been demonstrated. It was stated that a novel circuit was developed for this work, but the circuit was not really discussed so the novelty of it could not be determined by the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although this is a short-term Small Business Innovation Research (SBIR) project, the reviewer described potential collaboration identified for future research as outstanding because it includes a full spectrum of entities (researchers, Tier 1 suppliers, and an automotive OEM). The reviewer found apparent close coordination during the planning phase.

Reviewer 2:

According to the reviewer, the PI has reached out to automotive original equipment manufacturers (OEMs) and suppliers to understand customer requirements and interest in future development.

Reviewer 3:

The reviewer stated that no collaborations or partners were named on this project. It was mentioned that OEMs and Tier 1 suppliers were interested in the technology, but no partners have been established yet.

Reviewer 4:

There is no collaboration outside the company, but the reviewer said that the team successfully completed the project.

Reviewer 5:

This reviewer stated that there are no team partners; potential collaboration and communication with OEMs, suppliers, etc., is envisioned but has not been pursued.

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 state project ended.

Reviewer 1:

The reviewer reported that the proposed research plan contains a logical pathway that scales up in complexity to address concerns related to real-world applications. There are also provisions to account for the use of more sustainable composite reinforcements.

Reviewer 2:

The reviewer commented that because this is a Phase I SBIR project, the proposed future research to add a novel sensor to enhance the reliability for in situ damage detection and location is a logical step for Phase II funding, if available. The reviewer called the proposed future research to add a natural fiber to the polymer composite to reduce cost questionable. Although adding a natural fiber will reduce cost, the physical and structural properties of the polymer composites are typically degraded.

Reviewer 3:

This reviewer said that the project has ended.

Reviewer 4:

According to the reviewer, the project has ended.

Reviewer 5:

The reviewer indicated that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project supports the requirements identified by DOE Advanced Research Projects Agency-Energy (ARPA-E) for multifunctional composite materials for energy storage in structural load paths to make a step change in vehicle energy efficiency, particularly for autonomous vehicles and EVs. This project also supports the VTO Materials Technology R&D Program for vehicle weight savings by using integrated lightweight sensors in automotive components.

Reviewer 2:

Overall DOE objectives include enabling lightweight vehicles through development of NDE to track, predict, and extend CFRP lifetime. The reviewer commented that this project supports that objective with early-stage demonstration of a sensor concept that might be self powering and provide indication of CFRP damage in use.

Reviewer 3:

The reviewer stated yes and explained that one of the concerns of using CFRP by replacing metal is its brittle fracture behavior. CFRP is susceptible to a crack failure without noticing its prior damage. A self-damage detecting composite will facilitate the use of the composite.

Reviewer 4:

The reviewer indicated that integration of sensing capability is a key enabler to the incorporation of composite solutions in safety critical applications.

Reviewer 5:

The reviewer stated that this project meets a DOE objective of integrating in situ sensing into composite structures in vehicles.

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 funding of $200,000 to investigate simultaneous sensing and vibration energy harvesting as part of a multifunctional CFRP composite by the small research team is sufficient for this 9-month SBIR project.

Reviewer 2:

The reviewer indicated that the objectives of the project were completed with the resources available.

Reviewer 3:

The reviewer commented that the resources provided for this project were sufficient to meet the milestones established for the project.

Reviewer 4:

The reviewer said that the funding was sufficient to develop the technologies.

Reviewer 5:

The reviewer remarked that the project is complete.

Presentation Number: mat212
Presentation Title: Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles
Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

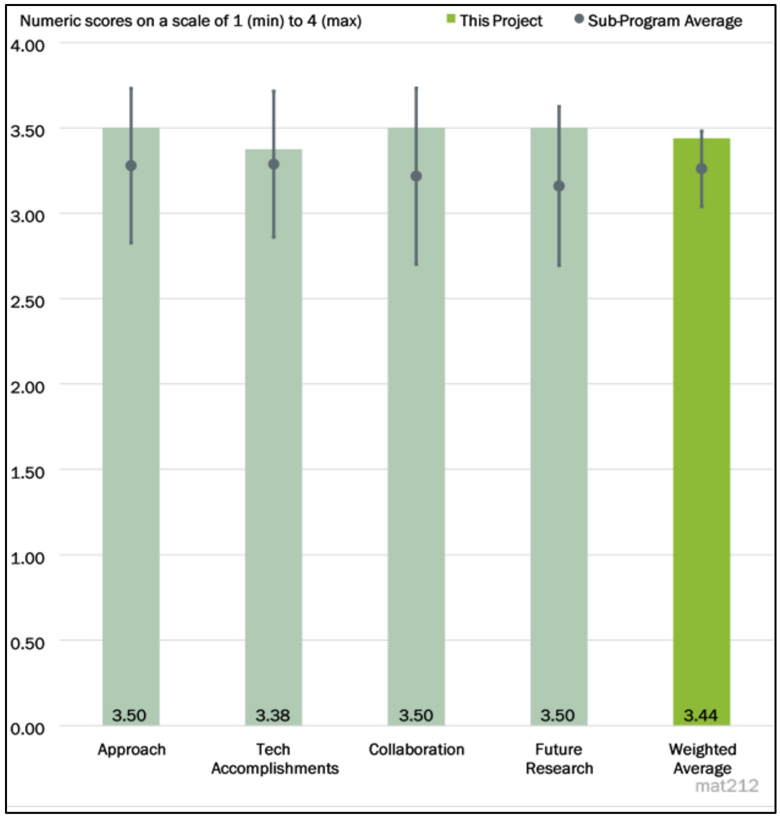


Figure 6-39 - Presentation Number: mat212 Presentation Title: Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

Presenter

Amrita Kumar, Acellent Technologies, Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that the approached for this project was good in that it looked at both active and passive sensing for both a pedestrian protection system and battery monitoring system. The project focused on creating a sensor suite that could be integrated into a vehicle. This addressed technical barriers in creating a system that could be integrated into a vehicle.

Reviewer 2:

The approach is to develop a sensor system utilizing embedded sensor networks designed into vehicle structures to provide weight savings through integration of materials with sensors, electronics, and batteries; to minimize parts counts; and to improve manufacturing processes that will enable significant cost savings. The system under development includes an integrated impact detection system in the front bumper of a car and a battery monitoring system. System integration during the manufacturing process is intended to create a structurally integrated sensor network. The reviewer commented that an integrated approach for both systems will achieve the technical targets identified by DOE ARPA-E for multifunctional composite materials for energy storage in structural components in future vehicles. The approach also supports the VTO Materials Technology R&D Program goals for vehicle weight savings by using integrated lightweight layered sensors in structural elements of a vehicle.

Reviewer 3:

The reviewer noted that the work plan addresses all key challenges and offers practical solutions for implementation.

Reviewer 4:

The project is a good combination of sensor development and design integration of a pedestrian protection system (PPS) and a battery management system (BMS) for autonomous vehicles and EVs. The approach taken by the project toward the goals is clear, and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer had several questions and comments:

- Because the interest is in monitoring structures for damage or actuation, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time? Can there be aging experiments done to look at sensor response degradation?
- There are a number of opportunities for materials development, too. What is the correlation between specific materials development approaches and their demonstrated sensor design in various thermoplastic and thermoset composites?
- What artificial intelligence (AI) methods may be employed that can be specific to improving sensor performance?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

For the very short period of performance (about 9 months), the reviewer asserted that there has been excellent progress for designing and installing a sensor network for pedestrian impact detection. Acellent and Stanford University also used piezoelectric transducers to accurately monitor the state of charge and end of life for battery cell monitoring when the sensors were embedded inside a composite structure. These are significant accomplishments for the short-term effort toward meeting the technical targets.

Reviewer 2:

All milestones were met for this project. At least two additional functionalities were integrated into vehicle composites. In the pedestrian protection system, the project team was able to demonstrate both a pedestrian and non-pedestrian impact event as well as provide image location information. The reviewer commented that good information was provided about how the sensors were fabricated and integrated into an actual bumper for testing. The project team demonstrated that the response time to an impact could be minimized by integrating an array of sensors as opposed to a single sensor that is currently used.

Reviewer 3:

According to the reviewer, the technical accomplishments match the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified. The partnership with Stanford and Ford is very productive. The reviewer suggested that more collaborative efforts with possible other external partners could be started.

Reviewer 4:

The presentation shows clear evidence to the reviewer that the sensing system under development can be very effective at detecting impact and, potentially, defects in composite components.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer applauded as excellent this small, collaborative project team, which includes a university, a supplier of commercial systems, and an OEM, all of whom are essential for a successful transfer of technology. This team exemplifies elements needed for acceptance of a multifunctional, structurally integrated sensor system by an automotive manufacturer.

Reviewer 2:

The reviewer commented that the PI has been extremely proactive in seeking guidance from existing industrial partners in order to fully understand downstream customer requirements.

Reviewer 3:

The project team collaborated with Stanford University and Ford. These were excellent partners for the project in that the project team utilized licensed technology from Stanford for the BMS as well as developing requirements for the systems from Ford. The reviewer stated that this provides a strong case for future deployment in future vehicles.

Reviewer 4:

The reviewer suggested that a new collaborative effort with possible external partners be started in the testing phase beyond PPS and BMS. This reviewer also noted focus on materials durability.

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 state project ended.

Reviewer 1:

Since this is a Phase I SBIR project, the proposed future research for Phase II, if funded, is to develop a PPS and a BMS using a unified architecture for implementation of both systems in a vehicle design. The reviewer said that this is a logical follow-on to Phase I. Future research proposed includes designing, developing, and testing of complete prototype systems; designing the architecture of a unified multifunctional sensing system for cars; and developing commercialization plans and cost targets with automotive companies. This is an outstanding approach to achieve transfer of the systems under development.

Reviewer 2:

The direction toward future research was clear to the reviewer and has been stated in the presentation well. This is appropriate to the current Technology Readiness Level (TRL) level. It is possible that a new direction toward unique geometries of the part and environmental testing methods can be employed.

Reviewer 3:

The reviewer commented that the proposed future research promises to address most of the scaling issues as well as highlighting implementation challenges that may remain unknown.

Reviewer 4:

The reviewer noted that the project has ended, but Phase II work has been proposed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE Energy Efficiency and Renewable Energy (EERE) VTO. It also addresses the challenges of the specific TRL level that is addressed from the phased project timeline.

Reviewer 2:

The reviewer said that this work supports development of composite materials applications, which in turn support more energy efficient transportation applications.

Reviewer 3:

The reviewer agreed that this project supports the DOE objectives of needing multifunctional composites to be integrated into the vehicle structure to reduce the weight of conventional components.

Reviewer 4:

This project supports the requirements identified by DOE ARPA-E for multifunctional composite materials for energy storage in structural load paths to make a step change in vehicle energy efficiency, particularly for autonomous vehicles and EVs. According to the reviewer, this project also supports the VTO Materials Technology R&D Program goals for vehicle weight savings by using integrated lightweight layered sensors in structural elements of a vehicle during manufacture.

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 funding of $200,000 to investigate self-sufficient, integrated, multifunctional sensors embedded in thin dielectric films for automotive applications by the small research team is sufficient for this 9-month SBIR project.

Reviewer 2:

The reviewer said that the objectives of the project have been completed with the resources made available.

Reviewer 3:

The resources were sufficient to deliver on all the proposed milestones in the proposed timeframe, according to the reviewer.

Reviewer 4:

The reviewer responded positively that the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestones.

Presentation Number: mat213
Presentation Title: Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor
Principal Investigator: Halina Tran (Intellisense Systems Inc.)

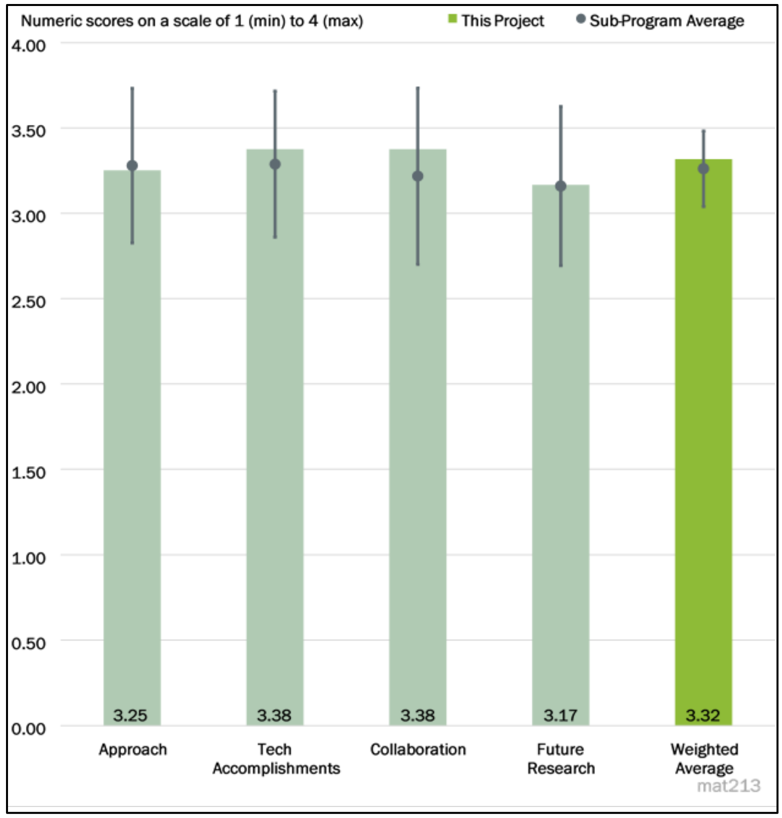


Figure 6-40 - Presentation Number: mat213 Presentation Title: Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor Principal Investigator: Halina Tran (Intellisense Systems Inc.)

Presenter

Halina Tran, Intellisense Systems Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The idea of placing thermoplastic functional fibers as sensors in the composite structure is novel as it has advantage of saving mass. Also, the reviewer indicated that the technology is being applied to many civil engineering applications.

Reviewer 2:

The reviewer stated that the primary objective in evaluating the potential of embedded sensors has been demonstrated per the original work plan.

Reviewer 3:

This reviewer remarked that the work is a good combination of sensor development and design integration in the structure or part monitoring research of the Materials Technology R&D Program. The approach taken by the project toward the goals are clear and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer offered the following questions and comments:

- Because the interest is in monitoring structures for damage or failure, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time or extreme conditions? Can there be aging experiments done to look at sensor response degradation? Or use of more environmentally challenging factors?

- There are a number of opportunities for materials development too beyond nylon. What is the correlation between specific materials development approaches and their demonstrated sensor design in various thermoplastic and thermoset composites beyond nylon?
- What, if any, AI or simulation methods may be employed that can be specific to improving sensor performance?

Reviewer 4:

This reviewer explained that in order to detect a mechanical deformation, the team developed a sensing fiber. In this project, the team embedded their sensing fibers in a CF mat and performed mechanical tensile, impact, and environmental tests. The approach was well designed. However, it was not clear to the reviewer what technical challenges the team overcame. It is not clear if the development of a sensing fiber itself was a part of this project or only the mechanical tests were done in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work presented showed the reviewer clear evidence of meeting the agreed-upon technical milestones. The ability of sensors to provide feedback to external events, such as strain, impact, and temperature, shows potential for the technology moving forward.

Reviewer 2:

The reviewer commented that the team has assembled test coupons and tested the response of functional fibers embedded in woven CFRPs. Improved manufacturing method has been conceptualized. During testing, the sensor fibers follow the strain readings within approximately 0.3% strain.

Reviewer 3:

According to the reviewer, the technical accomplishments match the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified.

Reviewer 4:

This reviewer noted that the team successfully weaved the sensing fibers in the CF mat and performed various types of mechanical tests. The team has verified that the reading from the sensing fibers followed the strain applied. However, the graph of tensile test shows that the strain (blue line) does not seem to match the resistance (reading – black line). If not matching, the reviewer indicated that a non-linear relationship between the strain and the reading should have been investigated, but it was not presented in the poster. Based on the test results (thermal test, impact test, and tensile test), the team developed an algorithm to automatically detect impact events.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the team is collaborating with the University of Southern California (USC), which is an excellent team member.

Reviewer 2:

Per the original project objectives, the reviewer remarked that the team has work effectively in both developing the technology and producing samples for testing at M.C. Gill Composites Center.

Reviewer 3:

The reviewer noted that the PI's team collaborated with the USC, which fabricated the test coupons and performed mechanical tests.

Reviewer 4:

The reviewer proposed that more collaborative efforts with possible other external partners be started.

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 state project ended.

Reviewer 1:

The reviewer stated that the proposed work is a logical progression of current research that aims to address scaling challenges as well as longer term quality and robustness concerns.

Reviewer 2:

The reviewer said that the project (Phase 1) has ended.

Reviewer 3:

The team developed an algorithm that can automatically detect impact events and determine mechanical properties. The reviewer suggested that this needs to be integrated in scaled-up manufacturing of parts.

Reviewer 4:

There is a need to carry the project to a higher goal, if possible, especially in materials development. The direction for future research was clear to the reviewer and has been stated in the presentation well. The work is currently appropriate to the lower TRL level. It is possible that even at this level a new direction toward new materials and unique geometries with environmental testing methods can be employed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE EERE VTO. It also addresses the challenges of the specific TRL level that is addressed in the phased project timeline.

Reviewer 2:

The reviewer indicated that embedded sensing is a key enabler to enhanced feature content in lightweight composite structures.

Reviewer 3:

The reviewer responded affirmatively and said that one of the concerns of using CFFP instead of metal is its brittle fracture behavior. CFRP is susceptible to crack failure without noticing its prior damage. An impact-detecting composite will facilitate the use of the composite.

Reviewer 4:

The reviewer commented that a lightweight multifunctional composite is desired for vehicle applications. Saving mass while incorporating advanced safety features can be accomplished if functional composites are deployed.

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

Reviewer 1:

The resources allocated appeared to the reviewer to be appropriate for the work completed.

Reviewer 2:

The reviewer said that the funding amount is sufficient to develop the technologies.

Reviewer 3:

The resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestone. It is possible that more materials development can be carried out at this stage beyond the current nylon, but the reviewer opined that this may require more resources.

Reviewer 4:

The reviewer stated that the project has ended.

Presentation Number: mat214
Presentation Title: Multifunctional Composites for Vehicles
Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

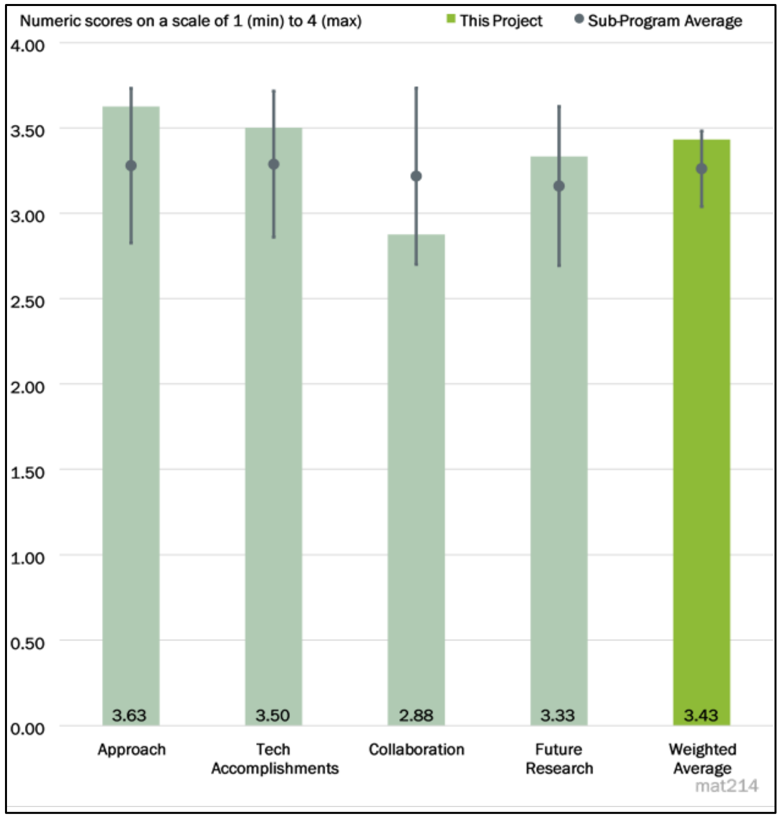


Figure 6-41 - Presentation Number: mat214 Presentation Title: Multifunctional Composites for Vehicles Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This was an excellent approach to integrate sensing, electromagnetic interference (EMI) shielding, and enhanced thermal conductivity into composites. The laser-induced graphene (LIG) technique is a unique approach to integrate additional functionalities into thermoplastic composites. According to the reviewer, this approach really overcomes the technical barriers of cost-effectively integrating sensors into composites while also enhancing the strength.

Reviewer 2:

The reviewer reported that the objective of this project is to manufacture a composite material including three functionalities—strain sensing, EMI shielding, and improving thermal conductivity. The approach to the objective includes optimizing the graphene array and density, optimizing processing parameters for the graphene structure, manufacturing composite panels, and testing mechanical, thermal, and EMI properties. The reviewer found the approach to be well designed, and the team showed the results that can lead to sensor and protection applications.

Reviewer 3:

The reviewer remarked that multifunctional composites exhibiting EMI shielding, strain sensing capability, and high specific strength and stiffness have been designed by use of graphene-based materials. These materials are expected to be cheaper than that of the carbon nanotubes (CNTs).

Reviewer 4:

The work is a good combination of sensor development and design integration in structure monitoring research with graphene as an active material in the Materials Technology R&D Program. The approach taken by the project toward the goals was clear to the reviewer, and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer presented the following questions and comments:

- Because the interest is in monitoring structures for damage or actuation with electromagnetic (EM) shielding, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time? Can there be aging experiments done to look at sensor response degradation?
- There are a number of opportunities for materials development too with other nanomaterials. What is the correlation between specific materials development approaches and their demonstrated sensor design in other nanomaterials like carbon nanotubes (CNT)? Are there other thermoplastic and thermoset composites to use?
- What are some possible simulation and AI methods that may employed that can be specific to improving sensor performance?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer explained that within just a short timeframe for this project, many different functionalities from static and fatigue sensing to EMI shielding and thermal conductivity have all been demonstrated for this LIG technology. The ability to tailor the LIG geometry was also demonstrated, which the reviewer commented really opens up many possibilities for different sensor designs.

Reviewer 2:

The reviewer noted that composites with strain-dependent electrical resistivity were developed, and such composites perform as a strain sensor. Capacitive-based touch sensors were developed, and those can measure strain.

Reviewer 3:

The technical accomplishments matched the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified. The different oxidation states of graphene are another variable. Also, the reviewer asked whether this oxidative stability changes with time and how they will be studied. The reviewer suggested that more collaborative efforts with possible other external partners could be started.

Reviewer 4:

The team has shown the effect of graphene length and process parameters on the resistivity. Also, the team designed the strain sensor using the material and showed a linear response from a mechanical deformation. The team showed the EMI shielding performance and, although not included in the original Objective section, showed a touch sensing capability. The project accomplished most of the objectives. A question from the reviewer to the team is about a thermal conductivity performance, which is in the Objective section. The conductivity result was not shown in the Accomplishment section.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that there was great collaboration with TPI Composites and Toyota. Working closely with both a composites company and an automotive company will help bring this technology to the market faster.

Reviewer 2:

The reviewer noted that this is a single PI project. The PI worked with Rhein Tech Laboratories to measure EMI shielding effectiveness.

Reviewer 3:

The reviewer suggested that more collaborative effort with possible other external partners could be started.

Reviewer 4:

Although several partners were listed, this reviewer found no collaboration described in the poster.

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 state project ended.

Reviewer 1:

The project is nearing the end, but the team has proposed some great work on making it a wireless sensor. The reviewer believed that the technology has excellent risk mitigation by having many different added functionalities to the composite.

Reviewer 2:

The direction of future research was clear to the reviewer and has been stated in the presentation very well. This is appropriate to the current TRL level. However, it is possible that a new direction for various oxidation states and clusters of graphene including environmental and stress testing methods can be employed.

Reviewer 3:

The project is 90% done, and it is ending. The reviewer noted that the PI is planning to apply wireless sensing capability.

Reviewer 4:

The project (Phase 1) has ended. According to the reviewer, the future research described in the poster is not for this phase of research but for the next phase if any additional funding is provided.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE-EERE-VTO and the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE). It also addresses the challenges of the specific TRL level that is addressed in the phased project timeline.

Reviewer 2:

According to the reviewer, not only does this project support DOE objectives, but it also offers a unique approach to integrating sensing, EMI shielding, and improved thermal conductivity to create multifunctional composites for automotive composites.

Reviewer 3:

The reviewer affirmed that a composite material with sensing capability that can be manufactured via a thermoplastic molding technique can facilitate the use of thermoplastic and help reducing the weight of vehicle components.

Reviewer 4:

The reviewer observed that multifunctional materials are needed for lightweight structures that can also sense applied stress or strain.

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

Reviewer 1:

With all the progress made, it was clear to the reviewer that the resources are sufficient to meet the milestones of the project in the proposed timeframe.

Reviewer 2:

The reviewer said that the funding amount is sufficient to develop the technologies.

Reviewer 3:

The reviewer responded affirmatively and said that the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestone. Further studies on new materials are possible, but the reviewer acknowledged that this may move the milestones' goal posts.

Reviewer 4:

The reviewer stated that the project has ended and met the goal.

Presentation Number: mat215
Presentation Title: Short Fiber Preform Technology for Automotive Part Production - Phase II
Principal Investigator: Dirk Heider (Composites Automation, LLC)

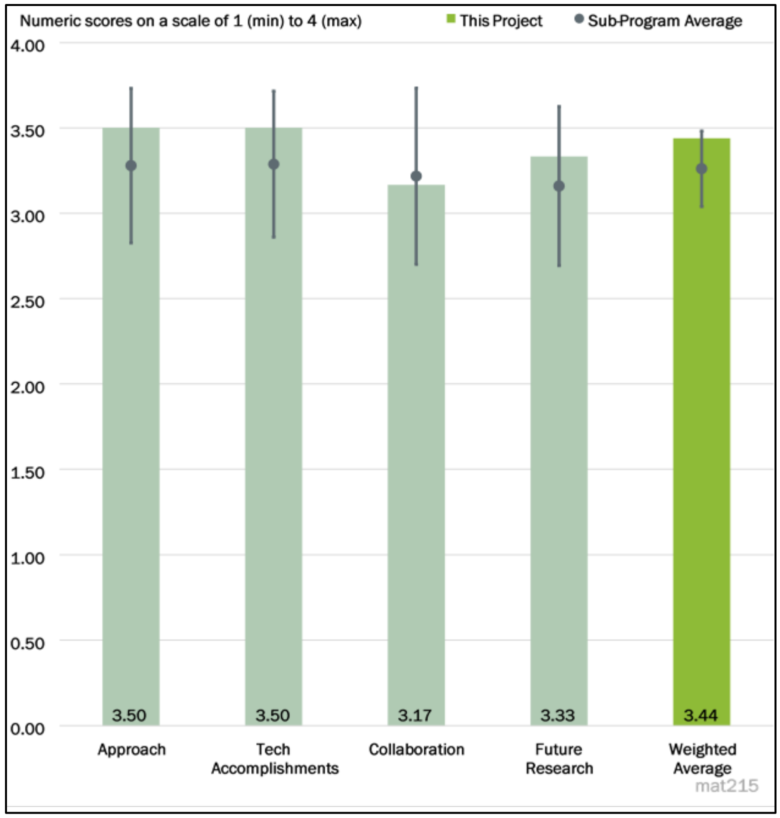


Figure 6-42 - Presentation Number: mat215 Presentation Title: Short Fiber Preform Technology for Automotive Part Production - Phase II Principal Investigator: Dirk Heider (Composites Automation, LLC)

Presenter

Dirk Heider, Composites Automation, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that the technical project provides a clear pathway from early concept development to concept prove-out. The work also does a good job at leveraging recent advances in CF recycling.

Reviewer 2:

This reviewer indicated that the current critical challenges for CFRP addressed by this project include low-cost high-volume manufacturing, low-cost fibers, and recycling (OFFAL/Vehicle). The reviewer commented that the project appropriately sought to demonstrate that the tailorable universal feedstock for forming (TuFF) net pre-form generation process enables effective use of low-cost virgin CF, scrap CF, and recycled CF in high-volume fraction composites with competitive performance. Investigation of fiber orientation and fiber length distribution in resulting composites was also part of the good project design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that excellent progress has been reported on tasks to date, including demonstration of the process with different fiber sources, demonstration of formability, and assessment of composite performance and resulting fiber microstructure.

Reviewer 2:

The reviewer indicated that the technical project has clearly demonstrated the potential of the new recycled CF format. This has been validated through experimental studies and subsequent mechanical testing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, excellent cooperation appears to have occurred between Composite Automation and team members (University of Delaware and Vartega). Other promising contacts are mentioned or targeted with Zoltec, Hexion, Barnet, Institute for Advanced Composites Manufacturing Innovation (IACMI), U.S. Automotive Materials Partnership (USAMP), OEMs, and suppliers.

Reviewer 2:

All aspects of the project showed evidence of excellent coordination to the reviewer as the support of several project partners has been required to complete the work to date.

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 state project ended.

Reviewer 1:

The key challenges to the "paradigm shift in composite processing" proposed by this project seems to be cost and throughput of conversion of received fibers into stabilized pre-forms ready for part production. The reviewer indicated that Proposed Future Research appropriately targets these challenges through focus on scale-up, automation, cycle time, rate, and cost benefits.

Reviewer 2:

The reviewer said that the next phase of the project addresses the majority of open issues while also securing engagement with prospective customers.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that effective methods to translate recovered and recycled fiber into equivalent-performance composites clearly support DOE efficiency objectives.

Reviewer 2:

The reviewer said that the project develops a low-cost source of carbon fiber materials from recycled feed stocks.

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 has been completed within the current resource plan.

Reviewer 2:

The reviewer commented that the level of remaining project resources is not reported.

Presentation Number: mat216
Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II
Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

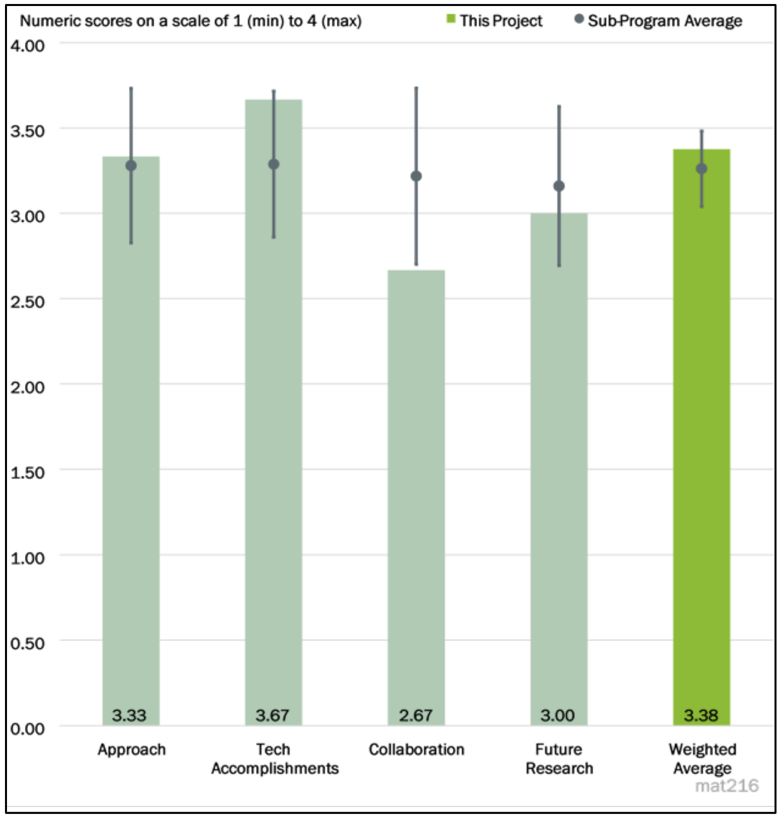


Figure 6-43 - Presentation Number: mat216 Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

A low-viscosity resin system with the capability of being cured at 140 degrees Celsius (°C) within 30 seconds (s) has been developed for efficient infusion and composite product manufacturing. The approach has not been shared in detail for proprietary reasons, but the involvement of TPI and IACMI Scale-Up Research Facility (SURF) was very encouraging to the reviewer.

Reviewer 2:

The reviewer noted that the Technical Barriers identified for this project are lack of cost-effective systems and designs, joining technologies for CFRP, and fiber and resin bond strength. The first two barriers correspond to the DOE Critical Challenges of Low-cost High-volume manufacturing and Joining. The third barrier, insufficient fiber and bond strength, may be important, but it is not mentioned in the USDRIVE Materials Technical Team (MTT) Roadmap 2017, Section 6, as referenced.

This project primarily supports the target of low-cost, high-volume manufacturing through development of a resin with very rapid cure time, even for thick components. According to the reviewer, nothing in the project poster describes any benefit of the resin technology being developed for addressing the need for multi-material CFRP joining methods or for improving fiber and resin interfacial strength.

The focus on fire resistance of the polymer under development may be important for EV battery casings but does not address an identified barrier for automotive lightweighting. The reviewer said that the strategy of the project to compare a long list of the fast-cure resin material properties with incumbent materials, to initially investigate environmental stability, and to evaluate thermal performance is well placed. Furthermore, the reviewer indicated that evaluating the resin in a CFRP is a reasonable project scope component that appears to be missing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The composites were successfully cured within 30 s, an accomplishment the reviewer found to be outstanding.

Reviewer 2:

The reviewer opined that excellent mechanical, thermal, and kinetic performance of the resin is demonstrated, which may be considered a technical accomplishment and progress. Evaluation versus proposed or planned targets is difficult with any list of milestones or deliverables. Technical targets appear to be the only similar information provided. Against these, no progress has been demonstrated addressing multi-material joining or improvement of fiber and resin bond.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that TPI and IACMI are involved, and they are scheduled to process parts at SURF this summer.

Reviewer 2:

This reviewer reported that IACMI-SURF and TPI Composites are listed as team partners, but no information was provided describing their contributions relative to Trimer Technologies or collaboration and coordination among the partners. Fatigue testing was apparently performed in collaboration with unnamed OEM partners, and fiberglass panels were burn tested at Test Corp.

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 state project ended.

Reviewer 1:

The reviewer suggested that scalability needs to be demonstrated, and that is what is already planned. However, the project has officially ended.

Reviewer 2:

The Future Research section communicates that commercialization of the Trimer resin will require extensive process development and material testing. Also, internal mold release agents, scale-up of the manufacturing process, and component level testing are mentioned as needs for commercial adoption. The reviewer indicated that this description does not constitute a plan, incorporate decision points, or consider risk mitigation strategies.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that the project supports DOE objectives. Lightweight materials from polymer composites capable of being formed in less than 1-minute (min) cycle are needed.

Reviewer 2:

This reviewer commented that fast-cure, high-performance thermoset resins could be a key enabling technology for low-cost, high-volume manufacturing and increased use of lightweight CFRPs. Achieving low-cost, high-volume manufacturing will require not only rapid cure times, but also affordable resin. The reviewer indicated that cost information and cost targets for the Trimer resin are not provided for comparison with the state of the art.

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 team has already met the goals and the project has ended.

Reviewer 2:

The reviewer found that it was impossible to assess if remaining resources are sufficient to complete the remaining milestones because neither remaining budget nor remaining milestones have been communicated.

Presentation Number: mat217
Presentation Title: New Higher Temperature Performance Alloys (1A2)
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

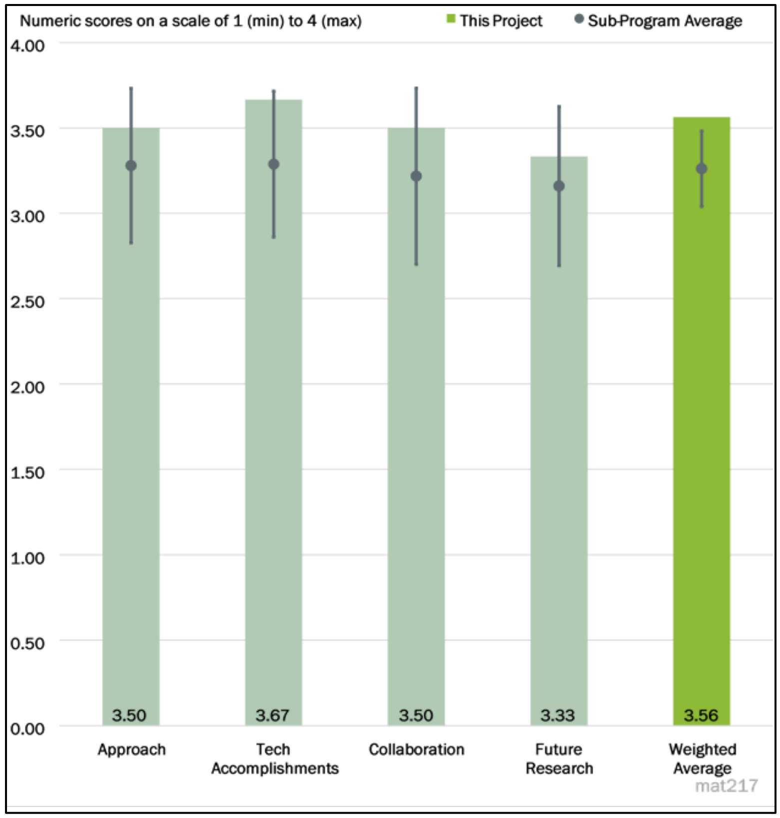


Figure 6-44 - Presentation Number: mat217 Presentation Title: New Higher Temperature Performance Alloys (1A2) Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that there is an excellent approach on understanding the influence of elemental segregation on delaying coarsening of the theta prime precipitate and on using Al-nickel (Ni) alloys as the base material.

Reviewer 2:

This reviewer indicated that the project team utilizes various state-of-the-art characterization tools to reveal microstructure details of the aluminum (Al)-copper (Cu)-magnesium (Mg)-zircon (Zr) (ACMZ) alloy. The selection of techniques shows the project team knows how to effectively utilize resources provided and supported by DOE to advance the project. The reviewer found that each experiment was well designed to address the scientific issues relevant to the project tasks.

Reviewer 3:

The reviewer asserted that most combustion engineers work within the constraints of materials properties currently being used in internal combustion engines (ICEs). This leaves an opportunity to find more efficient combustion recipes outside the envelope normally explored by the current modeling processes. This has led to increases in efficiency utilizing higher combustion temperatures and pressures, which help further opportunities like downspeeding. Tying this to fundamental material properties and then realizing the increases of the ability or the combustion components is exciting.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is great work and well executed. The abilities shown are relevant and significant and will increase engine efficiency. The reviewer applauded the well-reported, great accomplishments.

Reviewer 2:

The reviewer called the microscopy work on interfacial solute segregation impressive. It highlights the role of minor additions (e.g., Zr) on improving thermal stability by pinning the boundary of precipitates. The evolution of the volume fraction of various precipitates and phases as a function of annealing time was nicely characterized by synchrotron X-ray diffraction (XRD). This work takes advantages of the penetration power of high-energy synchrotron X-rays to accurately measure the volume fraction of different phases by probing the entire bulk specimen.

Reviewer 3:

According to the reviewer, these are excellent experiments demonstrating elemental segregation that contributes to elevated temperature properties by delaying coarsening of theta prime precipitates. The silicon mechanism was not clear to the reviewer. Integrated computational materials engineering (ICME) appears general to all similar projects. Application to the specifics of MAT217 was not clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project team has close collaboration with several DOE labs and a university to take advantage of the strength of each unique contributor to accomplish the tasks.

Reviewer 2:

There is good collaboration between the various national laboratories and industry, according to the reviewer.

Reviewer 3:

The reviewer noted that the presentation explained the partnerships between industry and national laboratories participating in this work.

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 state project ended.

Reviewer 1:

This is well thought out, and the reviewer believed that the work on the thermal and electrical conductivity-microstructure relationships co-optimized with mechanical properties could be significant in the EV arena as well as for ICEs.

Reviewer 2:

According to the reviewer, the project team nicely showed that interface boundary pinning by minor elements (e.g., Zr) is key to improving thermal stability. It is good to see the project team continuing to pursue this direction.

The project team mentioned a plan to "Employing new alloy design strategies to increase the temperature limit of Al alloys." The reviewer said that it would be nice if the project team can elaborate more on this point.

Reviewer 3:

It was not clear to the reviewer how neutron diffraction will apply to designing microstructures. Optimizing thermal and electrical conductivity with mechanical properties is a whole different undertaking, and the approach for this was unclear. What new strategies to increase temperature limits are being comprehended? This reviewer suggested to be specific on how lightweight brakes will exploit this alloy and how composites fit, unless the Al-Ni alloy is the matrix.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer asserted that development and improvement of lightweight alloys are critical for achieving DOE's goal of moving toward all EVs. Weight reduction of the vehicle will play a key part in improving range per kwh of EVs. For that perspective, the reviewer stated that R&D topics related to lightweight structural alloys will always be the focus for the years to come.

Reviewer 2:

The reviewer observed great work and further noted that this creates a platform for many opportunities to increase overall vehicle efficiency, lowering environmental impact.

Reviewer 3:

The reviewer indicated that improving elevated temperature and fatigue properties of aluminum is a good goal.

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 project team distributed the resources efficiently, and the tasks were accomplished in a timely manner.

Reviewer 2:

The reviewer observed that this is a well-managed project with clear goals, accomplishments, and data.

Reviewer 3:

The reviewer stated that the resources are sufficient for this difficult goal.

Presentation Number: mat218
Presentation Title: Selective Material Processing to Improve Local Properties (2B2)
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

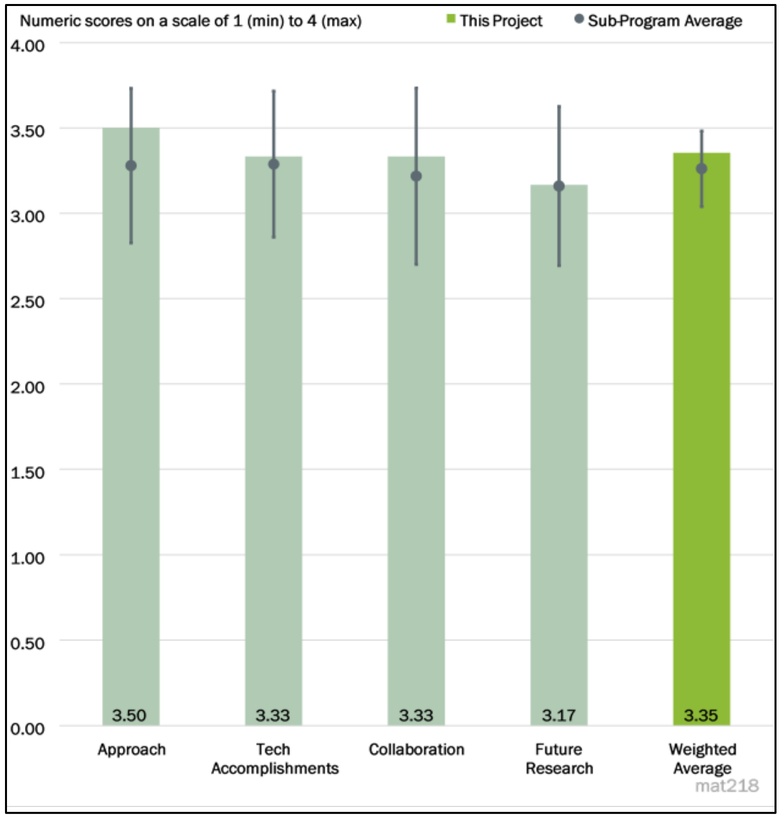


Figure 6-45 - Presentation Number: mat218 Presentation Title: Selective Material Processing to Improve Local Properties (2B2) Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the work is based on a relatively long research history of using friction-stir processing (FSP) to heal defects and to achieve grain refinement for improved performance. This project focuses on extending that work to a complex component. Work to initially validate the approach and define key challenges (robotic friction-stir welding [FSW] systems and path planning) is prudent and represents a well-thought-out approach.

Reviewer 2:

This is a novel approach to improving material properties, but the reviewer asked what the cycle times are for the process and whether FSW would be feasible in a production environment.

Reviewer 3:

This reviewer observed a comprehensive and reasonable list of challenges and barriers that was identified for current and future tasks. For Task 2B2, the Pacific Northwest National Laboratory (PNNL) team focused on put the right property in the right place, instead of putting the right material in the right place. This work developed an effective way of introducing cast-in holes at the desired locations to demonstrate the effectiveness of FSP, one of the proposed approaches for local property improvement, on porosity elimination.

The reviewer explained that it leads to improvement of fatigue properties of cast plates at low temperature. For high-temperature properties, especially fatigue life, the team proposed a novel hybrid-processing method, i.e., cold spray followed by FSP, to achieve local up-alloying. However, the reviewer suggested that it would be beneficial if the team could establish a quantifiable correlation between pore size and FSP tool geometry, i.e., what would be the upper limit of porosity elimination as a function of tool size. Furthermore, it was mentioned in the Remaining Challenges and Barriers that FSP creates a microstructure gradient (especially a softened heat-affected zone) and therefore a property gradient in high-strength materials. However, it was unclear to the reviewer whether the team will have potential solutions—how to optimize the gradient for property control—or it would remain as a challenge for application of this technique at the end of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The demonstration of basic processing and development of programming for the complex component are good. The reviewer suggested that some focus should be given to the constraint issues associated with complex Al castings.

Reviewer 2:

The reviewer found the results interesting results, but it would have been useful to the reviewer for the team to have differentiated what is new and novel from the project versus what is already known in industry about FSW.

Reviewer 3:

The PNNL team is making effective progress toward subtask 1a and 1b. As previously mentioned, the reviewer remarked that the accomplishments could be improved further if a quantifiable correlation between pore size and FSP tool geometry can be established, which serves as guidance for practical application of the processing technology.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that this project team has an excellent combination of two national laboratories, one company, and one university.

Reviewer 2:

This project appears largely to be a collaboration between PNNL and General Motors (GM). GM of course brings the product focus into the project. The reviewer suggested that the project would of course benefit from a greater number of automotive partners.

Reviewer 3:

The reviewer said that it is very good to have an OEM involved to have a direct impact on 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. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer remarked that the forward look is excellent. The reviewer expressed interest in seeing more focus on the challenges of FSP of complex castings. This would involve thermal and mechanical analyses, tooling developments, and design guidelines that would make products more amenable to the technology.

Reviewer 2:

The pathway from test coupons to real engine-part testing was not clear to the reviewer.

Reviewer 3:

The reviewer stated that the PNNL team has a reasonable plan moving forward for the majority of the challenges identified. However, it was pointed out that FSP creates a microstructure gradient (especially a softened heat-affected zone) and, therefore, a property gradient in high-strength materials. It was unclear to the reviewer what the research plan is for this challenge, whether there are alternate pathways, and what the appropriate decision point would be. Also, it is unclear whether the team will evaluate the additive FSP as mentioned in the Approach.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The technical target of this effort is to identify a suite of low-cost, advanced manufacturing processes that can improve the local properties of castings and allow higher performance. According to the reviewer, this project has well demonstrated the components having locally improved low-temperature mechanical properties and with no casting defects.

Reviewer 2:

Next-generation ICEs are a key component in the near-term energy-efficient transportation strategy. The reviewer remarked that this work clearly will play a role in enabling more compact and efficient ICE designs.

Reviewer 3:

The reviewer noted that improved material properties can help save engine weight, which will help reduce fuel consumption.

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 team has all the required resources in its possession, partly from the existing capability and partly from the assistance of the collaborating company, for the project to achieve the stated milestones in a timely fashion.

Reviewer 2:

The reviewer said that the project is on track.

Reviewer 3:

The reviewer would have liked to see more direct focus on the metallurgy of strontium (Sr)-stabilized Al castings.

Presentation Number: mat219
Presentation Title: Fundamentals of Non-Equilibrium Processing
Principal Investigator: Ying Yang (Oak Ridge National Laboratory)

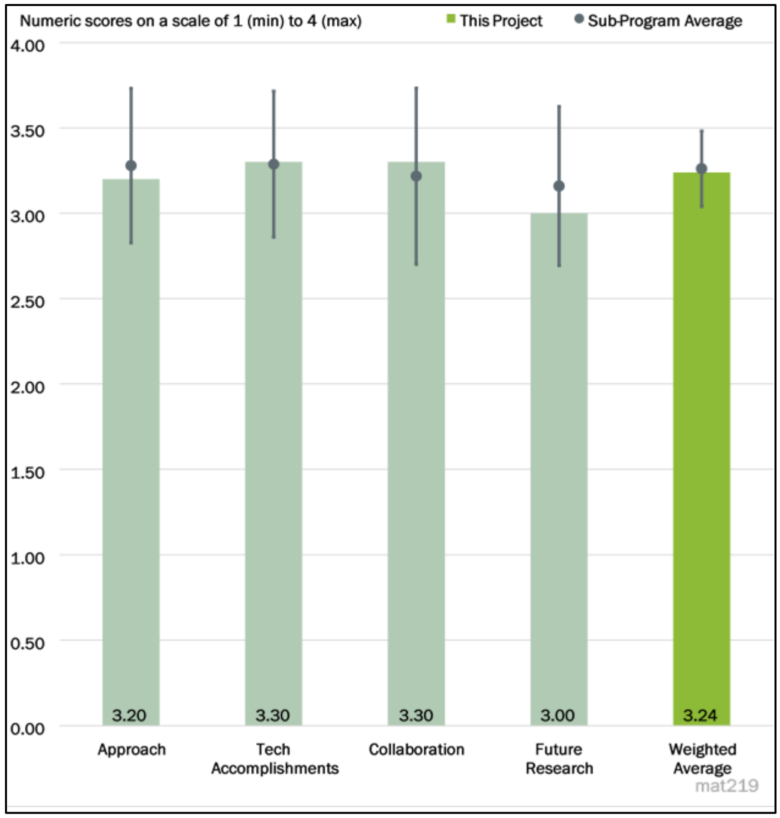


Figure 6-46 - Presentation Number: mat219 Presentation Title: Fundamentals of Non-Equilibrium Processing Principal Investigator: Ying Yang (Oak Ridge National Laboratory)

Presenter

Ying Yang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the PI’s approach toward the non-equilibrium AM processing is good. The presenter describes the Al-cerium (Ce)-manganese (Mn) investigation as both theoretical microstructural modeling and experimental. The project team has developed a thermodynamic database for Al-Ce-Cu system. The PI understands that the need to understand the discrepancy between calculated and experimental results.

Reviewer 2:

The reviewer said that it is a well-designed and well-planned project, and the technical barriers are addressed.

Reviewer 3:

The reviewer commented that this project is good in the sense that it will help to understand the material behavior during the AM process. Early results show that the AM alloys can show higher strength and ductility compared to the conventionally cast alloys. However, the reviewer stated that the goal is not specific enough. Maybe generating a phase diagram for an AM alloy would be a reasonable goal to achieve. Additionally, the reviewer noted that there is slight confusion in terms of progress and schedule. It shows that the project will start in October 2021, and yet it already achieved 50% of the goal.

Reviewer 4:

The reviewer remarked that this work addressed the challenge that phases observed in some Al alloys solidified at fast cooling rates associated with AM processes are not predicted using the conventional thermodynamic database. The ORNL team developed new databases using a combination of CALculation of PHAse Diagram (CALPHAD), first-principle calculations, and experimental verification through advanced characterization tools, which takes into consideration of solute trapping nucleation kinetics and growth kinetics. Reasonable agreement between the solidification model and experimental observation was achieved in AM of austenitic stainless steels and the Al-Ce-Ni-Mn system. A discrepancy was observed in the Al-Ce-Cu system, and the project team is planning to evaluate the kinetics effect; however, the researchers did not clarify how the kinetics term would be introduced in the AM microstructure with inhomogeneous composition distribution. The investigation of a diffraction profile in progress is expected to provide more in-depth understanding of the actual phase evolution.

Reviewer 5:

This reviewer noted that the approach starts with development of thermodynamic databases that would be used for populating the solidification models. The reviewer commented that this approach addresses, and attempts to improve on, the limited knowledge of microstructural evolution for materials fabricated from non-equilibrium conditions. The approach does not discuss limited phase diagram data as applied to new alloys fabricated by rapid solidification. The Background slides discuss phase diagram data and the problems with databases that are not sufficient to predict accurate phase diagrams, but this is not addressed on the Approach slide or discussed as part of the project approach. The rest of the presentation discusses solidification modeling. This could be an oversight by the presenter to focus on just one of the barriers. Maybe the phase diagram problem was solved in the first year of the project, but this is not indicated in the presentation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the team has developed a solidification model for understanding the as-printed microstructure of austenitic steels and produced one journal paper. In addition, the team has developed thermodynamic and kinetic models for understanding the as-cast microstructure of the Al ternary system from AM and submitted one manuscript.

Reviewer 2:

The project identified an important issue for characterizing material properties due to AM process and provides a design capability to improve material characteristics. According to the reviewer, the thermodynamic database of Al-Ce-Ni-Mn will be useful for future modeling and simulation. It just needs to be calibrated and validated for its accuracy.

Reviewer 3:

The PI and the project team developed a thermodynamic and kinetic model for understanding the as-cast microstructure of the Al-rich Al-Ce-Ni-Mn system ($Al_{11}Ce_3$, $Al_{10}Mn_2Ce$, $Al_{20}Mn_2Ce$, and $Al_{23}Ni_6Ce_4$) and M (M=Cu, Ni) ternary system from AM. The PI said that AM alloys show both increased strength and ductility compared to conventionally cast alloys, but the reviewer commented that this is not always true for testing the AM from within the plane of laser to the different layers on top of the plane.

Reviewer 4:

Reasonable agreement between the non-equilibrium solidification models and advanced experimental characterizations (e.g., atom probe tomography [APT]) has been demonstrated in AM austenitic stainless steels and the Al-Ce-Ni-Mn system. It would have been beneficial to the reviewer for the team to have clarified whether the continuous cooling transformation (CCT) diagrams will be updated for the alloy systems of interest, since the solidification rate may vary significantly across different AM processes.

Reviewer 5:

There was no project schedule or any performance indicators discussed in the presentation; so, it was difficult for the reviewer to determine the degree that progress has been made. The Milestone slide only gives two milestones for FY 2021 and states that one was completed, and the other is on track. The reviewer had to assume that there were more than two milestones for this project and there must have been performance indicators for regular and specific, measurable, attainable, relevant, and time-bound (SMART) milestones and go/no-go decisions that were achieved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that close collaboration has been demonstrated between the ORNL and the University of Tennessee-Knoxville (UTK) teams through successful completion of subtask 3A1. Good coordination has been demonstrated between ORNL and ANL team for the ongoing task of diffraction measurement in the Al-Ce-Ni-Mn system.

Reviewer 2:

The reviewer said that the ORNL team leads the tasks in partnering with UTK.

Reviewer 3:

The PI has assembled a good collaboration between the different national laboratories (ORNL and ANL) with some collaboration with academia (UTK); the reviewer suggested that this project could benefit from some industry involvement. For example, Eck Industries has completed a lot of work on cast Al-Ce-Cu systems.

Reviewer 4:

Collaboration is mentioned within the thrust areas. The reviewer stated that it would have been better to collaborate with academia and industry as well.

Reviewer 5:

The reviewer found the collaboration to be limited between ORNL, ANL, and UTK. The coordination between tasks for Thrust 3 appears to be good, but there was only one indication that ANL contributed to the task by investigating crystal structure at their Advanced Photon Source. There is no indication of external collaboration and who will benefit from the results 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer encouraged the project team to include a task to make 100% densification (no porosity) with avoiding a post process such as hot isostatic pressing (HIP). The tasks of complete development of thermodynamic databases and understanding phase formation and evolution in Al-Ce-Ni-Mn and Al-Ce-Cu alloys are well planned.

Reviewer 2:

The PI and the project team are going to work on incorporating additional factors into the existing microstructural models for non-equilibrium conditions due to rapid solidification during AM.

According to the reviewer, modeling Ce's electron valance shell is extremely complicated and needs further attention to the two electrons in its outermost ($6s^2$) shell. The valance shell behaves as though it has three or four valence electrons (the $5d^1$ and $4f^1$ electrons may also participate). This could be why the PI said that the thermodynamic databases are often not available or are not reliable for Al-Ce-X (X=Mn, Cu, Ni) systems.

Reviewer 3:

The reviewer said that most future research topics are the continuation of the current work.

Reviewer 4:

The updated and verified thermodynamic database will be incorporated into the existing microstructure models for more accurate prediction of microstructure evolution during AM processes with far-from-equilibrium solidification rates. However, the reviewer commented that there is insufficient information provided for the key barriers related to introducing additional factors into the solidification model.

Reviewer 5:

The reviewer indicated that the proposed future research is simply completing the existing tasks and then continuing the same database development and microstructural modeling if further funding is provided beyond FY 2022. Nothing is stated about what information or technology will be transferred that may require additional research or how much more is needed for database and model development. There are no timeframes for deliverables, which indicates there are no deliverables, just data generation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer reported that development of robust alloys for AM continues to be a large portion of materials R&D efforts around the globe.

Reviewer 2:

The reviewer said that the scope of work is well aligned with the overall DOE objectives.

Reviewer 3:

The reviewer remarked that characterizing AM material properties is closely related to DOE objectives.

Reviewer 4:

According to the reviewer, this project addresses the challenges related to limited phase diagram data and their applicability for AM of existing and new alloys due to far-from-equilibrium solidification.

Reviewer 5:

This project supports an overall DOE objective to address AM of advanced materials. The reviewer found no direct reference cited although the Workshop Report on Trucks and Heavy-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials states that there are insufficient computational modeling tools for materials development, manufacturing, processing, and assembly currently in place that focus on advanced powertrain materials.

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 takes a lot of resources to involve microstructural modeling with experimental validation, and the PI has good resources. However, again the PI might want to talk to industrial resources (i.e., Dave Weiss at Eck Industries) regarding the cast Al-Ce-Mn series.

Reviewer 2:

The reviewer noted that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

It seemed to the reviewer that the project has sufficient resources to perform the proposed tasks.

Reviewer 4:

According to the reviewer, the researchers have sufficient resources at ORNL and partner sites to achieve the stated milestones in a timely fashion.

Reviewer 5:

The funding shown is $140,000 for FY 2021 and a start date of October 2021, which has not occurred yet. The Overview slide shows zero funding previously although there is one slide that states, "New databases were developed that can predict the correct phase diagrams." The reviewer understood that the project was funded $140,000 in FY 2021 and that this has to last through the end of the project in September 2023 (FY 2022) since no FY 2022 funding is identified. With the project 50% complete in June 2021, $70,000 must have been spent in FY 2021 and $70,000 will be spent in FY 2022, which are adequate and sufficient for the database and modeling efforts described.

Presentation Number: mat220
Presentation Title: Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2)
Principal Investigator: Peeyush Nandwana (Oak Ridge National Laboratory)

Presenter

Peeyush Nandwana, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

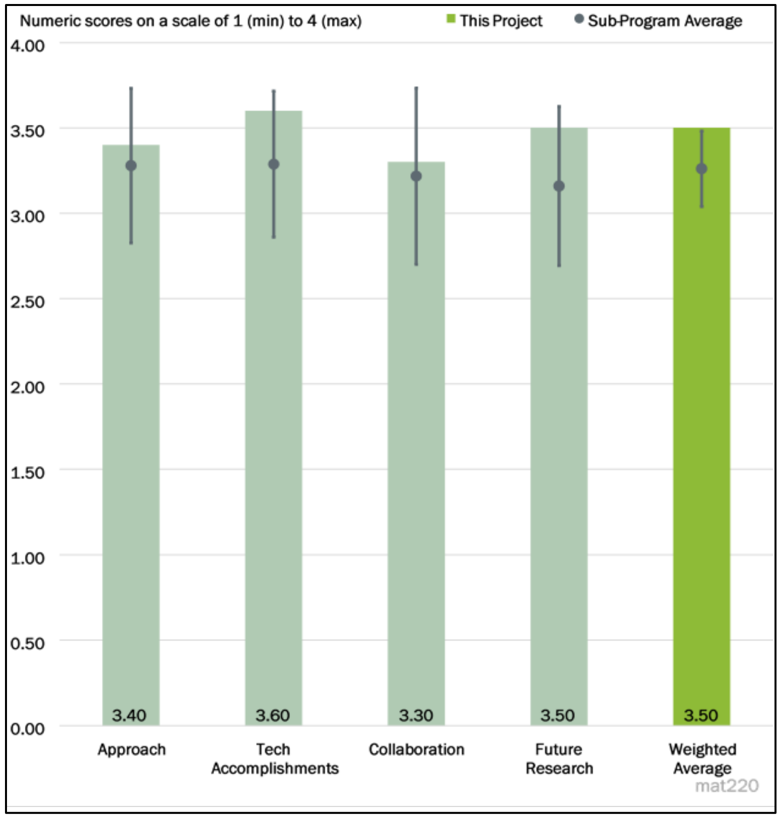


Figure 6-47 - Presentation Number: mat220 Presentation Title: Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2) Principal Investigator: Peeyush Nandwana (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is focused on one alloy system (H13) and its use in conjunction with binder-jet printing for producing materials for piston applications. The choice of this material as a focus is based on opportunities for improved oxidation resistance and potential for improved strength, relative to other steels used for this application. The approach integrates fabrication, characterization, and ICME modeling to optimize heat treatment. This approach was reasonable to the reviewer, although challenges associated with the predictive capabilities of the ICME models were described.

Reviewer 2:

The reviewer remarked that the project approach is to use binder-jet AM process to demonstrate fabrication of an engine component using a commercial alloy H13. The project involves ICME modeling, binder-jet printing, part densification, and characterizations. Challenges with binder-jet printing are related to distortion and dimensional changes post-densification, which the team has addressed by experimentation. Other challenges, such as microstructure evolution and process controls, are being addressed using modeling and experimental validations.

Reviewer 3:

The project uses the binder-jet process to produce a steel cylinder with densification and minimum shape change. It turned out that the manufactured material shows higher strength at low temperature (less than 500°C) but quickly deteriorates at high temperature. But, overall, the ultimate tensile strength (UTS) is higher than 4140. However, it was unclear to the reviewer if the final shape is good enough to be used as a cylinder because the part requires really tight geometric tolerances and surface smoothness. Eventually, the part may still need machining to be used in practice. The project started in 2018 and is ending in 2022, and yet, the 50% progress seems too slow.

Reviewer 4:

The approach is a typical generic linear process for material development going through the steps from material fabrication to materials characterization including some modeling for process optimization. There was nothing in the presentation that discussed the degree to which the technical barriers are now being addressed or will be addressed. The reviewer found nothing special about the approach, which has been previously demonstrated to be very feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The accomplishments include fabrication of binder-jet printed H13 samples with improved strength relative to 4140 and micro-alloyed steel (MAS), improved oxidation resistance relative to 4140, microstructural characterization of carbides that informs the need for homogenization and optimized heat treatments, and CALPHAD modeling of microstructure evolution that explains the origin of the impacts on strength associated with thermal history. Overall, the project has demonstrated good progress toward its technical goals.

Reviewer 2:

Results for the material characterization of carbide morphologies were excellent. Results for strength were good but did not demonstrate that the binder-jet H13 alloy was as good as conventional H13, only better than commercial steel alloys. Modeling results for the microstructure analysis and strength showed good results for comparing the as-sintered H13 to H13 up to 800°C. The results of the neutron diffraction studies were good for comparing the phase evolution of the as-sintered versus the sintered plus HIP plus high-temperature (HT) condition. HT cyclic oxidation results showed a two-fold reduction in oxidation for the binder-jet H13, which is much improved performance. Simulation results were excellent for the effect of packing density on part shrinkage. Overall, the technical accomplishments were outstanding for the amount of resources available.

Reviewer 3:

The project target to exceed the yield strength (YS) of 4140 and MAS steels might be achieved. It would be necessary to compare the manufacturing cost as well. Further investigation would be required to understand the rapid drop of strength over 500°C.

Reviewer 4:

Excellent technical progress has been made in the project. The project team has demonstrated fabrication of H13 alloy parts using the AM approach and performed characterizations to show that final mechanical properties of the material is superior to 4140 and MAS and similar to the conventional H13. However, the reviewer suggested that there are few items that need to be addressed, including the following: what the acceptable dimensional variabilities are on the component being targeted and how they compare with the part produced using the binder-jet processing approach; if there are any American Society for Testing and Materials (ASTM) standards that need to be adhered to; if there are any limitations on the size of the part targeted based on de-binding and densification steps; and if there is process repeatability from run to run.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project involves collaboration between ORNL and PNNL and partnerships with Zeiss and (starting this fiscal year) the Army Ground Vehicle Systems Center (GVSC). The reviewer mentioned that the collaborations and partnerships bring together a blend of complementary capabilities and appear to be effectively coordinated.

Reviewer 2:

The project is well coordinated with the Powertrain Materials Core Program (PMCP) program and the various teams at ORNL and PNNL. The reviewer suggested that it may be good to have some interaction with an OEM or component manufacturer to understand the challenges and requirements for the part manufactured at scale.

Reviewer 3:

The reviewer found a good collaboration within ORNL. It would be better to have collaboration with academia and industry.

Reviewer 4:

The reviewer indicated that the collaboration and coordination are mostly internal at ORNL between resources at the Spallation Neutron Source (SNS), the Center for Nanophase Materials Sciences (CNMS), and the Manufacturing Demonstration Facility (MDF). PNNL is only providing APT and transmission electron microscopy (TEM) for analysis. The collaboration with Zeiss is not stated. There is a statement regarding current and future collaboration with the Army's GVSC, but nothing is stated as to the extent of the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

A number of remaining challenges and barriers are identified, spanning understanding of the impact of long-term thermal exposure on materials properties, the mechanism of superior oxidation performance, improving the relevant ICME models, and establishing thermal properties. Creep and fatigue resistance testing was not mentioned in this context, but the reviewer anticipates that this will be important for establishing suitability of these materials for piston applications.

Reviewer 2:

The key challenge for the technology is the dimensional control and repeatability. The team has identified these challenges as well; however, the reviewer stated that a plan needs to be laid out as to how this will be addressed.

Reviewer 3:

The reviewer said that the future research proposes evaluating long-term thermal exposure, which also goes with the proposed work to evaluate thermal properties for piston applications. This will be needed for acceptance of the alloy by parts manufacturers. Predictive modeling using an ICME approach would be a good addition to this research. Design of new heat treatments using an ICME approach or modifications to the alloy chemistry will also be very beneficial to this new alloy development.

Reviewer 4:

The reviewer commented that it would be better if future research focuses on understanding the material property changes on temperature.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that the project supports the development of binder-jet AM as a solution for achieving improved efficiency of heavy-duty engines and as a means for low-cost tooling for automotive applications. These goals are consistent with DOE objectives in Thrust 3 on AM for Advanced Powertrains.

Reviewer 2:

According to the reviewer, this project directly supports the overall DOE VTO technical targets for materials development and the U.S. DRIVE roadmap strategy for advanced material development of high-performance materials used at elevated temperatures in automotive powertrains fabricated with advanced manufacturing process methods.

Reviewer 3:

The reviewer indicated that this project supports cost-effective manufacturing of vehicle engine components that will improve system efficiencies and minimize fuel consumption.

Reviewer 4:

The reviewer said that the project is closely related to 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:

The reviewer asserted that the funding is about $200,000 per year, which is sufficient for the material development and the characterization and analysis of the new alloy compositions fabricated by AM. The number of researchers and collaborators is adequate for each technical area being addressed.

Reviewer 2:

The resources appeared to the reviewer to be sufficient to enable the progress demonstrated, and the project appears to be on track.

Reviewer 3:

It seemed to the reviewer that the project has enough resources to perform all the tasks.

Reviewer 4:

The reviewer indicated that the project has sufficient resources for timely completion.

Presentation Number: mat221
Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials
Principal Investigator: Dean Pierce (Oak Ridge National Laboratory/Cummins)

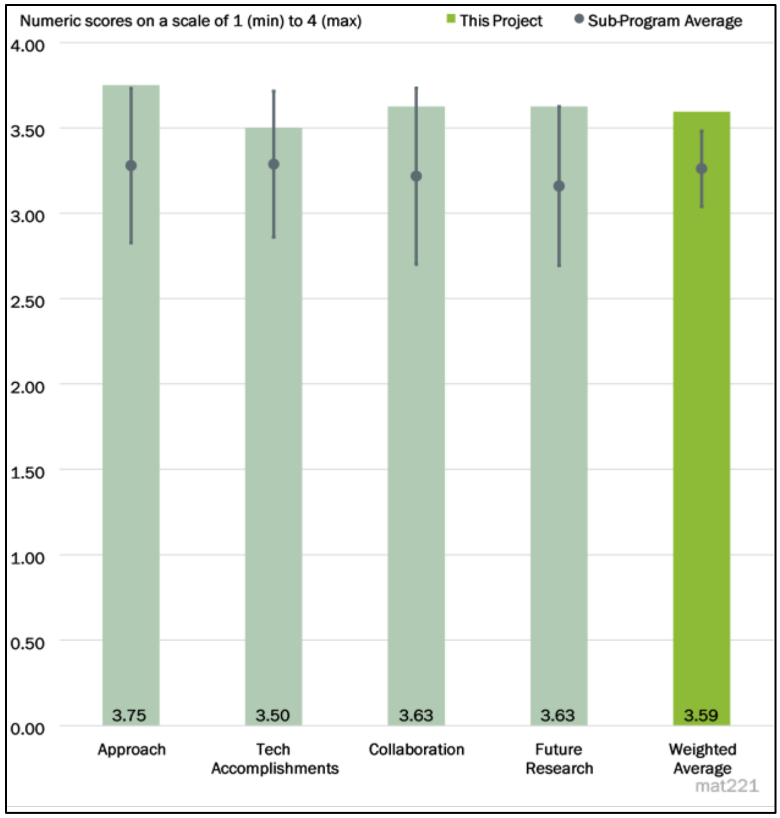


Figure 6-48 - Presentation Number: mat221 Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials Principal Investigator: Dean Pierce (Oak Ridge National Laboratory/Cummins)

Presenter

Dean Pierce, Oak Ridge National Laboratory/Cummins

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the work addresses a key technical barrier associated with the limits of currently used steels in the context of improving efficiency and downsizing and lightweighting of engines. This challenge has been addressed over the past year through an alloy design strategy that integrates computational modeling, lab-scale fabrication, and property testing. The emphasis has been on identifying alloys with combinations of oxidation resistance, strength, and fatigue resistance that enable applications for pistons operating at higher temperature (600°C) and pressure. Work is underway to scale up and to manufacture pistons for engine testing and design.

Reviewer 2:

Since it is an industry-led project, the reviewer noted that some of the details were not disclosed. Nevertheless, it is a well-planned and, so far, well-executed project. The focus is to develop novel alloys that perform at temperatures greater than 500°C for possible replacement of 4140 steel and MAS used for piston applications. The project utilizes computationally designed alloy compositions, lab-scale fabrication, and evaluation of thermo-mechanical properties. Successful alloy composition will be used for prototype fabrication for engine testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that good progress was demonstrated. Although the details were not authorized for public release, the successful development of a cost-effective steel with improved strength, oxidation resistance, and good fatigue properties was demonstrated at lab scale. The results show promise for applications at temperatures significantly higher than the existing 4140 steels that are limited to peak temperatures of 500°C.

Reviewer 2:

According to the reviewer, the project has progressed very well. Various alloy compositions have been fabricated and properties characterized. The new alloy has demonstrated superior strength, fatigue, and oxidation resistance at temperatures greater than 500°C as compared to the currently used 4140 steel and MAS. Based on the properties of the new alloy, using modeling the potential of increased engine efficiency has been demonstrated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that this work is being performed under a cooperative research and development agreement (CRADA) in close collaboration and coordination with Cummins, who is investing significant cost share.

Reviewer 2:

It was difficult for the reviewer to assess which task has been done by which partner. In any case, it appears that the collaboration of project partners Cummins and ORNL is excellent. In addition, it is nice to see that a project has involved a manufacturer of piston 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. Note: if the project has ended, please state project ended.

Reviewer 1:

It was not clear to the reviewer if one or more than one alloy composition is the target of the scale-up activities for the next year. These activities will address bottlenecks associated with manufacturing of pistons, and it would be interesting to understand whether pursuit of a few different alloys in parallel may be desirable in case unanticipated barriers are encountered in these scale-up and testing efforts.

Reviewer 2:

According to the reviewer, the project next steps are in accordance with the overall goal of the project. The team will perform scale-up of alloy fabrication to ensure that the properties are maintained. Following that, piston prototypes will be manufactured and tested in an engine to validate their performance. The team has indicated several manufacturing processes to make the piston. It may be better to downselect one or two manufacturing processes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the work is supportive of the DOE objectives by targeting a strategy for downsizing and lightweighting of engines for heavy-duty, long-haul freight.

Reviewer 2:

The reviewer commented that the project addresses development of new alloys for engine applications so that the engines can operate at higher temperatures reliably, leading to higher fuel efficiencies and lower environmental impact.

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

Reviewer 1:

The work seemed to the reviewer to have sufficient resources to support the modeling, fabrication, and property testing of candidate alloys. There was no evidence of resources placing limitations on the progress of the work.

Reviewer 2:

The reviewer remarked that the resources are adequate and readily available at both the partners for timely completion of the project.

Presentation Number: mat222
Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs
Principal Investigator: Jian Chen (Oak Ridge National Laboratory)

Presenter

Jian Chen, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

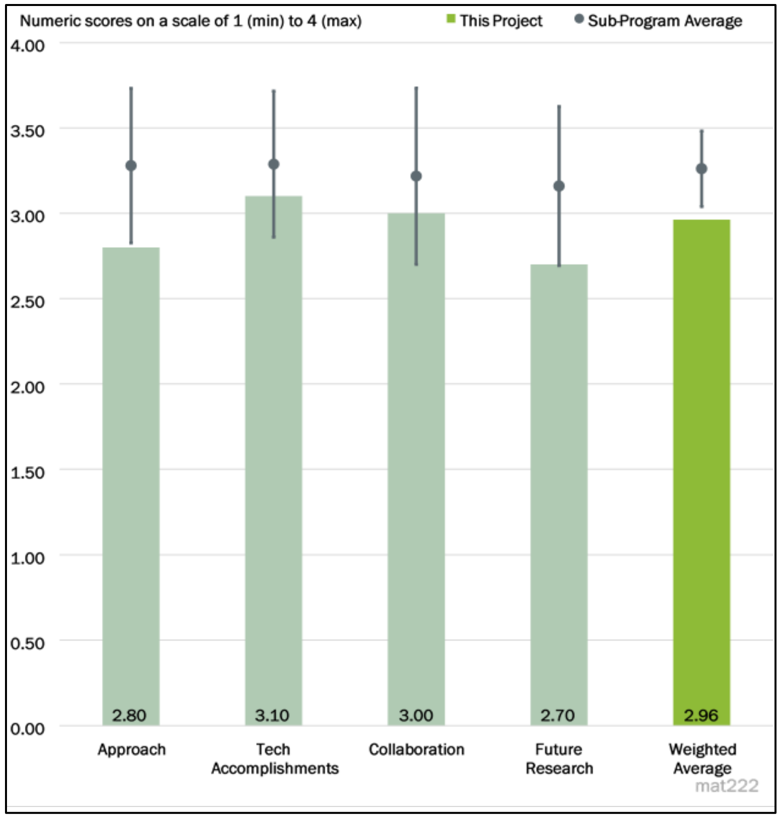


Figure 6-49 - Presentation Number: mat222 Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs Principal Investigator: Jian Chen (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The diagram on Slide 4 is quite clear. Process development and the effect on weld properties are clear along with imaging techniques being applied in situ. However, the reviewer suggested that it would be value added to consider how one would be able to capture the effects of modal interaction in situ.

Reviewer 2:

The approach is very clear and complete and looks competent. What was not clear to the reviewer is that what this project will add to the rather extensive understanding the community has of ultrasonic welding. Many materials pairs, thicknesses, and process variants have been used. It is not fully clear how this investment will produce truly new fundamental or applied knowledge. This may be mostly an issue of communicating the value.

Reviewer 3:

It is the first year of the project. There are not many details in the proposed technical approaches. It was not very clear to the reviewer what the differences are between this project and the Phase I project. It seems the material combinations and coupon geometry and size will be different.

Reviewer 4:

According to the reviewer, a clear objective was not provided, and the future work did not explain what type of characterization of the joints was to be conducted. Corrosion was not part of the picture, and this creates concerns when steel or iron (Fe) is to be joined to Mg. The plan should have involved the use of a barrier, and this was not discussed either.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Because the project just started in December, the reviewer remarked that the project has made appropriate progress in setting up the key variables and approaches.

Reviewer 2:

This project is in its early stages but appeared to the reviewer to be making clear progress with experiments and analysis underway.

Reviewer 3:

The reviewer indicated that the team has established the material set, welding schedule, and instrumentation for initial welding trials, temperature measurement, and initial numerical simulations.

Reviewer 4:

This is a relatively new project, and the reviewer remarked that progress to date is good.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the team consists of three national laboratories and fully utilized the expertise of each laboratory, such as expertise on welding from ORNL, advanced electron microscopes from PNNL, and X-ray synchrotron from ANL.

Reviewer 2:

The burden is on ORNL, and the funding distribution clearly supports that. However, it was not clear to the reviewer how the X-ray synchrotron source is to be used in this project.

Reviewer 3:

The project seemed to the reviewer to be a well-planned collaboration between national laboratory experts. It may be useful to engage universities, industry, and students to maximize dissemination of knowledge.

Reviewer 4:

The reviewer acknowledged that the tasks are well shared, but the nature of the collaboration (meetings, their frequency, and relevant feedback from the collaborators) is not given.

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 state project ended.

Reviewer 1:

The project has projected a logical progression to additional lightweight material pairs based upon initial success of steel-Mg joints. The reviewer strongly suggests prioritizing modal analysis modeling over the thermo-mechanical modeling. The internal work in ultrasonic spot welding (USW) of CFRP highlighted the strong impact of adjacent welds depending upon spacing on the heat generation. The reviewer assumed that that this would be no different in metals.

Reviewer 2:

The plan is clear. As stated before, it was not fully clear to the reviewer what is truly new to be provided by this project.

Reviewer 3:

It seems that for every material combination with the proposed methods, new research using USW has to be conducted, which is very time consuming. The reviewer suggested formulating a general trend or method to accelerate the development of USW with different material combinations.

Reviewer 4:

The reviewer found that the future work is rather sketchy, but perhaps this is due to the start date being only December 2020.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints, the knowledge of process parameters and their effect upon mechanical performance is necessary.

Reviewer 2:

The reviewer indicted that multi-material joining is essential to lightweighting and therefore minimizing energy use in transportation.

Reviewer 3:

According to the reviewer, joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency.

Reviewer 4:

The reviewer opined that joining of dissimilar materials is very important in 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 observed a very well-funded project.

Reviewer 2:

According to the reviewer, the national laboratories have enough resources to fulfill the research goals on time.

Reviewer 3:

The reviewer stated, however, that it is a little difficult to assess because the future work plan is not well detailed.

Reviewer 4:

A listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project. Also, as noted previously, Argonne’s contribution was not clear to the reviewer.

Presentation Number: mat223
Presentation Title: Extending High Rate Riveting to New Material Pairs
Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

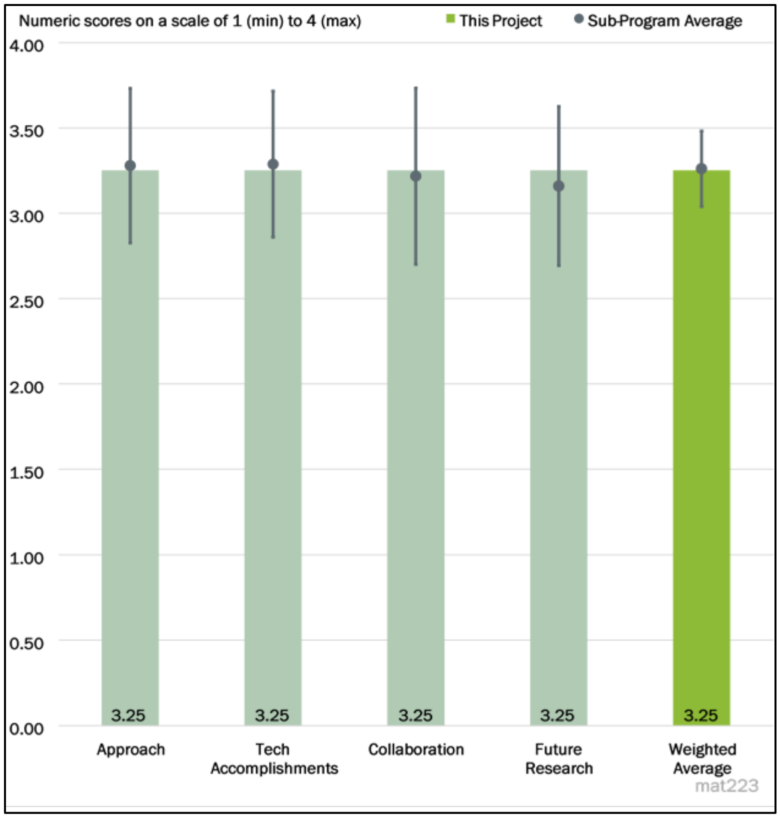


Figure 6-50 - Presentation Number: mat223 Presentation Title: Extending High Rate Riveting to New Material Pairs Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

Presenter

Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the technical approach is very comprehensive, from an experimental and modeling study of the joining processes to joint structure, performance, and end of life recycling.

Reviewer 2:

According to the reviewer, the project is well explained, and the goals are clear with the exception that how the model will be validated is not mentioned anywhere.

Reviewer 3:

This project studies two interesting and innovative processes. They are interesting and can have important impacts. It seemed prudent to the reviewer to really understand the process before developing it. Some more basic work on mechanisms, of the high velocity “riveting” in particular, needs to be performed. It seems that the basic mechanism of joining is not understood.

Reviewer 4:

Although some work has been completed regarding adhesives, none of the remaining three milestones mentions hybrid solid state/adhesive joining, and no go/no-go milestones were called out for the 3-year project. However, reading through the future work indicated to the reviewer that the approach is well thought out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Although this project is in its very early stages, it seemed to the reviewer that progress is going well with technical work underway.

Reviewer 2:

The reviewer reported that the team has accomplished milestones 1 and 2 in the first year.

Reviewer 3:

Given that this is a relatively new project, the reviewer commented that some of the tasks are in progress but may be on track.

Reviewer 4:

The reviewer found it difficult to assess technical accomplishments because progress is only at 5%.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The team consists of three national laboratories and fully utilizes the expertise of each laboratory, such as expertise of high-velocity rivet (HVR) and high-rate friction rivet (HFR) processing and characterization from PNNL, curing and rheology studies from ORNL, and X-ray synchrotron from ANL.

Reviewer 2:

The reviewer noted that the collaboration map is a very good feature and well-detailed as well.

Reviewer 3:

Slide 10 provides a nice overlap of the three national laboratories, but it is a bit disconcerting that ANL is not getting any funding in 2021. It seemed to the reviewer that some initial imaging should be completed in Year 1 to at least validate feasibility of future deliverables and provide feedback to the other members of the team.

Reviewer 4:

Good collaboration, but having no industry, universities, or students seemed to the reviewer to present a fundamental barrier to really getting the technology outside the 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. Note: if the project has ended, please state project ended.

Reviewer 1:

An excellent plan is being executed though it seemed to the reviewer that both fundamental joining mechanisms need to be studied. Also, equipment that can repeatedly develop 500 meters (m)/s impact is a real challenge. It seems prudent to examine the literature on dynamic forging presses. These had a lot of promise in the 1970s, but mostly fatigued themselves to death.

Reviewer 2:

In general, the proposed future research is logical, and this reviewer provided the following for the team to consider:

- Is the mechanical performance of an adhesive joint the same regardless of the path taken to achieve 100% cure?
- Adhesive is typically used for galvanic coupling so why investigate plasma pretreatment and not something like plasma coating or laser ablation, which has been shown to provide improved adhesive bond durability post environmental exposure (which plasma treatment alone does not)? It seems that would be more relevant.
- Include modeling of the hybrid joint, especially in the coupled adhesive-rivet plasticity and fracture behavior.

Reviewer 3:

The reviewer asserted that proposed future work meets the research goal very well. However, there is no task related to the end-of-life recycling that was mentioned in the research goal.

Reviewer 4:

The reviewer emphasized that model validation must be included here.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints, the knowledge of joint performance, such as the hybrid joints proposed here, is necessary.

Reviewer 2:

The reviewer remarked that dissimilar joining is key to vehicle mass reduction and improved efficiency.

Reviewer 3:

This reviewer indicated that joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Development of high- rate joining methods is important to industries requiring high production rates.

Reviewer 4:

According to the reviewer, the project is highly relevant; multi-material design is a key ingredient of 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 project is well resourced for the stated objectives.

Reviewer 2:

The national laboratories have enough resources to fulfill the research goals on time, according to the reviewer.

Reviewer 3:

The reviewer commented that the budget is adequate though more funding may be required in this very valuable project.

Reviewer 4:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat224
Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness
Principal Investigator: Piyush Upahdyay (Pacific Northwest National Laboratory/Oak Ridge National Laboratory)

Presenter

Piyush Upahdyay, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

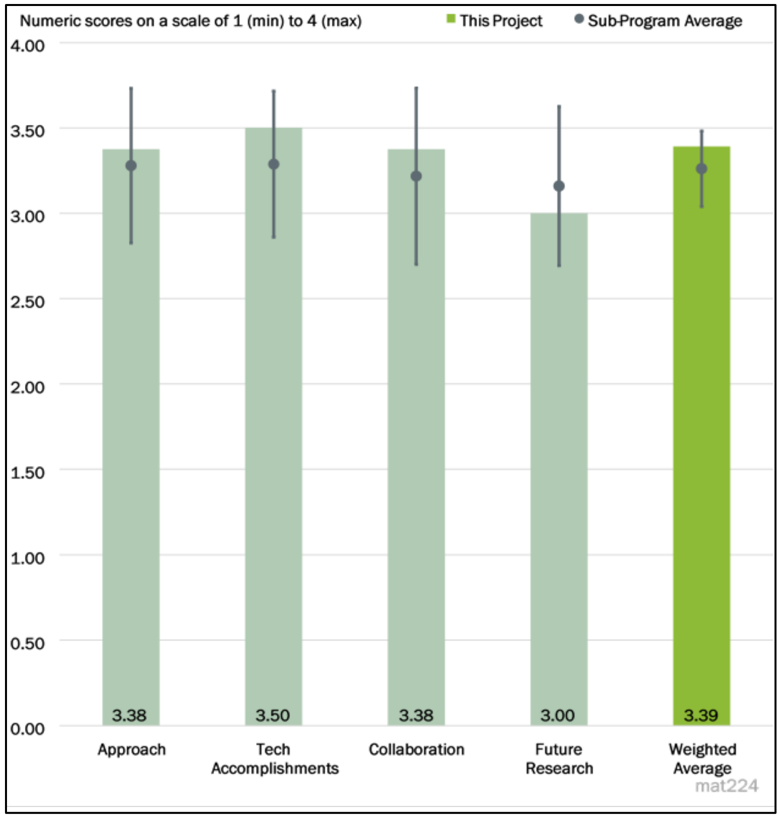


Figure 6-51 - Presentation Number: mat224 Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness Principal Investigator: Piyush Upahdyay (Pacific Northwest National Laboratory/Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is extremely well laid out, and a clear direction with go/no-go targets is evident. However, the reviewer would have liked to see a statement on how the team will determine if the project is successful or not. The go/no-go targets were for Year 1 only.

Reviewer 2:

Very good work is being done by a great team. The work is not highly innovative, but it is a requirement for scaling the technology to industrial use, according to the reviewer.

Reviewer 3:

The goal of this project is to scale up the lab processes (friction-stir linear welding [FSLW] and friction self-piercing rivet [F-SPR]) to production level. The preliminary experimental work has proved the feasibility of the proposed research. If this research could identify the difference between lab scale and real production in a more general way (e.g., through simulation or machine learning [ML]), the reviewer opined that will help to accelerate the scale-up of joining processes that share similarity with these two processes.

Reviewer 4:

All aspects are explained; the reviewer said that the potential challenges related to joining to Al to CFRP are not described.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team has made very good progress, given that the project is only 15% complete. This may be due to prior work or good organization but regardless, the reviewer called it well done.

Reviewer 2:

The program is in its early stages, but the reviewer said that research products are being developed at an impressive rate.

Reviewer 3:

Initial demonstration of the real production robotic system has been finished, which the reviewer found very impressive.

Reviewer 4:

The project is 15% completed though it is the first year and during COVID-19; the reviewer noted that other steps are on track.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that it is very good to see real industry collaboration with national laboratory resources. This bodes well for external application of the insights developed.

Reviewer 2:

The reviewer noted that this research will be performed by two national laboratories and three companies, which will strengthen the technology transfer.

Reviewer 3:

Collaboration is well explained in the presentation; the reviewer stated that there is good collaboration with the industry.

Reviewer 4:

The Responsible, Approved, Supporting, Informed, and Consulted (RASIC) management between ORNL and PNNL was not clear to the reviewer. If each lab has one joining method, then it would be critical to share joint knowledge transitioning from gantry to robotic application.

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 state project ended.

Reviewer 1:

According to the reviewer, the future work is very comprehensive and aligns well with the project objectives.

Reviewer 2:

The reviewer remarked that the plan going forward does address industry issues.

Reviewer 3:

In general, the future work is in line with the stated project targets; however, it seemed to the reviewer very limiting to only investigate corrosion of the self-piercing rivet (SPR) joints, especially with each joint having a unique path to failure.

Reviewer 4:

The reviewer suggested that more emphasis on the property evaluation of Al and CFRP joints needs to be included.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints for industrial applications, laboratory-based technologies must be transitioned and validated in production-like environments.

Reviewer 2:

According to the reviewer, joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Transferring the technologies from lab scale to real production will realize the benefits of these technologies.

Reviewer 3:

The reviewer observed that this project is very important also for EV construction.

Reviewer 4:

The reviewer said that this work supports 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 stated that this project is well funded at national laboratory rates.

Reviewer 2:

The reviewer asserted that the national laboratories and industrial partners have enough resources to fulfill the research goals on time.

Reviewer 3:

The resources are well planned and sufficient, according to the reviewer.

Reviewer 4:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat225
Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance
Principal Investigator: Mike Brady (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

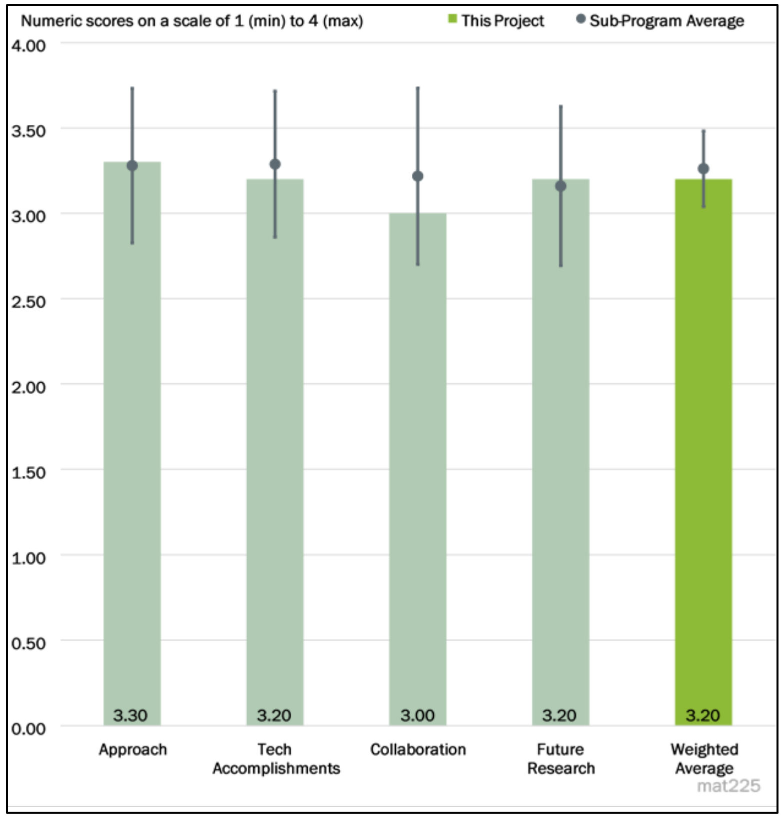


Figure 6-52 - Presentation Number: mat225 Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance Principal Investigator: Mike Brady (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

Presenter

Mike Brady, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project provides a highly innovative method for modifying surfaces that can have important effects in mitigating corrosion.

Reviewer 2:

The reviewer remarked that the proposed approach is very comprehensive and includes processing, characterization, and numerical modeling.

Reviewer 3:

The reviewer said that the plan and objectives are well explained.

Reviewer 4:

The concept of surface modification for improved bonding following environmental exposure is spot on. However, in the slides and presentation, it was not clear to the reviewer if atmospheric plasma is limited to plasma treatment only or if this includes atmospheric plasma applied coatings. It would be interesting if the project team addressed the relative importance of surface roughness versus surface chemistry in laser ablation of the Al surface.

Reviewer 5:

The reviewer found no actual accelerated corrosion exposure of the type used by the automotive OEMs is proposed in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project is early in its development, but the reviewer said it already has impressive results.

Reviewer 2:

The reviewer stated that 10% of the work has been completed, and work seems to be on target.

Reviewer 3:

The reviewer noted that the team has accomplished milestones as proposed in the first year.

Reviewer 4:

The project has a good plan but just started so it was difficult for the reviewer to assess progress.

Reviewer 5:

The project appears to have started very recently, and the reviewer commented that it does not present much in the way of accomplishments at this time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project structure appears to be collaborative, and the reviewer commented that there is an excellent opportunity for cross-project collaboration within the Joining Core Program (JCP) as well as with other DOE-funded projects.

Reviewer 2:

The reviewer noted that the team consists of three national laboratories and fully utilizes the expertise of each laboratory, such as expertise in joining processing, coating, and corrosion characterization from ORNL, friction-based fastener joint from PNNL, and X-ray synchrotron from ANL. It will be better for the team to differentiate the tasks led by ORNL and PNNL.

Reviewer 3:

Without formal industry or academic involvement, the reviewer warned that this project risks being largely confined to use in national laboratories.

Reviewer 4:

Collaboration is well explained in the documents; the reviewer suggested that perhaps collaboration with academia may be included on galvanic corrosion aspects.

Reviewer 5:

The reviewer indicated that the only reported collaboration is primarily limited to national laboratories with little to no participation by industry or academia. While the coordination among labs seems sufficient, the reviewer asserted that more collaboration from outside the national laboratories, especially more guidance from industry (beyond just periodic interaction through other JCP thrusts), would be desirable to ensure that final results are meaningful and useful to the automotive 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the plan going forward can have a significant impact on improving corrosion resistance of multi-material systems.

Reviewer 2:

According to the reviewer, the proposed future work meets the research goal and addresses the research challenges.

Reviewer 3:

Proposed future research fits well with the stated goals of the project. However, it was not completely clear to the reviewer how this research is intended to be used by industry to improve corrosion resistance of multi-material joints.

Reviewer 4:

The reviewer suggested that galvanic corrosion work can be shared with academia.

Reviewer 5:

The reviewer suggested that the project team consider the following points:

- Investigation of a novel fastener design (US2020/0116188), which is currently being commercialized for metal-CFRP joining by MNP Corporation.
- Plasma treatment alone is known to activate the surface and thereby enhance adhesive bonding, but it has a very short “open time,” which has industrial significance, and does not improve the post-environmental exposure adhesive bond performance.
- Application of atmospheric plasma coatings, which can be sub-micron for galvanic protection on dissimilar metal joints (refer to DOE DE-FOA-0001465 [Starfire Industries Prime]: “Atmospheric Cold Plasma Jet Coating and Surface Treatment for Improved Adhesive Bonding Performance of Dissimilar Material Joints subject to Harsh Environmental Exposure”).
- Application of a commercial laser ablation system that has commercial relevance; for example, a cover gas can be of interest technically, but production applications do not employ these. The following provides a summary of recent work: “Application of laser ablation in adhesive bonding of metallic materials: a review,” Optics and Laser Technology, 128, Aug. 2020, 106188.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG emission reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, it is imperative to achieve dissimilar material joints. The current strategy for such joints uses hybrid joining solutions involving adhesive bonding. The understanding of the adhesive-substrate interface under environmental exposure is imperative to joining dissimilar materials.

Reviewer 2:

Joining of dissimilar materials is an important area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Corrosion is a critical barrier in broadening the application of dissimilar materials joints. The reviewer stated that this research aims to address this issue by modifying the bonding surfaces to improve the galvanic corrosion resistance.

Reviewer 3:

The project focuses on corrosion of dissimilar material joints, which the reviewer said is a key technical challenge for lightweight multi-material automotive structures.

Reviewer 4:

According to the reviewer, this kind of work is essential for lightweight next-generation transportation systems.

Reviewer 5:

The reviewer found this project to be very important for multi-material design of vehicles.

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

Reviewer 1:

Work in national laboratories is expensive, but the reviewer commented that this seems like a good investment.

Reviewer 2:

According to the reviewer, the national laboratories have enough resources to fulfill the research goals on time.

Reviewer 3:

The reviewer suggested that some allocation toward academic collaborators would be interesting (to train future scientists and engineers in this strategic work).

Reviewer 4:

It seemed to the reviewer that $3.225 million is excessive for a project that does not indicate a clearly defined path for reducing corrosion resistance of lightweight multi-material automotive structures.

Reviewer 5:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat226
Presentation Title: Machine Learning for Joint Quality and Control
Principal Investigator: Keerti Kappagantula (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

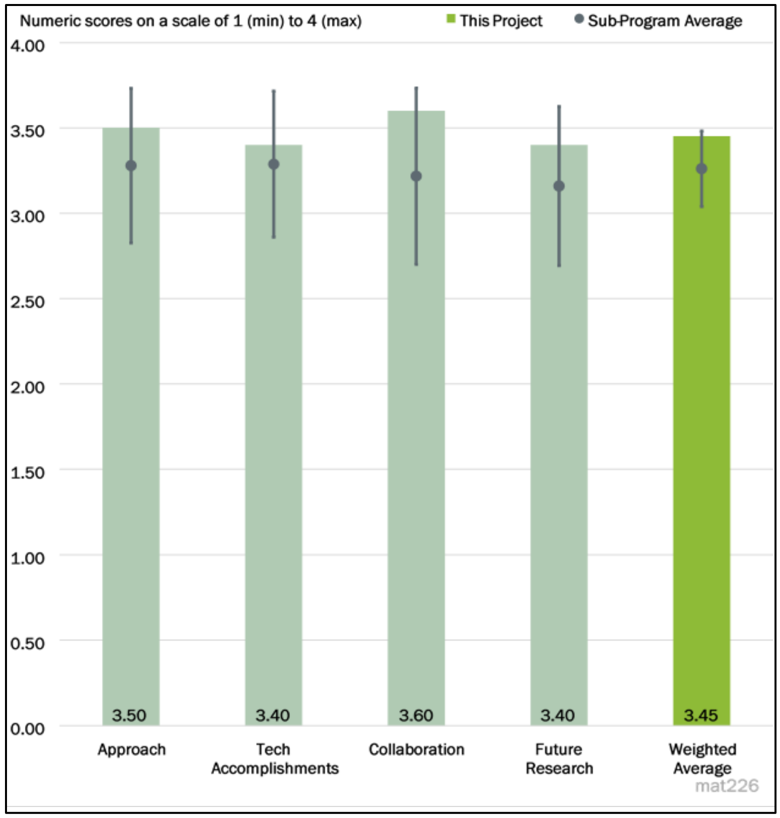


Figure 6-53 - Presentation Number: mat226 Presentation Title: Machine Learning for Joint Quality and Control Principal Investigator: Keerti Kappagantula (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

Presenter

Keerti Kappagantula, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is leveraging a large volume of weld data provided by an industrial partner, GM, for ML algorithm development. The approach adopted here is excellent. The reviewer found that Phase 1 is very well planned as evidenced by the fact that the team was able to obtain the datasets from GM and begin analysis in a short amount of time.

Reviewer 2:

The approach of evaluating resistance spot weld (RSW) joints provided by GM to evaluate the effect of process parameters and material properties on weld properties and to develop ML models from those data is a logical approach, according to the reviewer.

Reviewer 3:

Identifying critical process parameter during dissimilar materials joining is very important to improve joint quality. The team is using joint performance data provided by GM and mining the data to optimize RSW process. The reviewer said that it will deliver understanding of the process-properties relationship including weld feature-properties relationship.

Reviewer 4:

This is an important approach to "tune" welding and other processes using AI and ML processes. It was not fully clear to the reviewer how this work is distinguished from the many neural-net or ML approaches that are now becoming common.

Reviewer 5:

ML is an effective approach to link the welding process, microstructure, and joint performance data. More details could have been given on the ML approach. ML will link process to joint performance by PNNL and microstructures to joint performance by ORNL. How to link the process to microstructure was unclear to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project is progressing well so far. The 20,000-weld datasets provided by GM will certainly enable some interesting analysis and are already supporting development of ML algorithms. So far, the ML algorithm is showing some predictive ability (and hopefully the correlation will be improved as the project progresses). This is not an easy thing to do, and the reviewer stated that the team is undertaking it with a solid approach. The team has made good progress in less than 1 year of effort.

Reviewer 2:

PNNL has processed numerous steel/Al joints, and ORNL has characterized the structural features of those joints. The team has also reviewed and categorized more than 20,000 datasets for GM for deep ML. About 60 material combinations and stack-up coating, adhesive, welding schedule, and bake conditions were studied. The team then evaluated weld performance peak load, extension at peak load, energy, and fracture mode under different loading and mechanical property testing conditions. The team has made a good start, and the reviewer had high expectations for this team.

Reviewer 3:

The reviewer said that the two team members have accomplished two milestones on each side, and the process is on the right track.

Reviewer 4:

This reviewer indicated that the project seemed to be off to a very good start. The work conducted so far shows meaningful progress at accomplishing the stated goals of the project.

Reviewer 5:

The reviewer remarked that good results are coming from the project. Hopefully, detailed results will be published in the coming periods.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project is a great example of an effective collaboration between national laboratory and industrial partners. For one, the reviewer was impressed by the sheer volume of data that GM has provided to the lab partners for use in ML algorithm development. This contribution of rarely available data is an outstanding asset for this project, and the team appears to be leveraging it well. In addition, the project team plans to coordinate with GM on weld schedules for validation. Overall, the reviewer applauded this collaboration as excellent.

Reviewer 2:

The approach and the accomplishments thus far appeared to the reviewer to indicate that the collaborators are working well together and will hopefully lead to good performance throughout the remaining bulk of the project.

Reviewer 3:

The team consists of two national laboratories and one industrial partner. PNNL and ORNL will work with the weld data provided by GM. The co-PIs' groups at PNNL and ORNL should also have their weld data. The reviewer wanted to know if one of the groups plan to use its data as model validation or as part of model development.

Reviewer 4:

This reviewer observed good collaboration, although it seemed that the PNNL and ORNL efforts are somewhat duplicative, despite a more physics base at ORNL. It is good to see explicit industry involvement.

Reviewer 5:

The reviewer noted that the partnership with GM via a CRADA is very good. The reviewer hoped that it becomes productive as the reviewer was not sure what new GM would learn from this process. GM has the data, and it would be difficult to believe that GM has not already mined such a huge dataset.

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 state project ended.

Reviewer 1:

The reviewer stated that this kind of work has a clear future, and the plan shows this well.

Reviewer 2:

The reviewer commented that the proposed future work meets the research goal very well.

Reviewer 3:

According to the reviewer, the proposed future work seems to be a logical extension of existing work and should assist in producing accurate models to improve multi-material weld reliability.

Reviewer 4:

The team plans to mine the data obtained during Phase 1 of the program (JPC 1). The reviewer hoped that those data are available for the other teams, too.

Reviewer 5:

Phase 1 future research plans seem appropriate and well aligned with project objectives. The reviewer found the Phase 2 future research plans to be a bit vague, however. The future work tasks listed for Phase 2 on Slide 14 do not yet appear to justify a 2-year effort. This will need some fleshing-out prior to the planned start of work in the fall.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Efficient joining of multi-material components in a vehicle is very critical. Also, the joints must exhibit significant corrosion resistance. Therefore, the reviewer stressed that this research is highly relevant.

Reviewer 2:

Joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. The reviewer commented that ML will accelerate the understanding of process-structure-performance relationships and the development of dissimilar material welding processes.

Reviewer 3:

The reviewer indicated that mass reduction through multi-material systems is essential and done well here.

Reviewer 4:

According to the reviewer, the project supports DOE objectives of reliable joining of dissimilar material joints, in this case Al to steel.

Reviewer 5:

The reviewer said that this project directly supports DOE objectives in multi-material joining.

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 national laboratories and the industrial partner have enough resources to fulfill the research goals on time.

Reviewer 2:

Project is progressing well, and resources (computational, laboratory, and monetary) appeared to the reviewer to be sufficient.

Reviewer 3:

The reviewer stated that the accomplishments thus far provide a good indication that the available resources will be sufficient for successful completion of the stated future research goals.

Reviewer 4:

The team has met specific milestones with given, allocated resources, according to this reviewer.

Reviewer 5:

The Overview slide does not give the broad scope, nor the full budget and fraction performed. It was a little hard for the reviewer to tell whether the resources were sufficient.

Presentation Number: mat227
Presentation Title: Prediction of Aluminum/Steel Joint Failure
Principal Investigator: Chris Smith (Pacific Northwest National Laboratory/General Motors Company)

Presenter

Chris Smith, Pacific Northwest National Laboratory/General Motors Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

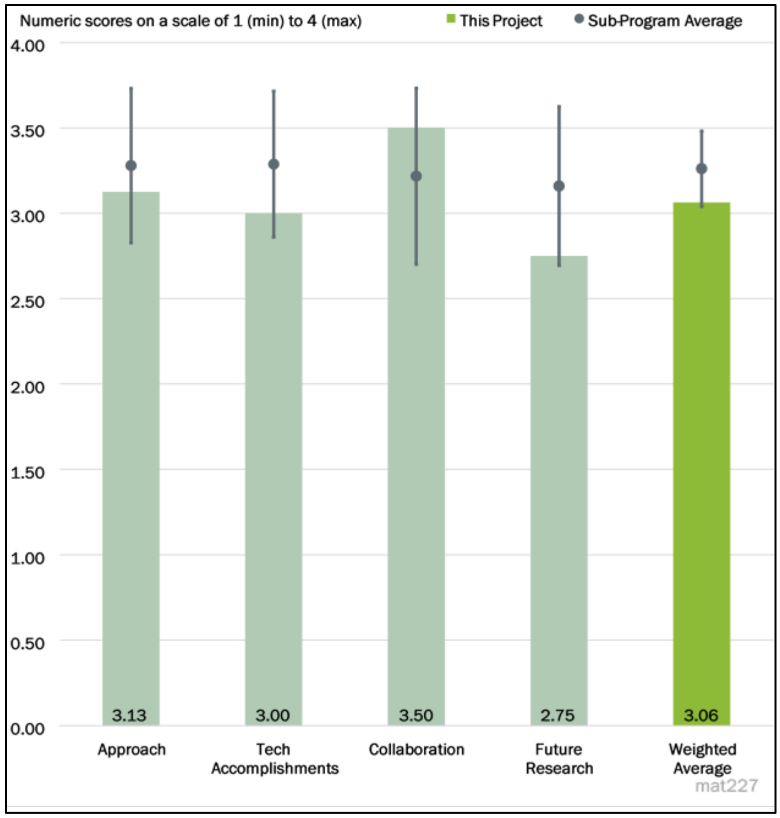


Figure 6-54 - Presentation Number: mat227 Presentation Title: Prediction of Aluminum/Steel Joint Failure Principal Investigator: Chris Smith (Pacific Northwest National Laboratory/General Motors Company)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach seemed to the reviewer to be a logical progression from producing actual physical weld coupons, testing and characterizing the joints, modeling, and validation of the models.

Reviewer 2:

The reviewer stated that the primary objective of this project is to develop fine-resolution mechanical property data in and around the weld nugget in order to support predictive model development. The project roadmap demonstrated a solid approach, though some challenges unfolded during the project itself that required pivots from the original plan.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Reported accomplishments indicate good progress toward achieving the project's stated goals of predictive modeling of Al to steel joint failures, but the reviewer warned that there are challenges remaining to achieving the desired level of accuracy.

Reviewer 2:

The reviewer noted that the project team ran into challenges with several of their planned approaches, including micro-digital image correlation (DIC) and nanohardness testing. The team also experienced some delays due to COVID-19. In light of these challenges, the team pivoted to alternate characterization techniques (topographical microhardness mapping and tensile testing), which yielded some interesting results, though the team obviously lost the resolution it was hoping for in a move from nanoscale to microscale to macroscale techniques. The team also increased its focus on simulation work that could be performed remotely during COVID-19 (in lieu of experiments). The simulation work showed decent predictive capability, and the team has identified a number of key factors that warrant further exploration, such as residual stresses.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, this project seems to be a good collaboration between PNNL and GM with good coordination between the partners. While PNNL is the funded PI, GM (cost share industrial partner) seems to have made a lot of key contributions to this work, including performing a large fraction of the experimental work.

Reviewer 2:

This reviewer observed good collaboration between GM and PNNL as indicated by reported progress to date.

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 state project ended.

Reviewer 1:

Proposed future research is logically focused on developing solutions to challenges encountered in the project to date, according to the reviewer.

Reviewer 2:

The reviewer remarked that there are some good ideas for future work that would align well with project objectives; however, near exhaustion of funding and COVID-19 delays have been identified as a barrier to pursuing some of the identified work and overcoming the remaining technical challenges.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project focuses on predicting dissimilar joint failure in Al to steel joints, which is likely to be the most prominent joint configuration in lightweight, multi-material automotive structures in the near future.

Reviewer 2:

The reviewer asserted that this project supports DOE objectives in multi-material joining.

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 team has nearly exhausted their funding, in part due to COVID-19 delays and impacts and in part due to unexpected challenges with the experimental work. As a result, the team had to scale back the scope of the effort. The team will likely need to leave some interesting findings (such as the residual stress questions) unexplored.

Reviewer 2:

According to the reviewer, the project report identifies “Limited funding remaining in relation to remaining challenges” as one of the remaining barriers to successful completion of the project objectives.

Presentation Number: mat228
Presentation Title: New Technologies for High-Performance Lightweight Aluminum Castings
Principal Investigator: Paul Jablonski (National Energy Technology Laboratory/General Motors Company)

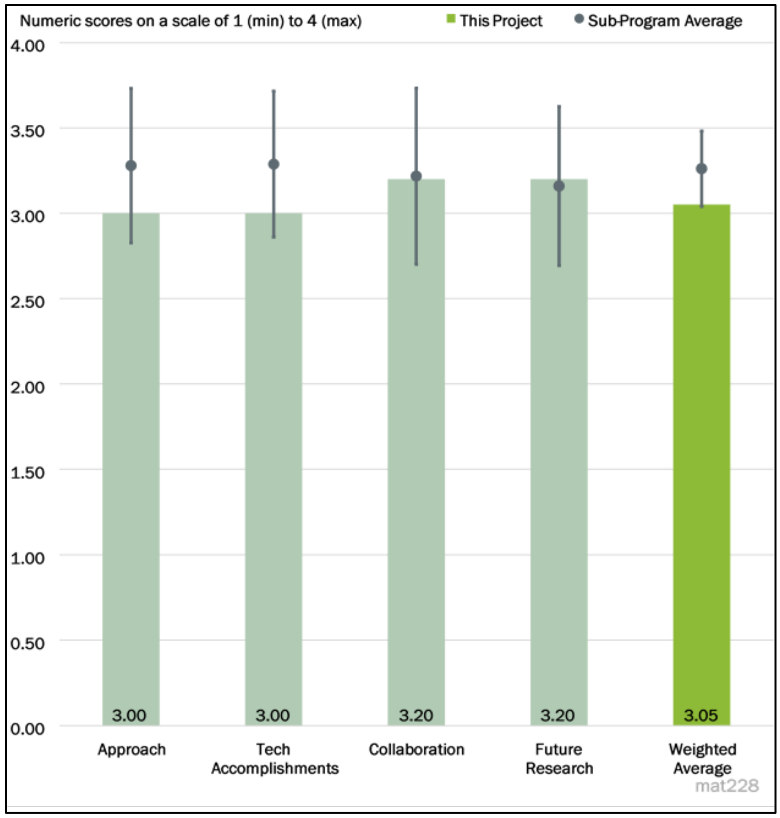


Figure 6-55 - Presentation Number: mat228 Presentation Title: New Technologies for High-Performance Lightweight Aluminum Castings Principal Investigator: Paul Jablonski (National Energy Technology Laboratory/General Motors Company)

Presenter

Paul Jablonski, National Energy Technology Laboratory/General Motors Company

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the approach simple but appropriate for this project. The team will develop the pressure-assisted precision sand casting (PAPSC) process on a simple plate mold and then confirm the process steps on a production-like, water cooled deck face insert. Concurrently, the casting material microstructure and mechanical properties including tensile, fatigue, creep, and thermal mechanical fatigue will be characterized to guide process development.

Reviewer 2:

Within the framework of the minimal details provided, the approach seemed sound to the reviewer. The PAPSC approach is intriguing for reduction of flaws. A more thorough description of the unique nature of the National Energy Technology Laboratory (NETL) casting capabilities being used would be helpful next year.

Reviewer 3:

The reviewer commented that the approach is generally good. Some information about the mechanical testing process of the cast component to be adopted by the PIs (methodology and where samples will be taken from for a representative set of results) will be beneficial. Central to this project is increasing strength and fatigue resistance by greater than 25%.

Reviewer 4:

The project approach is aligned with addressing the technical barriers and targets.

Reviewer 5:

This project is not investigating novel technology or alloy systems. Pressure-assisted casting technology has been put into production in the past (e.g., Cosworth process). It was difficult for the reviewer to see where this project is addressing technology barriers other than potentially the water-cooled chill. The addition of novel technology such as rapid sand core printing or a novel alloy might be an improvement. However, given the short timeline, it is unclear that there will be time for a pivot.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent technical accomplishments on progressing the die design and the process development based on numerical simulations. According to the reviewer, the efforts to cast and characterize the initial prototype castings are excellent. The development of the PAPSC process developed at GM is a crucial part of the accomplishments.

Reviewer 2:

Given the constraints of lockdowns related to COVID-19, the progress appeared to the reviewer to be adequate for the technology deliverables.

Reviewer 3:

The reviewer stated that there were very few results to assess thus far, due to unavoidable schedule delays related to COVID-19. The development of the mold chill and design of the casting process and system seem to be the primary progress to date.

Reviewer 4:

Progress is generally good, considering that it was hampered by the COVID-19 global pandemic. The reviewer expected that work will accelerate once the pandemic restrictions are eased.

Reviewer 5:

Technical accomplishments were made and presented; however, the reviewer noted that COVID-19 had affected progress in 2020.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer indicated that collaborators seemed to be working well together, and further noted that work is evenly distributed.

Reviewer 2:

The reviewer said that Coordination among the partners is good.

Reviewer 3:

The project appeared to the reviewer to coordinate and collaborate across the team.

Reviewer 4:

The strong accomplishments indicate excellent collaboration between the partners, NETL, GM, and Eck Industries. The reviewer would have liked to see a chart or table with the typical interactions (i.e., weekly, monthly, and quarterly) and a clear list of roles and responsibilities plus a "gives and gets" table showing the interactions as the cylinder head castings move forward.

Reviewer 5:

The team of NETL, GM, and Eck appear to be well positioned for success, but at this stage of progress the quality of collaborations was not yet clear to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that there is an outstanding plan to cast, then characterize and test prototype cylinder heads. The plan includes microstructure and thermo-mechanical property characterization. The addition of dynamometer testing of the prototype cylinder heads is an excellent addition to the overall plan.

Reviewer 2:

The project plans to meet planned deliverables by working into 2022 on a no-cost extension. The reviewer suggested that future work could also consider or model the projected tool life for the head deck face chill.

Reviewer 3:

According to the reviewer, the proposed future research does appear to address the objectives of the project. A no-cost extension would give the required time to complete the work.

Reviewer 4:

The reviewer asserted that the proposed work is intriguing and if successful could be remarkably impactful to reduce casting flaws and improve reliability and fatigue life in highly stressed cast components.

Reviewer 5:

The future work proposed will contribute to the goals and milestones of the project. A cost analysis of the part produced by the process is warranted if that has not already taken place to confirm a favorable cost-benefit. The reviewer reference earlier comments and said that provision of more detail about the mechanical testing to be performed on the part(s) would be helpful.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that higher quality castings would be a key step toward enabling higher power densities and improved efficiencies in future ICE and hybrid vehicles.

Reviewer 2:

The reviewer remarked that achieving the stated goals will lead to better energy efficiency and likely to higher engine durability.

Reviewer 3:

The reviewer stated that the project is relevant to deliver high-quality powertrain casting for smaller displacement engines with the same power.

Reviewer 4:

The reviewer observed that the improvements in strength and fatigue resistance will enable higher compression ratios leading to improved fuel efficiency.

Reviewer 5:

This project as written is not novel. The PAPSC process and the use of chills with a standard Al alloy for ICE castings has been done in prototyping and production for many years. The idea of using chills and characterizing the effect on microstructure and mechanical properties performance in cast Al alloys has been well established in the literature. There are several areas of research in the sand-casting area that are novel and could meet the goals of the DOE objectives. The reviewer suggested that new Al alloys, a novel sand core-making process, and large thin-walled castings using PAPSC are all areas that might be of interest.

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, funding appears sufficient to meet project goals as stated.

Reviewer 2:

The reviewer said that an appropriate level of resources has been applied to this project.

Reviewer 3:

The reviewer noted that the remaining resources are sufficient to complete this project, which has been delayed due to COVID-19 safety protocols.

Reviewer 4:

The funds appeared to be sufficient to the reviewer. More information is required to make a better assessment. Amount of work completed was stated, but the amount of money spent was not.

Reviewer 5:

This reviewer described project resources as sufficient.

Presentation Number: mat229
Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components
Principal Investigator: Govindarajan Muralidharan (Oak Ridge National Laboratory/FCA LLC)

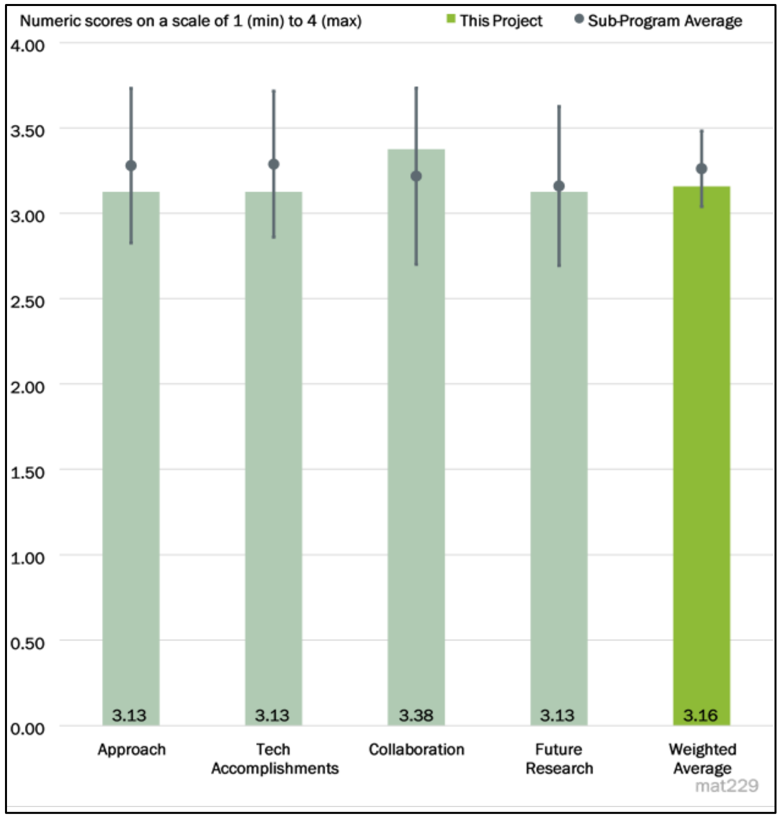


Figure 6-56 - Presentation Number: mat229 Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components Principal Investigator: Govindarajan Muralidharan (Oak Ridge National Laboratory/FCA LLC)

Presenter

Govindarajan Muralidharan, Oak Ridge National Laboratory/FCA LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the stated objectives are to develop a new Mg alloy that will process easily in thixomolding™ and will have the desired elongation and mechanical properties of an AM60 alloy. The project is well designed to meet those objectives. The project team utilizes an ICME approach and some very targeted property selection to achieve that goal.

Reviewer 2:

Performing alloy design to match a thixomolding process is a justifiable task. The application presented, a spare tire carrier, however, lacks the requirement for high ductility that the thixomolding process naturally entails. The details of the alloy design strategy via CALPHAD were not entirely clear to the reviewer. Also, the current state of the project with regard to meeting all project targets (a combination of processability, strength, and ductility) was not clearly presented.

Reviewer 3:

The approach for the project is well defined and designed to overcome the potential barriers related to use of Mg alloys for automotive applications. The project is using computational modeling, lab scale heats, ingot fabrication, characterizations, component fabrication, and testing. The project will also be addressing the corrosion behavior of the fabricated component. The pathway presented is appropriate for the demonstration of the thixomolding fabrication approach for Mg alloys with improved properties. It was not clear to the reviewer why corrosion tests are planned for the component level only. It may have been better to perform some corrosion tests at the ingot scale as well.

Reviewer 4:

The approach is sound and will lead to the goals being achieved, according to this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the project has made excellent progress. The new alloy composition, as determined by modeling, has been fabricated. Material properties (ductility and strength) are superior to the current commercial alloys. The progress is on track per the project tasks.

Reviewer 2:

The researchers have found some candidate alloys and have stated they are on track for physical testing of a larger component. The timing for completion of evaluation of components produced using the new alloy seemed very tight to the reviewer. However, other than corrosion testing, it could be complete in the next 8 months.

Reviewer 3:

The reviewer referenced earlier comments and stated that the exact status of the project remains vague.

Reviewer 4:

Work progress is good considering the impact of the COVID-19 pandemic on work execution. The reviewer commented that no corrosion resistance data were presented (marked as complete March 2021 on Slide 8) for alloy downselection. Downselection criteria used for corrosion and mechanical properties would be helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project appeared to the reviewer to have the appropriate number of participants. All key players appear to be capable of achieving project goals. There are no apparent gaps.

Reviewer 2:

The project team of ORNL, FCA, and Leggera Technologies complements the various tasks of the project. The reviewer found that specific roles of each partner have been clearly defined. Progress on the project reflects that there is good collaboration between the team members.

Reviewer 3:

As far as presented, the reviewer stated that there did not appear to be any shortcomings regarding cross-team collaboration.

Reviewer 4:

Collaboration is good, according to 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The presented plan is fine with the reviewer.

Reviewer 2:

Overall, the project has been very well planned. The future tasks are well laid out. One comment from the reviewer, as alluded earlier, is that there should be some corrosion testing conducted early on (at lab-scale heats) rather than doing it once the component is fabricated.

Reviewer 3:

In general, the project seems to have a identified a few alloys that could be used for evaluation if a lead alloy does not work well. However, it was difficult for the reviewer to evaluate since the candidate alloy chemistries were not identified. It is not clear if an existing alloy was simply tweaked or if new alloy systems were attempted. Other issues, such as constituent availability or recyclability, were not evaluated. While there has been some preliminary lab-scale testing, the behavior of the alloy candidates in actual thixomolding trials has not been evaluated. Other factors could show up with a shortened time frame to complete. There is some risk to the project completing objectives on time.

Reviewer 4:

This work seeks to extend the knowledge gained in fabricating wheel holders from new alloy chemistries to other auto parts. The reviewer suggested that a listing of those auto parts and the target properties and parameter values would be helpful (a simple table would suffice). A basic cost analysis for each part using the new chemistries and relevant fabrication methods would be beneficial to determine viability of these extensions and to support the PIs' conclusions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that Mg is a potential candidate material for lightweight vehicles and EVs. Development of fabrication methods and materials with improved mechanical properties (ductility and strength) is critical for their commercial use. In that respect, the project is highly relevant to DOE objectives for fuel reduction and environmental benefits.

Reviewer 2:

This project does address lightweighting in large vehicle components by addressing some of the challenges of thixomolding of Mg parts. The ability for Mg components to replace high-pressure die casting (HPDC) high ductility Al components in structural applications can contribute significantly to lightweighting the glider. Die casting of Al parts tends to require special alloys and post-process heat treatments, which are not required by Mg. However, challenges with die casting Mg remain that can be solved using the thixomolding process. This could become an enabler, and the project specifically uses a thin-walled part to assist in this evaluation, according to the reviewer.

Reviewer 3:

The reviewer noted that thixomolding offers great opportunities for lightweighting, and thus this project lies within the scope of the DOE.

Reviewer 4:

The reviewer stated that weight reduction of auto bodies and components is essential for fuel efficiency in autos.

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 resources are sufficient if the downselected alloy is successfully thixomolded.

Reviewer 2:

The reviewer reported no shortages of resources.

Reviewer 3:

Project resources are sufficient and adequate, according to the reviewer.

Reviewer 4:

Resources seem sufficient. The amount of work done was presented, but the amount of money spent was not presented, so it was difficult for the reviewer to make the fund sufficiency assessment.

Presentation Number: mat230
Presentation Title: Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction
Principal Investigator: Aaron Greco (Argonne National Laboratory/General Motors Company)

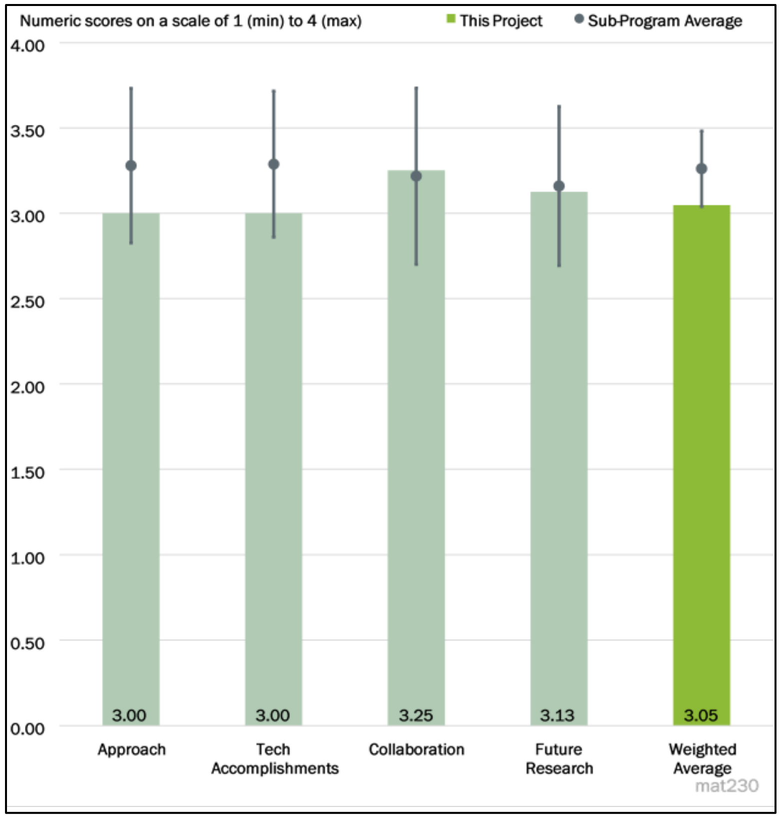


Figure 6-57 - Presentation Number: mat230 Presentation Title: Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction Principal Investigator: Aaron Greco (Argonne National Laboratory/General Motors Company)

Presenter

Aaron Greco, Argonne National Laboratory/General Motors Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work is providing valuable experimental results to complement local thermal predictions from simulation and will be important for assisting in determining alloy compositions and laser processing parameters that work best to meet the goals of higher performance and lower cost alloy systems. The reviewer noted that the correlation of the in situ parameters and actual parameters used in the laser power bed fusion (LPBF) process will be important.

This work appears to address keyholing porosity, but it was difficult for the reviewer to see if it also addresses lack of fusion porosity. More detail on hot tearing would be useful as well.

Reviewer 2:

The reviewer said that the approach is good.

Reviewer 3:

This project aims to accelerate alloy development through observation of the LPBF process through in-situ X-ray imaging. Considering the challenge associated with developing new alloys for LPBF and for a smaller

Lightweight Materials Consortium (LightMAT) project, this effort appeared to the reviewer to lack focus. Too many alloys and applications are being targeted simultaneously. In addition, given the very local nature of the in-situ technique, it is a stretch to claim that this effort can lead to substantial progress.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the technical accomplishments to be reasonable, given the obstacles such as lab and beamline closure faced by the team members due to COVID-19.

Reviewer 2:

A lot was accomplished even with stay-at-home orders, but there still appear to be setbacks. The reviewer warned that finishing within the project timing may be difficult.

Reviewer 3:

Technical accomplishments are good given work restrictions imposed by the global COVID-19 global pandemic. The reviewer proposed the following for the project team to consider:

- At least mention the method of AM used to produce the parts. The methodology matters.
- A word on process control. How is it being done? All the analyses will mean nothing if the part coming off the production line is different (e.g., microstructure and mechanical and chemical properties) all the time.
- Please comment on pore density and distribution where and when it occurs (surface, middle, through thickness, evenly distributed, etc.).
- Consider listing the possible parts the new chemistries and AM technique (optimized printing parameters) being evaluated will be extended to and why. A basic cost analysis will be beneficial to support the conclusions of the PIs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration seemed effective to the reviewer. The alloys studied were relevant to the automotive partner. The cost-sharing tasks appear to be very equivalent.

Reviewer 2:

Good synergy seems to exist between ANL and GM, according to the reviewer.

Reviewer 3:

This reviewer remarked that collaboration between the national laboratory and university partner seemed to be progressing smoothly.

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 state project ended.

Reviewer 1:

The reviewer asserted that the remaining modeling work and comparison to the in-situ results will be important. Since alloy #2 will be a very different alloy, the modeling may be challenging.

Reviewer 2:

Not much was said about fatigue and strength evaluations of the alloys and printed parts. The reviewer inquired about how these are being evaluated in this project and correlated to the processing parameters.

Reviewer 3:

The reviewer commented that future research can once again benefit from focusing the project effort.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project addresses fundamental ICME for automotive relevant alloys (ferrous and Al) that will be enablers for lightweighting from a design perspective and a business case perspective.

Reviewer 2:

The reviewer remarked that reduction of component weight and increased durability are central to cost reductions and efficiency gains in auto production.

Reviewer 3:

The reviewer commented that the project is relevant in that new LPBF alloys have the potential to change the landscape of powertrain applications.

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

Reviewer 1:

The resources for beam time appeared to be sufficient to the reviewer.

Reviewer 2:

Project resources appeared sufficient to the reviewer.

Reviewer 3:

Funding appears to be sufficient. There is no mention from the PI about the percentage and/or amount of money spent versus the amount of work and/or scope completed. It was therefore difficult for the reviewer to assess whether the funds are sufficient.

Presentation Number: mat232
Presentation Title: Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet
Principal Investigator: Darrell Herling (Pacific Northwest National Laboratory)

Presenter

Darrel Herling, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

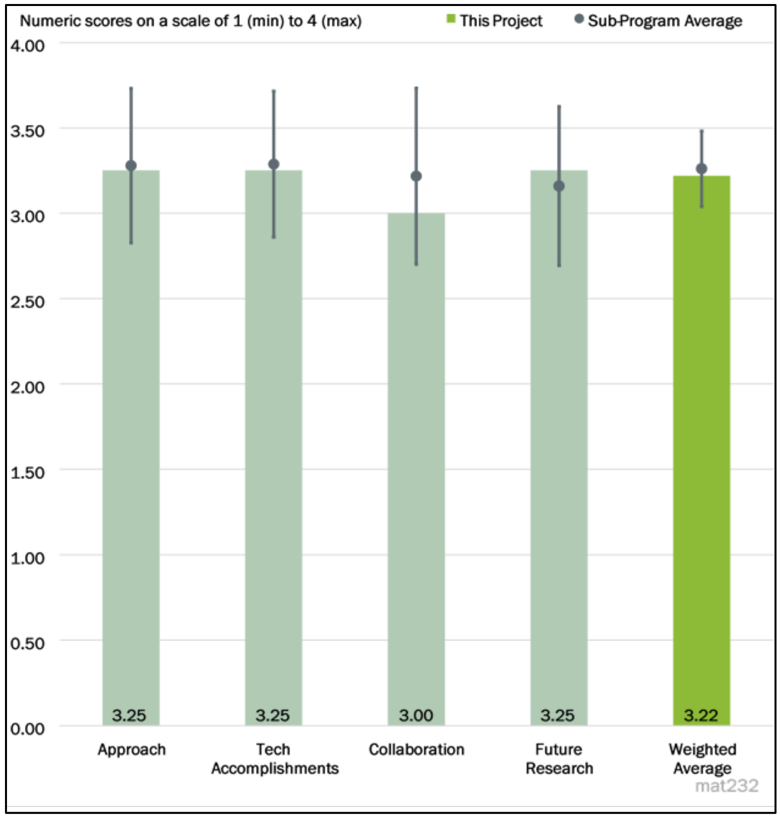


Figure 6-58 - Presentation Number: mat232 Presentation Title: Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet Principal Investigator: Darrell Herling (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this high-level project approach is aligned to address stated barriers and technical targets to implementation of Al and Mg in automotive applications using technologies in solid-phase processing, AM, and thermochemical treatments.

Reviewer 2:

The reviewer stated that this project is developing enabling technologies for Al sheet with three tasks underway—one on composite rolling process, a second on AM reinforcement, and a third on surface modification technologies to change properties. Of these, the first one is not very important for the sheet development because extruding a tube and converting it to a sheet is very long process and will not justify the cost. The reviewer asserted that changing the local properties or size is a good value proposition, but the approach needs to be changed. The AM process for supporting structure is good concept; as the interface characterization and optimum choice of material need to be developed, the proposed approach is good. Surface or structure modification through processing is also good.

Reviewer 3:

The projects are set up to loosely complement each other as various ways to selectively reinforce Al sheet materials. This approach is important because each of processes can have use in specific situations. From a mechanical performance and initial processing perspective, the projects do seem to address the challenges. However, there do seem to be gaps in material compatibility using different alloys and effects for other processing aspects (coatings, corrosion, and recyclability) that do not seem to be taken into account. Perhaps that is outside the scope, but consideration should be made on the alloy combinations from this perspective. Also, Project 1A is designed such that the extrusion would subsequently be formed; however, it was not clear to the reviewer if Project 1C (which has a major focus on sheet forming) is going to be addressing those issues or if Project 1A will use lessons learned, etc. Coordination here is not apparent.

Reviewer 4:

The reviewer noted that this project has three sub-projects, so the approach varies slightly among the three sub-projects. The concern that the reviewer had is that it seems that the researchers proposed the work based on their available equipment, rather than identifying the problems that the industry has and then looking for the best solutions. For example, producing automotive sheet using the Shear Assisted Processing and Extrusion (ShAPE™) process does not make sense from the cost point of view. On the other hand, multi-alloy extrusion using ShAPE makes more sense.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the projects seem to be making good progress. Regarding Project 1A, the project has developed the tooling and done some initial extrusions but no forming of microstructure. This seems on track for the project. A focus on the variable thickness or varying the properties using changes in processing conditions during the extrusion might be a more fruitful route than changing alloys within the same extrusion and more in keeping with the goal of recyclability for sheet production.

Regarding Project 1B, this reviewer indicated that the project team has downselected the filler material but will not complete the coupon trials until September. This seems on track for the project.

Regarding Project 1C, the reviewer noted that this project seems to be on track for the first year.

Reviewer 2:

The reviewer had comments about each project. Specific to Project 1A, the reviewer stated that multi-extrusion work is showing good progress. Regarding Project 1B, only initial single bead deposits have been made. Alloy selection and interfacial strength are the key to the success of this project. Further, the reviewer observed the most progress in Project 1C and suggested that a demonstration part is needed to validate the improvement.

Reviewer 3:

Development in extrusion is good but the reviewer said that it will not justify sheet development; variable thickness and multi-alloy extrusion are quite significant and can be developed further for extrusion itself.

The project has just started and, for the time, the progress in the tasks is reasonable. The cost of using FSW and other processes to soften the edges and improve bendability needs to be estimated.

The work on developing a new standard to evaluate bending is a good task suitable for national laboratory activities.

Reviewer 4:

This is a new project; hence, the reviewer found the accomplishments to be preliminary with experiment planning, material collection, and initial proof of concepts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The core project team appeared to the reviewer to share resources and meet frequently.

Reviewer 2:

The reviewer commented that collaboration is generally good but could be more open to broader participation of the light metals community.

Reviewer 3:

Cooperation between three labs is good with tasks distributed based on the strength of teams at labs. As of now, there are no industrial partners, but there is advice from various industry leaders. The reviewer encouraged the team to focus efforts on involving industry partners to assess the feasibility of the processes under development.

Reviewer 4:

It appeared to the reviewer that there could be more coordination, particularly between Project 1A and Project 1C1 with the bending and unbending rolls development and the goal of cutting and forming the extrusions into sheets. These projects seem to be loosely complementary. Also, since the stated goal is to reduce alloys, it would be good to see more coordination around alloys used in the three 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer called this a very strong plan for novel and unique manufacturing technology development for Al and Mg.

Reviewer 2:

The reviewer observed that it would be great to have demonstration parts from industry.

Reviewer 3:

All these projects need to be investigating aspects of scaling up the technology. Some deliverables around speed, output, and repeatability would be useful for the reviewer to see.

Reviewer 4:

The focus on the extrusion process needs to be modified as it may not be the best route for sheet making, or, the reviewer suggested, the team should change the focus of the project to all thermo-mechanical processing (TMP) routes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that Al sheet (and, to a certain extent, extrusions) will contribute significantly to weight reduction for EV platforms. Extending the range or making smaller batteries will improve the energy density and performance of these vehicle. Work to improve formability and performance of sheets will contribute to the DOE objectives.

Reviewer 2:

Localized reinforcement in sheet materials is important for lightweighting strategies overall. The reviewer stated that this work investigates several novel technologies to address that capability.

Reviewer 3:

According to the reviewer, such new technology is needed to address the limitations to the manufacturing and use of Al and Mg in automotive applications.

Reviewer 4:

The reviewer's overall impression of the "Light Metals Core Program," not just this project, is that this program seems an "add-on" to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing. Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

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 projects seem to be well resourced, given the funding amount.

Reviewer 2:

The project has appropriate resources to deliver milestones, according to the reviewer.

Reviewer 3:

The reviewer indicated that enough resources are available for the tasks identified.

Reviewer 4:

Resources are generally sufficient, but the reviewer opined that they should be adjusted to focus on more successful sub-projects and drop ideas that do not work out so well.

Presentation Number: mat233
Presentation Title: Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

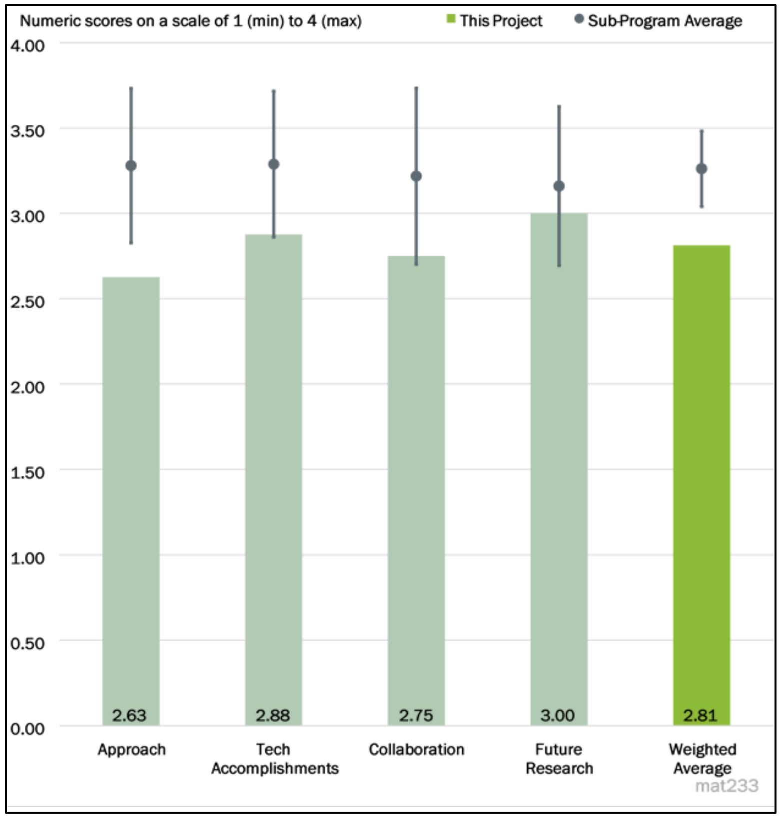


Figure 6-59 - Presentation Number: mat233 Presentation Title: Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The three sub-projects are generally feasible with capable teams. One of the barriers listed was "very high integrity castings can be obtained with vacuum high pressure die casting but costs are high, especially when complex designs are high." The reviewer did do not agree with this statement. In fact, vacuum die casting is very affordable and significantly lower cost than some of the techniques in this project.

Reviewer 2:

The reviewer commented that the project is taken up to improve the performance of castings; while Tasks 1 and 3 focus on die castings, Task 2 is on metal molds. The tasks are diverse with use of FSW and AM to modify or add surfaces for die cast alloys. The focus of Task 2 is to use ultrasonic surface processing to reduce grain size and improve properties. Although the approach is good, the reviewer asserted that the use of HPDC needs to be re-evaluated. The reviewer further explained that the surface layer in HPDC components, which is less than 1 millimeter (mm) thick, is critical for performance. Modification of this could reduce the performance significantly. Larger castings from sand or permanent molds may benefit from such activities.

Reviewer 3:

The reviewer observed that the approach includes too many materials and processes investigations and too few practical applications: 380, 356, Aural 2, Aural 5, HPDC, FSW, book mold, additive, ultrasonic, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

All three sub-projects have shown some modeling and preliminary experimental results, but the reviewer said that it is still too early to judge the outcome.

Reviewer 2:

Project has just started. Task 1 identified the material for testing; testing of other cast materials will be useful. In Task 2, the modeling is complete; the reviewer said that the change in cooling rates with thickness needs to be taken into account when using ultrasonic processing. For Task 3, only the planning is complete; the reviewer's comment is similar to Task 1 in that the use of other cast materials will be useful instead of only HPDC.

Reviewer 3:

The reviewer found no progress to date after two quarters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, cooperation between labs is good; the in-kind contributions from OEM are a good start.

Reviewer 2:

The project team has demonstrated some collaboration with industry in sample sharing and modeling work. The reviewer expected more collaboration when there are more experimental results and testing.

Reviewer 3:

The reviewer saw no mention of collaborating, rather independent research efforts by ORNL and PNNL. ANL is included in the award, but tasks are not defined for work conducted by ANL.

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 state project ended.

Reviewer 1:

The reviewer found sound future plans but asserted that the team needs close collaboration with industry in terms of demonstration parts and performance testing.

Reviewer 2:

The reviewer suggested that the team consider adding other cast materials for comparison purposes.

Reviewer 3:

The reviewer emphatically remarked that the project approach appears disorganized.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that Al castings will contribute significantly to energy density and long range for EVs. Local property enhancement will be useful as the castings are required to perform in various conditions on different surfaces.

Reviewer 2:

The concept of increased use of lightweight materials into the vehicle structure is a DOE objective, according to this reviewer.

Reviewer 3:

The reviewer's overall impression of the "Light Metals Core Program," not just this project, is that this program seems an "add-on" to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing.

Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

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 project is well funded.

Reviewer 2:

Resources are decoupled, as the reviewer said that the teams are working independently.

Reviewer 3:

Resources are generally sufficient, but the reviewer opined that they should be adjusted to focus on more successful sub-projects and drop ideas that do not work out so well.

Presentation Number: mat234
Presentation Title: Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings
Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Presenter

Vineet Joshi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

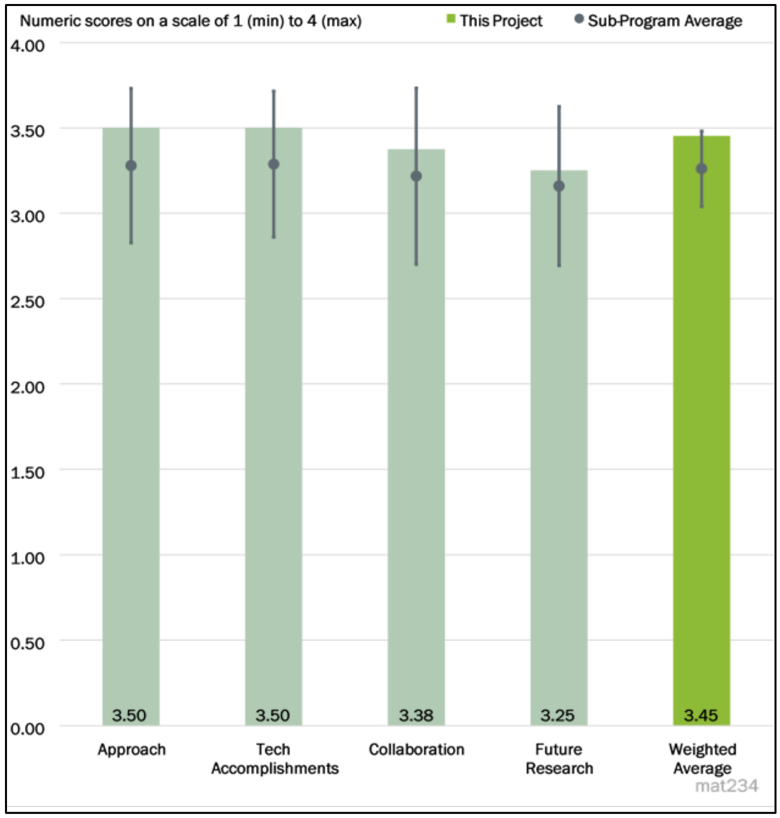


Figure 6-60 - Presentation Number: mat234 Presentation Title: Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer reported that the project clearly identified the major barriers of Mg casting applications in the automotive industry and proposed two projects as the first steps of the research.

Reviewer 2:

Corrosion is the major issue to be resolved for Mg alloys used in structural applications in vehicles, and surface modification is the most direct way of improving the performance. This project is aiming to investigate many technologies to improve the performance. The reviewer commented that there is a good work plan and noted that it would be nice to have seen the current state of the art on this as the subject has been studied many times. A few solutions are available with higher cost.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Despite a short time in the project, the reviewer indicated that it has generated some promising preliminary results in both sub-projects. Since the “skin” effect (fine microstructure and almost no porosity) on the die casting surface is critical to the mechanical properties of Mg die casting, coating solutions (retaining the die cast “skin”) are preferable to the friction stir process to improve the overall performance of Mg die castings.

Reviewer 2:

This reviewer noted that the project has started this year; progress so far is on planning and start up. Reactive surface oxidation process is well studied and could be useful to show how the new process varies from the old ones. Additionally, the reviewer explained that modeling efforts are useful in identifying the surface but need to be supported by surface analysis (assuming that it is part of another project).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer indicated that collaboration seemed to be good within the project team and with industry.

Reviewer 2:

The reviewer reported that DOE labs are collaborating on this and suggested that it would be useful to have an industrial advisory board to validate the assumptions and 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer suggested that a demonstration part is needed for future research to validate the technologies in more complex automotive castings.

Reviewer 2:

The reviewer stated that the alloys chosen contain Al as the major element. According to the reviewer, it would be useful to have other casting alloys with other major elements (rare earth element [REE], Zr, or zinc [Zn]).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that Mg could significantly contribute to mass reduction and solving the corrosion problem would enhance its use in vehicles.

Reviewer 2:

The reviewer’s overall impression of the “Light Metals Core Program,” not just this project, is that this program seems an “add-on” to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing.

Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

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 are enough funds and efforts for this task.

Reviewer 2:

The reviewer’s preference would be for more resources for coating solutions than FSP, which actually reduces the “skin” effect in die castings.

Presentation Number: mat235
Presentation Title: Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle
Principal Investigator: Arun Devaraj (Pacific Northwest National Laboratory)

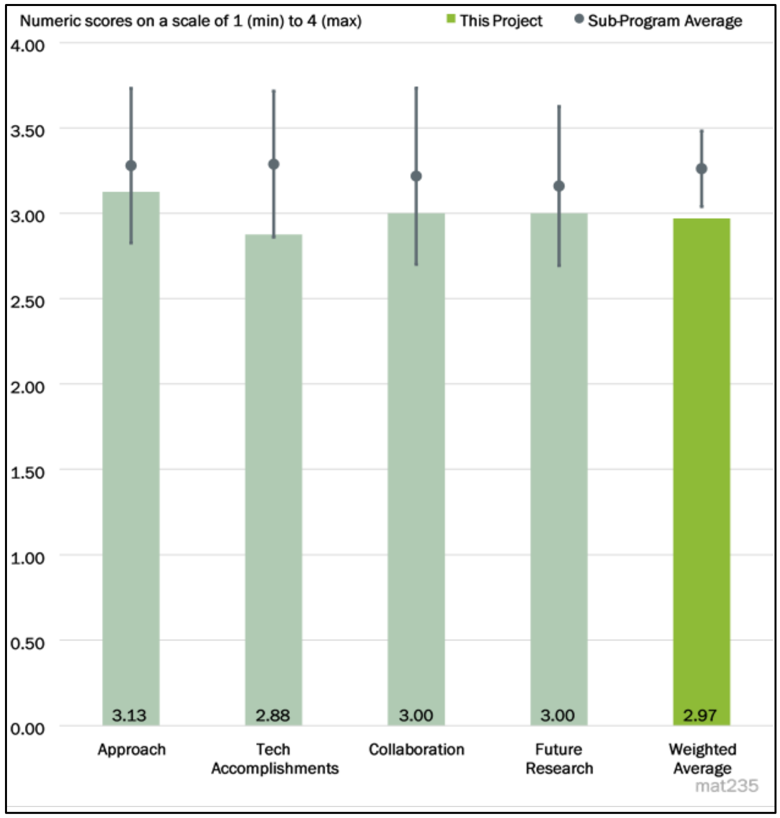


Figure 6-61 - Presentation Number: mat235 Presentation Title: Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle Principal Investigator: Arun Devaraj (Pacific Northwest National Laboratory)

Presenter

Arun Devaraj, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that a unique and attractive mix of equipment and expertise has been established in this effort. The approach builds on the successful model built on the PMCP from VTO.

Reviewer 2:

The project supports the other tasks of Al sheet, castings, and Mg corrosion by conducting modeling, characterization, and testing. The reviewer commented that there is good planning on experiments and models and. also life-cycle analysis (LCA) efforts on light metals.

Reviewer 3:

This project is a cross-cut thrust, so the reviewer found it to be quite broad as it includes characterization, modeling, and lifecycle. The project clearly identified barriers in light metals research and application. Compared with characterization and modeling, material lifecycle has a much smaller effort, which should be strengthened.

Reviewer 4:

According to the reviewer, the approach is a series of decoupled research projects. Each project has independent basic research value.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The effort is a new start, and the reviewer indicated that the initial progress is already excellent. More attractive results are expected in the future.

Reviewer 2:

The reviewer stated that enough effort has been spent on the planning as the project is just starting. Materials have been obtained, and modeling efforts have begun.

Reviewer 3:

Both characterization and modeling projects are showing good progress. It was not very clear to the reviewer how the lifecycle research will contribute to increased recycling or increased use of secondary alloys in the automotive industry.

Reviewer 4:

The reviewer found no progress to date after two quarters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that most of the research in this thrust is to support projects in the other three thrusts, reflecting excellent collaboration with other project teams.

Reviewer 2:

The collaboration and co-ordination across the national laboratory team (three national laboratories) were very impressive to this reviewer.

Reviewer 3:

Internal collaboration within the teams and labs is good; planning on meetings and interactions are satisfactory. The reviewer suggested that having an industrial panel to advise will be good.

Reviewer 4:

The projects do not include collaboration, which would require coordination across a project team. According to the reviewer, each project is a separate research 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Proposed future research includes a second call for proposals. The reviewer asserted that residual stress analysis and materials lifecycle analysis are all very well thought out.

Reviewer 2:

The research is in response to other teams’ products; planning is difficult, but the reviewer said that it is managed well.

Reviewer 3:

The reviewer felt that this thrust should be open to universities and other labs with expertise in the needed areas, such as process modeling, microstructure and defect simulation, and recycling research.

Reviewer 4:

According to the reviewer, the research proposed does not include decision points, barriers, and risk assessment.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Light metals are very important materials for vehicle lightweighting. According to the reviewer, this program will provide fundamental support to research and applications of light metals.

Reviewer 2:

The reviewer asserted that the understanding of the material performance will enable the development of new materials and processes. This will help reduce the cost and improve the use of light metals in vehicles.

Reviewer 3:

The reviewer said that the project is set up to be impactful through the LMCP and directly benefits the EERE VTO mission.

Reviewer 4:

The reviewer stated that each research topic is relevant to the DOE 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 personally felt that this is the area where the national laboratories are best equipped to support the automotive industry in modeling, characterization, and recycling research, which will have long-term impacts on the automotive and light metals industries.

Reviewer 2:

The reviewer found that the funding is sufficient for the work identified.

Reviewer 3:

Resources are sufficient, according to the reviewer.

Reviewer 4:

The reviewer said that 42 people are working on the project.

Acronyms and Abbreviations

°C	Degrees Celsius
μm	Micrometer
3-D	Three-dimensional
ACMZ	Aluminum-copper-manganese-zirconium
AD	Additive manufacturing
AFA	Alumina-forming austentitic
AFRL	Air Force Research Laboratory
AI	Artificial intelligence
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
AM	Additive manufacturing
AMIPC	Advanced Materials Intelligent Processing Center
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APS	Advanced Photon Source
APT	Atomic probe tomography
ARPA-E	Advanced Research Projects Agency-Energy
ASTM	American Society for Testing and Materials
$BaTiO_3$	Barium titanate
BCC	Body-centered cubic
BMS	Battery management system
BOTTLE™	Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment
C	Carbon
CALPHAD	CALculation of PHAase Diagram
CCT	Continuous cooling transformation
Ce	Cerium
CEM	Composite epoxy material
CF	Carbon fiber
CFD	Computational fluid dynamics
CFRC	Carbon fiber reinforced composite

CFRP	Carbon fiber reinforced polymer
CFTF	Carbon Fiber Technology Facility
CGS	Compressed gas storage
CNC	Computer numerical control
CNG	Compressed natural gas
CNMS	Center for Nanophase Materials Sciences
CNT	Carbon nanontube
COVID-19	Coronavirus disease 2019
Cr	Chromium
CRADA	Cooperative research and development agreement
Cu	Copper
DFT	Density function theory
DIC	Digital image correlation
DICTRA	DIffusion-Controlled TRAnsformations in multi-component systems, a software diffusion module within Thermo-Calc for accurate simulation of diffusion-controlled reactions in multi-component alloy systems
DIW	Direct ink writing
DOE	U.S. Department of Energy
EBSD	Electron backscatter diffraction
EERE	Energy Efficiency and Renewable Energy
EM	Electromagnetic
EMI	Electromagnetic interference
EMSL	Environmental Molecular Sciences Laboratory
EV	Electric vehicle
FCA	Fiat-Chrysler Automobiles
Fe	Iron
FEA	Finite element analysis
FEM	Finite element method
FSLW	Friction-stir linear welding
FSP	Friction-stir processing
F-SPR	Friction self-piercing rivet
FSW	Friction-stir weld(ing)

g	Gram
GF	Glass fiber
GHG	Greenhouse gas
GM	General Motors
GVSC	Ground Vehicles Systems Center
HFR	High-rate friction rivet
HIP	Hot isostatic pressing
HPC	High-performance computing
HPDC	High-pressure die casting
HT	High temperature
HTC	High-temperature carbonization
HVR	High-velocity rivet
IACMI	Institute for Advanced Composites Manufacturing Innovation
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
ILSS	Interlaminar shear strength
INL	Idaho National Laboratory
JCP	Joining Core Program
kg	Kilogram
k_p	Parabolic rate constant
kPa	Kilopascal
LCA	Life-cycle analysis
LIG	Laser-induced graphene
LightMAT	Lightweight Materials Consortium
LLNL	Lawrence Livermore National Laboratory
LPBF	Laser powder bed fusion
LTC	Low-temperature carbonization
m	Meter
M/O	Metal and oxide
MAS	Micro-alloyed steel
MAT	Materials Technology Program
MD	Molecular dynamics

MDF	Manufacturing Demonstration Facility
MFI	Materials Flow through Industry
Mg	Magnesium
min	Minute(s)
MIT	Massachusetts Institute of Technology
mm	Millimeter
Mn	Manganese
MOOSE	Multiphysics object oriented simulation environment
MPa	Megapascal
MSU	Michigan State University
MTT	Materials Technical Team
NDE	Non-destructive evaluation
NETL	National Energy Technology Laboratory
Ni	Nickel
nm	Nanometer
NREL	National Renewable Energy Laboratory
O	Oxygen
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PACE	Partnership for Advanced Combustion Engines
PAN	Polyacrylonitrile
PAPSC	Pressure-assisted precision sand casting
PE	Polyethylene
PEEK	Polyetheretherketone
PEKK	Polyetherketoneketone
PET	Polyethylene terephthalate
PI	Principal Investigator
PMCP	Powertrain Materials Core Program
PNNL	Pacific Northwest National Laboratory
PP	Polypropylene
PPS	Passenger protection system
PVDF	Polyvinylidene fluoride

Q	Quarter
R&D	Research and development
RASIC	Responsible, Approving, Supporting, Informed, and Consulted
ReaxFF	Reactive force field
ReaxFFMD	Reactive force field molecular dynamics
REE	Rare earth element
RF	Radiofrequency
RSW	Resistance spot weld
RTM	Resin transfer molding
s	Second(s)
SBIR	Small Business Innovation Research
ShAPE™	Shear Assisted Processing and Extrusion
SHM	Simple harmonic motion
SOA	State of the art
SPI	Stochastic pre-ignition
SPR	Self-piercing rivet
Sr	Strontium
SSL	Self-supervised learning
SStAC	Stainless steel alloy corrosion
STEM	Scanning transmission electron microscopy
SURF	Scale-Up Research Facility
T	Temperatue
TEA	Techno-economic analysis
TEM	Transmission electron microscopy
TFP	Tailored fiber placement
Tg	Glass transition temperature
Ti	Titanium
TiAl	Titanium aluminide (gamma titanium)
TMF	Thermochemical fatigue
TMP	Thermo-mechanical processing
TRL	Technology Readiness Level
TuFF	Tailorable universal feedstock for forming

U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UCLA	University of California at Los Angeles
USAMP	U.S. Automotive Materials Partnership
USC	University of Southern California
USW	Ultrasonic spot welding
UTK	University of Tennessee-Knoxville
UTS	Ultimate tensile strength
VTO	Vehicle Technologies Office
WPI	Worcester Polytechnic Institute
wt.%	Weight percent
XCT	X-ray Computed Technology
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
Y	Yttrium
YS	Yield strength
Zn	Zinc
Zr	Zirconium

7. Technology Integration

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Technology Integration (TI) subprogram covers a broad technology portfolio that includes alternative fuels (e.g., advanced biofuels, electricity, hydrogen, renewable natural gas) and energy efficient mobility systems. The successful deployment of these technologies can support the decarbonization of the transportation sector, strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, address the needs of underrepresented communities, and support energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations. At the national level, the Technology Integration Program offers technical assistance, information resources, online training, and an array of data and analysis tools. At the local level, Clean Cites coalitions leverage these resources to create networks of community stakeholders and provide hands-on technical assistance to fleets.

The Technical Assistance activities support projects to provide information, insight, online tools, and technology assistance to cities and regions working to implement alternative fuels and energy efficient mobility technologies and systems. Projects will; demonstrate proof-of-concept of alternative fuel/advanced technology vehicles, charging infrastructure, new mobility systems for goods and people movement and modeling and simulation.

The Data Collection and Dissemination activity will collect and provide objective, unbiased data, information, and real-world lessons learned to inform future research needs and provide fleets and local decision makers with a suite of resources to identify and address technology barriers. This includes projects to disseminate data, information, and insights.

The EcoCar Mobility Challenge challenges 12 university teams to apply advanced powertrain systems, as well as connected and automated vehicle technology to improve efficiency, safety, and consumer appeal. In FY 2022, student teams will complete and implement their vehicle design through hardware development and engineering.

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	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
ti106	Natural Gas Vehicle (NGV) UP TIME Analysis: Updated Performance Tracking Integrating Maintenance Expenses	Megan Stein (Clean Fuels Ohio)	7-5	4.00	3.50	3.25	4.00	3.25	3.53
ti107	Next Generation Natural Gas Vehicle Drive Information Systems	Devin Halliday (Gas Technology Institute)	7-9	4.00	3.75	3.25	4.00	3.5	3.60
ti108	Smart Compressed Natural Gas (CNG) Station Deployment	Jason Stair (Gas Technology Institute)	7-12	3.75	3.75	2.75	2.50	2.5	3.10
ti109	Carolina Alternative Fuel Infrastructure for Storm Resilience Plan	David Doctor (E4 Carolinas, Inc.)	7-15	3.75	3.25	3.25	3.75	3.75	3.45
ti110	Statewide Alternative Fuel Resiliency Plan	Sean White (Florida Department of Agriculture and Consumer Services)	7-18	3.50	3.50	3.75	3.50	3.5	3.60
ti111	Integration of Smart Ride-Sharing into an Existing Electric Vehicle Carsharing Service in the San Joaquin Valley	Caroline Rodier (University of California-Davis)	7-21	2.50	2.60	2.50	3.00	2.3	2.55
ti112	The Clean Rural Shared Electric Mobility Project	Kelly Yearick (Forth)	7-26	3.30	3.10	3.10	3.50	3.2	3.19

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
ti113	Holistic and Energy-Efficient Rural County Mobility Platform (RAMP)	Sean Qian (Carnegie Mellon University)	7-31	3.20	3.10	2.50	2.90	2.80	2.83
ti114	Rural Open Access Development Mobility Action Plan	Sarah Conley-Ballew (Rural Action, Inc.)	7-36	3.20	2.80	3.10	3.20	3.10	3.07
ti115	Electric First/Last Mile On-Demand Shuttle Service for Rural Communities in Central Texas	Elizabeth Munger (Lone Star Clean Fuels Alliance)	7-41	3.13	3.13	3.38	3.50	3.38	3.29
ti116	East Zion National Park Electric Vehicle Shuttle System	Tammie Bostick (Utah Clean Cities Coalition)	7-45	3.33	3.50	3.00	3.33	3.33	3.23
ti117	Electrifying Terminal Trucks in Unincentivized Markets	Kelly Gilbert (Metropolitan Energy Center)	7-48	3.50	3.50	3.67	3.17	3.33	3.52
ti118	Heavy Duty EV Demonstrations for Freight and Mobility Solutions	Megan Stein (Clean Fuels Ohio)	7-50	3.50	3.33	3.50	3.33	3.00	3.40
ti119	Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions	Brian Roy (Akimeka, LLC)	7-52	3.50	3.33	2.83	3.33	2.83	3.12
ti120	Mid-Atlantic Electric School Bus Experience Project	Alleyn Harned (Virginia Clean Cities at James Madison University)	7-55	3.50	3.00	2.83	3.33	3.16	3.08
ti121	Medium and Heavy-Duty Electric Vehicle Deployment's Data Collection	Jasna Tomic (Calstart, Inc.)	7-58	3.50	3.50	3.50	3.75	3.25	3.50

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Objectives	Approach	Accomplish-ments	Collaborations	Overall Impact	Weighted Average
ti122	Supporting Electric Vehicle Infrastructure Deployment Along Rural Corridors in the Intermountain West	Tammie Bostick (Utah Clean Cities)	7-60	3.83	3.83	3.50	3.67	3.50	3.65
ti123	Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility	Megan Stein (Clean Fuels Ohio)	7-63	3.67	3.33	3.33	3.67	3.00	3.40
ti124	Developing an Electrified Vehicle Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region	Pingen Chen (Tennessee Tech University)	7-65	3.50	3.33	3.33	3.33	3.50	3.38
ti125	EcoCar Mobility Challenge	Kristen Wahl (ANL)	7-68	4.00	3.83	3.83	3.83	4.00	3.88
Overall Average				**3.51**	**3.35**	**3.21**	**3.43**	**3.21**	**3.32**

Presentation Number: ti106
Presentation Title: Natural Gas Vehicle (NGV) UP TIME Analysis: Updated Performance Tracking Integrating Maintenance Expenses
Principal Investigator: Megan Stein (Clean Fuels Ohio)

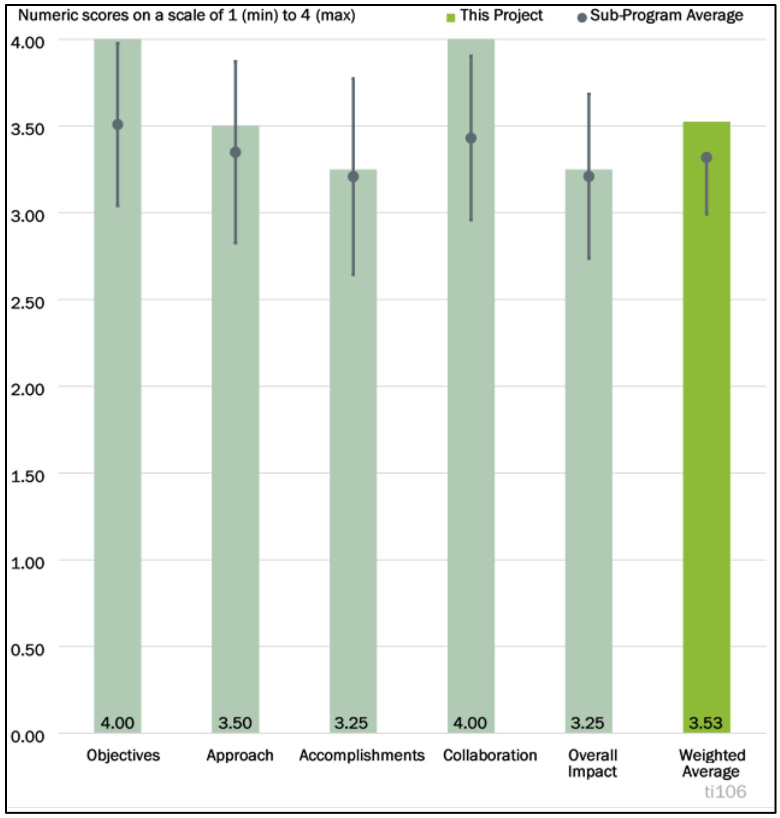


Figure 7-1 - Presentation Number: ti106 Presentation Title: Natural Gas Vehicle (NGV) UP TIME Analysis: Updated Performance Tracking Integrating Maintenance Expenses Principal Investigator: Megan Stein (Clean Fuels Ohio)

Presenter

Megan Stein, Clean Fuels Ohio

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that this project has the potential to increase the use of not only natural gas vehicles (NGVs) but also other alternative fuel vehicles (AFVs) by documenting the maintenance costs of diesel vehicles, which would allow fleets to better understand how AFVs compare to modern diesel freight trucks. Specifically, by documenting NGV maintenance data, this will provide greater confidence to fleets without NGVs to adopt a new technology if the project shows favorable costs for those vehicles. In addition, this project could help the NGV industry by documenting best practices to lower maintenance and improve reliability.

Reviewer 2:

According to the reviewer, this project strongly supports Vehicle Technologies Office (VTO) objectives by ensuring that fleets have up-to-date information on the real cost of maintenance and repair costs of natural gas trucks in comparison to similar diesel vehicles. The lack of data on this issue and perceptions based on earlier generation vehicles are barriers to the use of more AFVs powered by natural gas so this project is important to overcoming barriers and helping fleets select fuels that will save them money.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

This reviewer indicated that the project is well designed in first securing fleet partners and setting up the data collection procedures. It is beneficial that the project is securing initial fleet partners for data collection and then continuing to add others as the project progresses. Fleets will be able to provide data even if they sign up later in the project. The major challenge that the reviewer saw as limiting is that of time for cleaning up and analyzing data prior to the end of the project.

The use of Vehicle Maintenance Reporting Standards (VMRS) data tracking will allow for a certain amount of data standardization, which will make the analysis easier and the results more robust. It is very useful that DOE, national laboratories, and universities will be given access to the anonymized dataset at the end of the project.

Reviewer 2:

The approach seemed right to the reviewer by trying to ensure that extracting data is as easy as possible and consistent with the data collection and reporting procedures used by major fleets.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer asserted that the most important part of the project is to have data-sharing agreements with freight NGV and diesel fleets. This project has been successful in securing those agreements, likely due to the connections of the strong Clean Cities coalition partners in the project. The reviewer remarked that it is useful that the project is looking to gather additional data from other fleets, even after securing the initial agreements to get as wide of a range of fleets as possible (e.g., duty-cycle, geography, and fleet size). Hopefully, the project can secure the agreements that are “in progress” but not finalized.

One challenge identified by this reviewer is the project has is to collect data from small fleets not utilizing VMRS data tracking as it will make data clean up, analysis, and comparison difficult. However, the project team should still work to collect small fleet data as the American Transportation Research Institute (ATRI) summary cost analysis shows that fleet size does impact costs. If the project can use the sample maintenance data forms, that would be useful if the smaller fleets are willing to submit data in that manner. However, the reviewer suggested that it might be useful to minimize the burden on the small fleets and obtain raw maintenance data if the fleets are willing to provide it. While it might be difficult for the project to clean up and anonymize all these data, the reviewer said that it could still be useful data for further analysis done by DOE.

Reviewer 2:

Although it is difficult to get fleets to share data, good effort was apparent to this reviewer. It could be better if more fleets had been signed up or confirmed to date, but the reviewer realized that this is a difficult effort.

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 opined that the Clean Cities coalition's ability to identify project partners and secure agreements is paramount to the project's success. Having 6 fleets with 2,736 vehicles secured is definitely a great start to the project.

Additionally, the reviewer stated that the project has a strong technical team for data collection and analysis, as well as an excellent Project Advisory Committee. In particular, Energetics is currently working on another DOE project collecting data that the reviewer was familiar with so that should be beneficial to the data collection, cleaning, and analysis portions of the project.

Reviewer 2:

Based on the presentation, it appeared to this reviewer that the project teams are collaborating with appropriate stakeholders and industry players.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the project has a very good approach and looks to be on track for success with it securing a significant number of fleets and vehicles. The project team is very strong and has a track record of success. The reviewer hoped that the data collection process will be smooth as that will be crucial to the project and will not begin until the latter parts of Budget Period (BP) 2. The concern would be that the pandemic will have impacted either the willingness of the project partners to participate or impacted operations that make the most recent data less applicable. Hopefully, as the project is collecting maintenance records, the project team will be able to navigate any pandemic-related operational data concerns. Additionally, this reviewer suggested that it would be beneficial if the project can continue to add fleets to make sure the dataset has a wide range of geographies, duty cycles, and fleet size.

Reviewer 2:

The reviewer found it difficult to answer this question because the results really will not be evident until the project is complete and best practices are revealed.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer believed that this project is wisely using DOE resources, as this type of public data collection would be very difficult (if not impossible) without the funding and backing of a government agency. Currently, there is not a public dataset of maintenance costs for diesel freight trucks, not to mention any AFVs. As diesel truck maintenance costs have become an important anecdotal talking point about the benefits of AFVs, it is great that the DOE is using its resources to collect, analyze, and publish findings on this topic. DOE should fund similar projects in the future, leveraging its resources and credibility to collect real-world data that will help the AFV industry document its costs and benefits. Fleets that are interested in AFVs, but hesitant because cost information is not available from unbiased sources, will definitely benefit from these types of projects.

Reviewer 2:

The reviewer responded absolutely, and added that technology fortunately continues to evolve and that means these types of reports or studies are necessary on a continuing basis. Also, as new technology remains in the field for longer time periods, it is important to understand how costs are impacted by aging of technology.

Presentation Number: ti107
Presentation Title: Next Generation Natural Gas Vehicle Drive Information Systems
Principal Investigator: Devin Halliday (Gas Technology Institute)

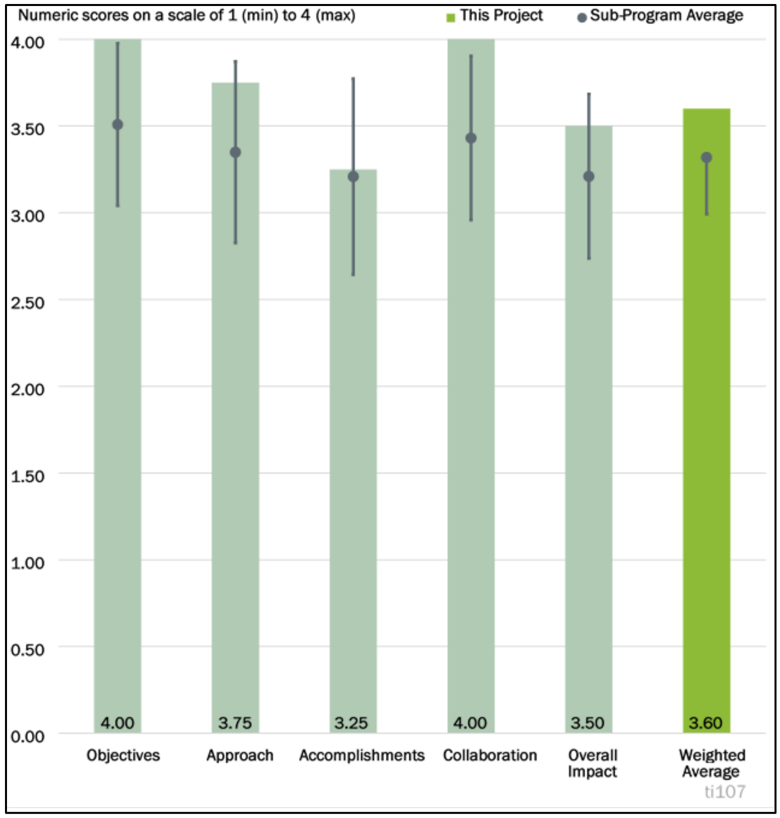


Figure 7-2 - Presentation Number: ti107 Presentation Title: Next Generation Natural Gas Vehicle Drive Information Systems Principal Investigator: Devin Halliday (Gas Technology Institute)

Presenter

Devin Halliday, Gas Technology Institute

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer noted that this project addresses an important obstacle to natural gas use—range anxiety—which also impacts the use and cost of NGVs. By focusing on information monitoring to determine more accurately how much fuel is onboard, this technology will help address concerns about using NGVs and could allow vehicles to be equipped with smaller fuel systems, saving money upfront, and improving vehicle efficiency and operational costs.

Reviewer 2:

The reviewer remarked that the project addresses the very specific concern of range anxiety by attempting to provide accurate gaseous fuel level and range information to users of NGVs. Successfully completing this project will allow users to specify vehicles properly, reduce the number of fueling stops, and operate them with confidence.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer indicated that the project approach is a cost-effective, common-sense solution with universal applications. Making a modular, easily installed sensor and recording array will allow users to analyze their fuel use by accurately predicting range and fuel economy. This will remove a large barrier to adoption of gaseous fuels and encourage other fleets and end users to follow suit.

Reviewer 2:

The reviewer observed a very solid approach to developing a technology solution. There are some questions about cost and the ability to scale up, but those should not be significant barriers if technology proves to be accurate and deployable.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer reported that the project has achieved its goal of developing and installing test units and is on schedule to build and install more units. The data are being generated and analyzed and have shown the potential of such a system to remove barriers to the adoption of gaseous fuels.

Reviewer 2:

According to the reviewer, the presenter stated that installations are running behind and the project is 20% complete.

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 team looked strong to the reviewer, and the application (cement trucks) is probably an excellent environment to test these systems as they will need to be robust to survive in their duty environment.

Reviewer 2:

The reviewer observed that the project partners were chosen wisely to maximize their contributions to the overall project. Each partner has a vital role to play, and the workload and expertise are divided equally among the partners so no one partner is carrying the bulk of the load. Collaboration and cooperation among the partners are evident.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer called the overall impact of this project clearly promising. Measuring units have been built, tested, and installed. They are not only providing valuable data for current users, but also showing excellent potential for providing an effective solution for this particular problem. The importance of having accurate fuel usage data was clearly explained in the presentation, and the solution developed and achieved by the project partners will have an immediate and universal positive effect on the adoption and use of alternative fuels.

Reviewer 2:

Preliminary results of a single system demonstrated to the reviewer that the technology is promising and can achieve targets results for measurement and accuracy.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer indicated that this project has made appropriate use of its resources, has been cost conscious in the development of the testing prototypes, and has smartly developed a universal, modular system that can be easily installed in a variety of vehicles at a reasonable cost.

Reviewer 2:

The reviewer remarked that the project seems, to some extent, like a one-off type of project. If the technology proves feasible, then it should be deployed by manufacturers who can address cost, scaling, and other manufacturing issues.

Presentation Number: ti108
Presentation Title: Smart Compressed Natural Gas (CNG) Station Deployment
Principal Investigator: Jason Stair (Gas Technology Institute)

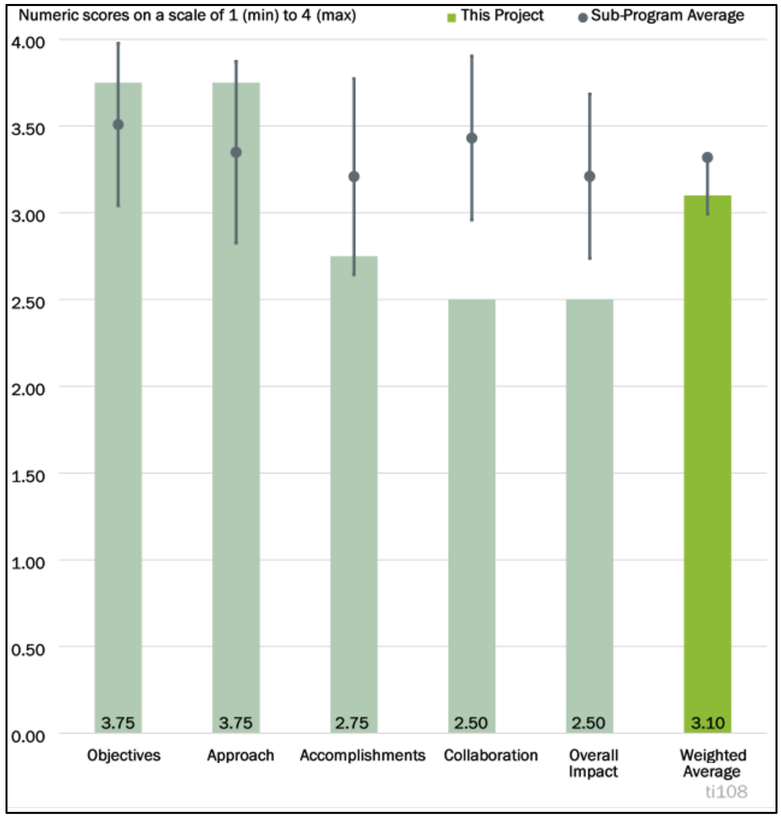


Figure 7-3 - Presentation Number: ti108 Presentation Title: Smart Compressed Natural Gas (CNG) Station Deployment Principal Investigator: Jason Stair (Gas Technology Institute)

Presenter

Jason Stair, Gas Technology Institute

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

50% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 50% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project addresses an important barrier to the greater use of natural gas. The reviewer indicated that this is a very targeted approach to overcoming one of the key barriers for NGVs, which is high upfront costs, and which could be better addressed if fleets were sure that they were getting a full fill on trucks.

Reviewer 2:

The cost of compressed natural gas (CNG) tanks is the major incremental cost for NGVs. For several reasons that include thermodynamics, station design, station and cylinder sensors, and communication, tanks may not fill completely. Therefore, not being able to use the entire amount of the tank volume leads to less range and can require the purchase of larger tank packages. The reviewer opined that the project objective of quantifying the amount of underfilling at existing stations and developing a cost-effective system to address this would be beneficial for the deployment of NGVs to address these issues. If fills could provide 25% more fuel consistently, that would have a large impact on CNG vehicles; however, if the amount is around 10%, then there would still be a benefit that would likely help with range, rather than allowing for less tank volume.

The presenter mentioned the impact on safety of CNG, and while not highlighted as much, the problem of overfilling comes to mind. The reviewer would assume that is going to be addressed by the equipment as well, but in further presentations it would be useful to further highlight the potential safety benefits.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

Developing technology for stations and vehicles so there is simultaneous communication is critical to ensuring full fill and addresses safety issues.

Reviewer 2:

The project is well designed to first develop the data acquisition systems and deploy them for testing, although the reviewer was a bit surprised that there were not "off-the-shelf" data acquisition systems the team could have used. The reviewer explained that it will be crucial to understand the amount of underfilling based on different conditions and parameters (vehicle, station, weather, etc.); so, first testing in a controlled fashion at the Gas Technology Institute (GTI) test site and then deploying them at multiple sites is a good strategy.

The reviewer suggested that it makes sense to speak with the codes and standards committees as soon as possible and potentially reach out to NGV organizations to make sure that the algorithm and software are going to be allowed.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

This reviewer stated that systems developed, initial deployment underway, and data collection confirm the need for this technology.

Reviewer 2:

While somewhat understandable due to the pandemic, the reviewer noted that the project is behind schedule and is only about 20% complete in month 17 (April 2021) of a 39-month project. The dual data acquisition system development, while not efficient, ultimately seemed to work out as one of the options would not work. However, it seems the project timing would have been improved if the bandwidth issues had been addressed before getting too far along. The challenge of not being able to use third-generation (3G) technology and having to upgrade to fourth-generation (4G) technology looks to be another setback. The presenter said that the project has been doing better in the past few months and is reaching completion of all the milestones in BP 1. If DOE decides to continue the project after the go/no-go point, hopefully the project will continue to go more smoothly, but it will be necessary for DOE to pay close attention to project challenges and see how to resolve them quickly.

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 called the project team strong. GTI is uniquely positioned to lead the effort, to test systems at its own facilities, and to use its knowledge of the key industry players.

Reviewer 2:

As the project has been delayed, it was a bit difficult for the reviewer to rate the project in this category. However, it looks like the team has challenges with two of the three partners—a new dispenser manufacturer looks to be needed to replace Kraus Global, and Clean Energy may now not want to put the equipment on their public sites and will negotiate after a dispenser partner is finalized. Hopefully, Ozinga will continue to be a strong GTI partner, and the project can use both their vehicles and stations.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer stated that it is still early in the project, but initial data indicate that this is very worthwhile effort.

Reviewer 2:

The project objectives, approach, and team (both Principal Investigator [PI] and initial partners) are all strong, but the actual implementation of the project has seen delays and loss of a partner (Kraus Global) and a second partner (Clean Energy) looks to be questioning its involvement. If the project is successful, the reviewer commented that it will definitely have potential.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The targeted funding in this project addressing a very specific issue that could have immediate impact in next 2–3 years, so the reviewer thought that this is very worthwhile and could end up as very economical solution for fleets deploying NGVs.

Reviewer 2:

The reviewer thought that this is a worthwhile project to meet DOE and VTO objectives of increasing fuel diversity through the use of alternative fuels. The GTI team has great experience in this area, and the reviewer saw why this project was selected. However, the project implementation has had significant delays and with the potential loss of two project partners, project success is in jeopardy. It is possible that if a new dispenser partner is secured, then the project can move forward, but it should be scrutinized heavily at the go/no-go decision point as that is a major concern. The loss of Clean Energy would also limit the ability of the project to test and collect data based on the initial plans of the project. It is possible that Ozinga's stations could provide sufficient data for the project, although it is unclear if Ozinga would agree to that.

While this project may not ultimately be a success, the reviewer opined that DOE should still fund projects in this vein of supporting technology development on refueling infrastructure as it is a key barrier for alternative fuels like natural gas, hydrogen, and electricity.

Presentation Number: ti109
Presentation Title: Carolina Alternative Fuel Infrastructure for Storm Resilience Plan
Principal Investigator: David Doctor (E4 Carolinas, Inc.)

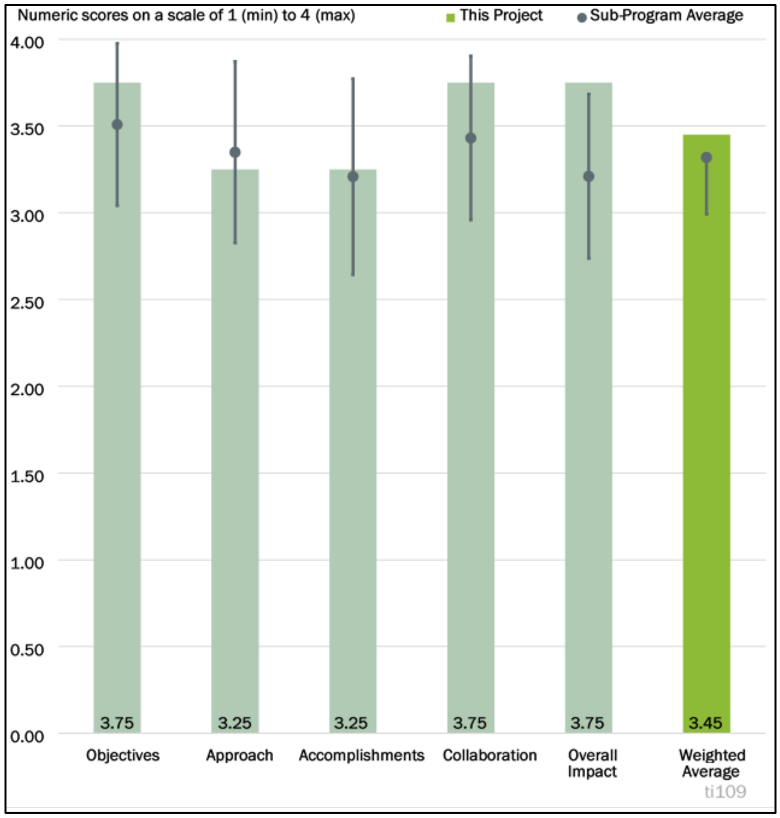


Figure 7-4 - Presentation Number: ti109 Presentation Title: Carolina Alternative Fuel Infrastructure for Storm Resilience Plan Principal Investigator: David Doctor (E4 Carolinas, Inc.)

Presenter

David Doctor, E4 Carolinas, Inc.

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer stated that the presenter provided a very clear description of the project plan to achieve its goals and how the project team will convene stakeholders to achieve their goals.

Reviewer 2:

According to the reviewer, the availability and use of alternative fuels and power sources in times of emergency, natural disasters, and the like have proven to be very beneficial. Assessing the readiness of any given area, creating a workable plan, and educating first responders, officials, and the general public on the use and benefits of alternative fuels in these situations have tremendous value in expanding their adoption and have tremendous potential to save lives and property in times of great need.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

Considering coronavirus disease 2019 (COVID-19) restrictions, the reviewer commented that the project appears to be on track. The team is taking a very detailed approach, and it appears all milestones were completed. There are a great number of organizations (15–20) working together on complex deliverables, including surveys for creating an inventory. All milestones for BP 2 appear to be on track so far. It is the project team’s expectations that the full resiliency plan will be drafted by the end of this year. Also, the plan for BP 3 looked realistic to the reviewer. Climate change is being considered using third-party sources like the

National Oceanic and Atmospheric Administration (NOAA), and the team is aware of the serious challenges facing the region due to increased storm frequency.

Reviewer 2:

The reviewer indicated that this project is well aligned with other efforts, is looking at other parts of the country, and is learning from its successes and shortcomings. The reviewer indicated that the team is taking a measured, systematic approach to assessing the project area's current situation by identifying needs and working on a solid plan to maximize the availability and use of alternative fuels in emergency situations.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer stated that the project team is taking an adaptive approach to reflect information as it is being learned. There is a good focus on water and flooding impacts. Climate change is being considered using third-party sources like NOAA, and the reviewer said that the team is aware of the serious challenges facing the region due to increased storm frequency.

Reviewer 2:

According to the reviewer, the inventory phase of the project was completed in 2020, and the draft plan is due to be completed in August 2021, with assessment and implementation to follow. Like many other projects, COVID-19 closures caused delays in certain practical aspects, but the team has worked to overcome these obstacles through virtual methods of interaction and remains on track to accomplish the project objectives in a timely fashion.

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 found the collaboration and cooperation among the project members to be outstanding. Four working subtask groups were created, with each tackling a piece of the assessment and draft plan. Partners have a breadth of experience and areas of expertise, and the workload has been distributed evenly.

Reviewer 2:

The reviewer noted this is a very hard project requiring coordination across a large number of groups. The project team appeared to be bringing the right people together and making progress according to their plan.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

Planning for resilience is critically important as climate impacts are felt more frequently and severely. The reviewer commented that it is essential that projects like this one succeed in influencing disaster preparedness and infrastructure investments.

Reviewer 2:

The reviewer stated that the project has already contributed to the knowledge database of how AFVs are being used by first responders, utility companies, and government agencies and where infrastructure is currently deployed and available along evacuation routes. The reviewer opined that the planning, assessment, and deployment phases will have a valuable and lasting impact on the readiness and resiliency of the Carolinas to deal with emergency and storm situations.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

According to the reviewer, this project has made smart use of its resources, has shown the flexibility and organization to overcome obstacles, and is contributing valuable information and action plans to the emergency preparedness knowledge base for the project area and other parts of the country.

Reviewer 2:

The reviewer asserted that DOE should consider focusing future projects on investment decisions, particularly around infrastructure as regions adapt to climate change.

Presentation Number: ti110
Presentation Title: Statewide Alternative Fuel Resiliency Plan
Principal Investigator: Sean White (Florida Department of Agriculture and Consumer Services)

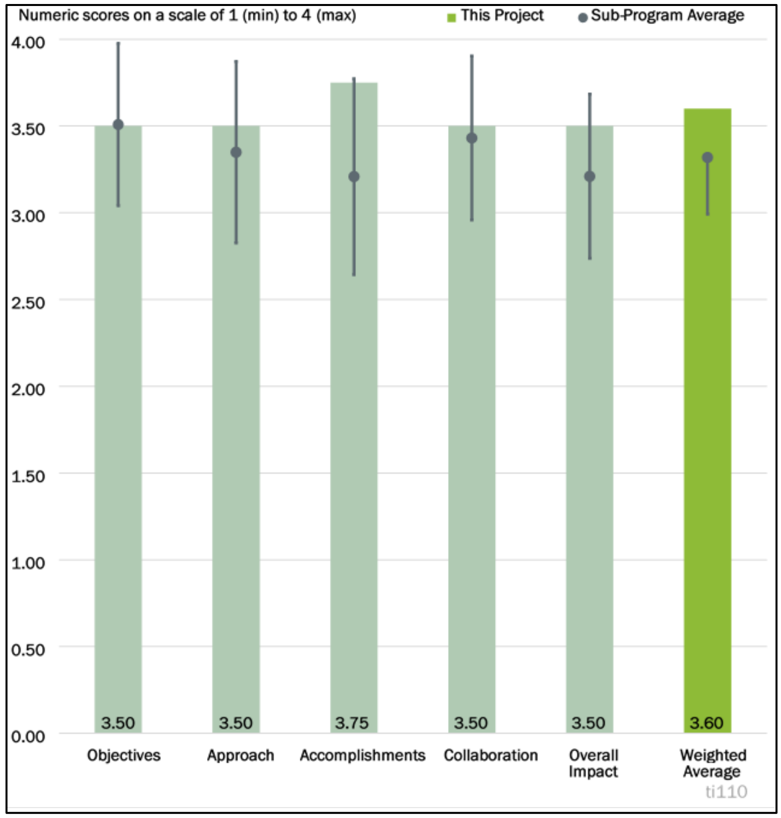


Figure 7-5 - Presentation Number: ti110 Presentation Title: Statewide Alternative Fuel Resiliency Plan Principal Investigator: Sean White (Florida Department of Agriculture and Consumer Services)

Presenter

Sean White, Florida Department of Agriculture and Consumer Services

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

According to the reviewer, the availability and use of alternative fuels and power sources in times of emergency, natural disasters, and the like have proven to be very beneficial. Assessing the readiness of any given area, creating a workable plan, and educating first responders, officials and the general public on the use and benefits of alternative fuels in these situations have tremendous value in expanding their adoption and have tremendous potential to save lives and property in times of great need.

Reviewer 2:

The reviewer remarked that the project has a solid, broad objective that captures many aspects of resiliency. The reviewer also observed that no environmental benefit was included in the project.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer asserted that the project approach is systematic and comprehensive because it is gathering and assessing data from numerous sources and providing concrete, actionable plans and best practices for Florida and other areas to follow in preparing for, and responding to natural and man-made disasters.

Reviewer 2:

The reviewer commented that the project is taking a thoughtful approach that includes data collection, plan development, and the sharing of best practices. It is good to see that the plan is to be implemented statewide. Understandable delays from COVID-19 restrictions caused delays in BP 1 but do not appear to affect the overall project timeline.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Considering delays due to COVID-19 restrictions, the reviewer indicated that the project has made excellent progress. The electric vehicle (EV) roadmap is an important report on ensuring that Floridians can purchase and operate EVs.

Reviewer 2:

The project has accomplished about 25% of its goals and is on schedule to meet the intended timeline for completion of all tasks. The reviewer stated that valuable information on state of readiness and best practices has already been produced via the Florida EV Roadmap and Resilient Florida Buildings brochure, along with site visits and stakeholder workshops.

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 remarked that it is good to see the project expanding stakeholder engagement with a group focused on corridors.

Reviewer 2:

The reviewer found that collaboration and cooperation among the project team have been excellent. Each partner adds to the diversity of knowledge and experience on the team, and the workload has been evenly divided among the members.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer stated that Florida is a critically important state related to climate change, and it is essential that the state builds a resilient infrastructure that enables consumers to purchase and operate EVs without concern as extreme weather events occur more frequently in the near future. The reviewer observed that this project will hopefully help inform these investments.

Reviewer 2:

The reviewer commented that this project should make a tremendous impact for Florida and other areas, not only in education about the benefits of fuel diversity, but also in practical planning for responding to natural and man-made disasters.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer indicated that this project has made excellent use of its resources and has already delivered valuable tools and best practices information that can benefit first responders, municipalities, and utility companies immediately.

Reviewer 2:

The reviewer asserted that DOE should consider making sure that environmental benefits and infrastructure investments are core parts of future resiliency projects.

Presentation Number: ti111
Presentation Title: Integration of Smart Ride-Sharing into an Existing Electric Vehicle Carsharing Service in the San Joaquin Valley
Principal Investigator: Caroline Rodier (University of California-Davis)

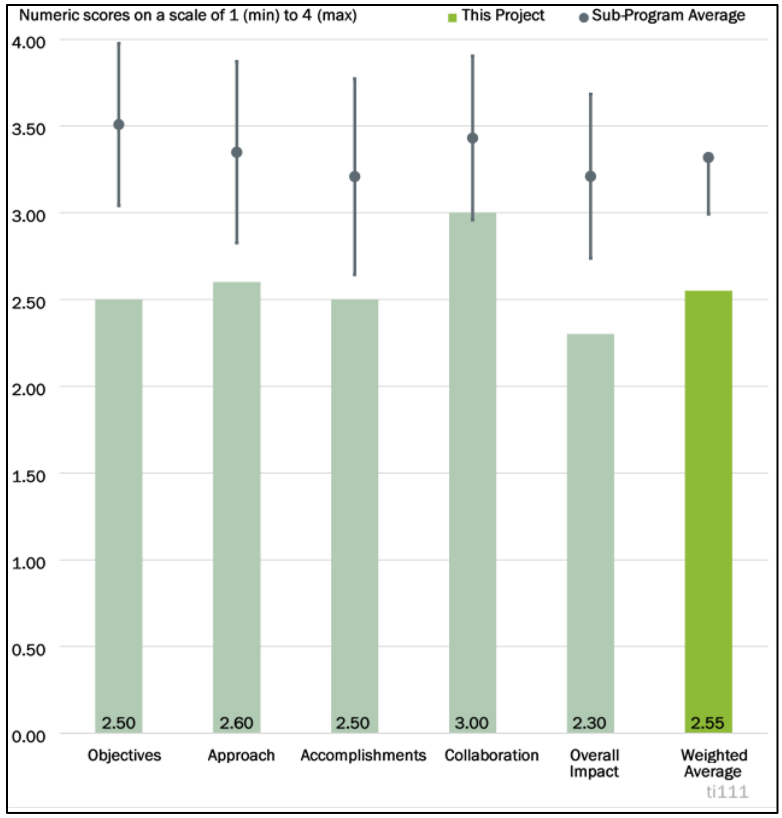


Figure 7-6 - Presentation Number: ti111 Presentation Title: Integration of Smart Ride-Sharing into an Existing Electric Vehicle Carsharing Service in the San Joaquin Valley Principal Investigator: Caroline Rodier (University of California-Davis)

Presenter

Caroline Rodier, University of California-Davis

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 0% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer indicated that partners Miocar (e-carshare) and Mioride (e-rideshare) already promote AFVs in the area. Assisting a disadvantaged population by allowing volunteers to transport them via Miocar EVs to appointments and errands will contribute a small amount to fuel diversity (a VTO objective). The reviewer stated that the success of the project is dependent on the number of riders, the number of rides, and whether a passenger would have walked or biked if not for this option (no petroleum reduction in these cases).

Reviewer 2:

This reviewer commented that the Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. The project addresses several of VTO TI goals, such as national security, fuel diversity, affordability, mobility enhancements, reliability, and resiliency, through the design and operation of a volunteer ridesharing pilot with e-carshare to fill access gaps in low-income, rural communities. Project objectives appeared to the reviewer to be generally effective for the planned scope.

Reviewer 3:

This reviewer asserted that the project's stated objectives of designing and operating a volunteer ridesharing pilot within an existing e-carshare service to fill access gaps in low-income rural communities and evaluating performance on a number of factors aligns with DOE VTO objectives of increasing fuel diversity through the use of alternative fuels (electricity) and increasing transportation efficiency (ridesharing). The degree to which this is done, however, seems limited given the fact that the e-carshare service was already in existence and the novel factor of this project is getting individuals to volunteer to provide other individuals with rides in the existing electric vehicles.

Reviewer 4:

The project is focused on low-income and rural communities, which aligns with DOE VTO goals; however, it was unclear to the reviewer how the project increases fuel diversity since it is a modification of an existing EV ridesharing program. In addition, it is unclear how the project would effectively increase transportation efficiency.

Reviewer 5:

The reviewer noted that the project addresses rural mobility barriers and the difficulties of presenting a business case for electric ridesharing services in low-income, rural areas. The use of EVs aligns with project objectives; however, the project heavily leverages an existing electric car sharing ecosystem, and the reviewer noted that the presenter was not able to elucidate how exactly this project is substantially changing the status quo for this operation nor how it would influence projects in other rural parts of the country.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer said that the project provides a sensible approach. Some tasks were delayed but are in progress now that states are opening.

Reviewer 2:

This reviewer found the Project Approach section provides a satisfactory methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The Project Approach is divided into three project periods (Development, Implementation, and Continuation and Evaluation), each containing associated tasks. Adequate detail is provided on the Approach and Milestone slides regarding the planned tasks and activities. The technical concept and project site map slides should better clarify the specific framework of the project. However, it was difficult for the reviewer to determine the hierarchy of this project in terms of how it interfaces with existing programs (i.e., the ownership and use of the vehicles and charging was unclear).

Reviewer 3:

This reviewer remarked that the market and types of trips have not been determined, and the project team is still trying to figure it out. A utility was not engaged initially in the project, but discussions have begun, which is good. Using volunteers to reduce insurance costs is a good approach as insurance can be a significant long-term cost. However, volunteer drivers are compensated with use of the vehicle, which in the long run will increase other costs. It was unclear to the reviewer who pays for the electricity, but for long-term sustainability, this cost needs to be factored in. No marketing metrics were identified to assess the success or failure of efforts. It does not appear that focus testing or surveys were performed in the initial launch period to test rider interest or desirability. It was unclear to the reviewer how volunteer and rider targets will be reached.

Reviewer 4:

The reviewer observed that project design, deliverables, and milestones lack some important details about what exactly this project is hoping to accomplish. It is clearly aligned with an existing program, but it struggles to differentiate itself from what already exists. The concept of providing ride credits for being a volunteer driver is an interesting concept and incentive for use of EV carshare vehicles. The reviewer would have liked to hear more about that element.

Reviewer 5:

The sustainability of this concept appears to be limited from the reviewer's perspective. The fact that only four volunteers have been trained and recruited as of this review indicates that the project concept may not have been well designed. The project approach does contribute to achieving some project objectives and the pandemic apparently has delayed success of the project milestones. The researcher's plans for sharing best practices or lessons learned from this project with regional transportation organizations or similar planning organizations was unclear to this reviewer.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

This reviewer asserted that much was accomplished, even with the COVID-19 delays. The project appears to be ahead of schedule in many milestones and tasks. With states opening, the reviewer opined that more volunteers and hopefully more riders would come forward.

Reviewer 2:

The reviewer noted the marketing plan and strategy tasks are well on track. The Miorides tasks are behind schedule along with rider and driver targets being unmet due to COVID-19 restrictions. The reviewer noted that the revised timelines are ambitious and will require a dedication to making volunteers and clients feel safe in the ridesharing environment post-COVID-19. Collection and analysis of data will hopefully lead to some meaningful findings.

Reviewer 3:

This reviewer indicated that satisfactory progress has been made toward achieving project goals, taking into account the unforeseen delays associated with the COVID-19 pandemic. The project has made progress on several key activities: SNAP software development and testing; rider and driver data collection and evaluation; and marketing of the Miorides program. Delays associated with COVID-19 restrictions have impacted the launch of the operational pilot, as well as limiting the number of potential pool riders (i.e., riders are concerned about sharing the ride with others).

Reviewer 4:

Although the project has some accomplishments, the lack of progress to date with executing rides was concerning to this reviewer. While some blame can be placed on the societal impact of COVID-19, individuals using this service would, in theory, need rides regardless of the state of the pandemic. The researcher describes the marketing aspect of this activity as a success; however, that seems inaccurate given that marketing has resulted in only four volunteer drivers and otherwise promoted a program that is not yet accessible to users.

Reviewer 5:

The reviewer reported that key components—finding volunteers and riders—have not been achieved. The reviewer thought that the presenter said only four volunteers have been recruited. COVID-19 restrictions impacted this; so, it is unclear if targets will be reached as the community opens back up and travel increases. The reviewer suggested that it would be good to know how the number of riders compares to the number of drivers over the previous year who utilized the primary platform (carsharing) from which this project is built;

this would have been a good comparison. This reviewer further commented that additions to SNAP and administration functionality seem beneficial.

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 commented that the project indicates an effective collaboration process, including community-based operators, planning, and research organizations.

Reviewer 2:

The reviewer asserted that this project could not have happened without the PI's eight partners, particularly the rideshare, carshare, volunteer, and mobility partners, who are all very involved in the implementation of the project.

Reviewer 3:

This reviewer observed an effective project team of academia, community groups, public agencies, private industry, and the local Clean Cities coalition has been assembled to carry out this project and provide 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 commented that the project team includes diverse members, and the team meeting cadence is robust. The reviewer would have liked to hear more about the roles of the various team members and how the team was formed, particularly the genesis of the involvement of the affordable housing provider. The presenter did not elaborate on specific roles for team members.

Reviewer 5:

Check-in and collaboration seem sufficient among the project team. There are a wide variety of partners, but it was not clear to the reviewer if the partners are the right mix to increase or recruit volunteers and riders.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer remarked that, as the pilot gains momentum, it has the potential to be a welcome addition to the community and a model to be replicated. It will have a small impact on fuel diversity, but it will undoubtedly foster goodwill in the service areas. Miocar and Mioride marketing is already in place, and it appeared to the reviewer that the purpose of this project is more to provide transportation options to the disadvantaged than to increase fuel diversity or provide outreach on AFVs. The current project will have minimal impact unless it can be replicated nationwide.

Reviewer 2:

The reviewer commented that the project has good potential to contribute to increasing transportation efficiency by building knowledge associated with the development and implementation of a volunteer ridesharing program with e-carsharing in low-income, rural communities. The ability to potentially reduce the current $50 cost per one-way trip to $5-$12 per trip will significantly lower the cost of on-demand transit services in these rural communities. However, until the deployment of the project is up and running at full capacity and the anticipated results are documented, it is difficult to evaluate the effectiveness of this research at this time.

Reviewer 3:

The reviewer was not sure how this project advances rural e-carsharing services because the service existed prior to the project and a number of project tasks have yet to launch in a meaningful way.

Reviewer 4:

Based on progress to date and a lack of evidence of this model’s sustainability, it did not appear to the reviewer that the project has a high degree of likelihood of increasing fuel diversity or increasing transportation efficiency.

Reviewer 5:

It was unclear to the reviewer if the project will be able to recruit sufficient volunteers and what the degree of interest from the community in the project is so that sufficient drivers will utilize the platform. It is unclear as to whether the volunteer program will fill access gaps above the current programs. It is also unclear as to how the project will meet VTO objectives of advancing alternative fuels and increasing transportation efficiency.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

This reviewer reported that ridesharing and carsharing programs with EVs currently exist here, and those programs are generous and integral partners in the project. The project piggybacks on their efforts, as an assistive transport program for communities with limited access and options for transportation. The reviewer noted that this project will promote fuel diversity on a very small scale and, because of that, falls within the goals of VTO. However, the effort shines more as community assistance for those needing rides.

Reviewer 2:

The reviewer commented that use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is a critical strategy and activity to increase transportation system efficiency. Projects that serve as “living labs” are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems. Subsequently, it was hard for the reviewer to judge the merits of funding additional e-carsharing projects until this project has been completed to determine its effectiveness.

Reviewer 3:

The reviewer acknowledged that increasing awareness and providing access to EVs in low-income, rural communities are important. However, it was unclear what the overall program value is versus the program from which it is being built, what need it is filling, and what the actual interest in the community is to utilize it.

Reviewer 4:

It is possible that this project will yield a meaningful finding about the feasibility of providing volunteer drivers to existing rural EV carsharing services, but the reviewer opined that it is not yet far along enough to demonstrate those findings.

Reviewer 5:

Although the identified 50/50 cost share was satisfactory, this reviewer recommended that DOE should not fund similar projects in the future, particularly when additionality or impact is unclear.

Presentation Number: ti112
Presentation Title: The Clean Rural Shared Electric Mobility Project
Principal Investigator: Kelly Yearick (Forth)

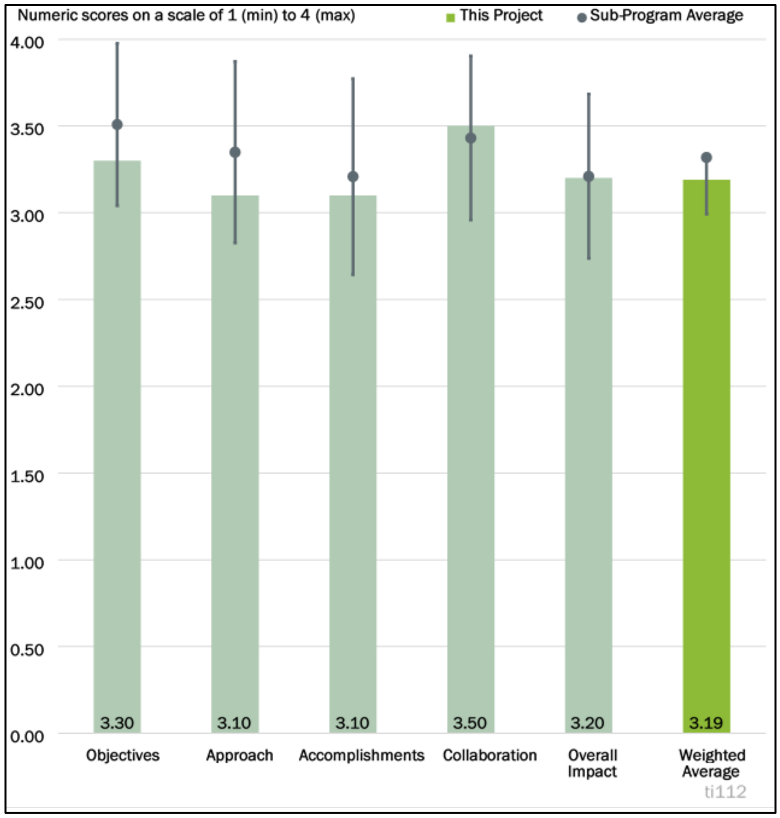


Figure 7-7 - Presentation Number: ti112 Presentation Title: The Clean Rural Shared Electric Mobility Project Principal Investigator: Kelly Yearick (Forth)

Presenter

Kelly Yearick, Forth

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

40% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 60% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer remarked that the project objectives—developing and launching an EV carshare program, collecting and analyzing data, determining a model for financial sustainability and replicability, and disseminating learnings—supports the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 2:

The reviewer stated that the project has selected sites that will provide visibility of EV charging and could help to raise awareness of EVs, which have the potential to increase EV adoption in the community. It will install chargers on five sites in the community, including one in an area where tourists visit.

Reviewer 3:

The project is located in an area with low EV adoption and addresses limited access to EVs in this community along with the business case for carsharing services in rural areas. The reviewer commented that the goal is to develop a model for financially sustainable EV carsharing services in rural areas.

Reviewer 4:

The reviewer indicated that the project supports the VTO objective of increasing fuel diversity (in a measurable, but small amount) by launching an EV carshare program in areas that are underserved for AFV use and transportation options. Success of this effort could allow more transportation options to a diverse population.

Reviewer 5:

This reviewer commented that the Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing transportation efficiency. The project addresses several VTO TI goals, such as national security, economic growth, affordability for businesses and consumers, reliability, and resiliency through the development and deployment of an EV carshare service in a rural community (Hood River, Oregon). Project objectives appeared to the reviewer to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

This reviewer described the project as appearing to be well designed and well thought out. Community feedback has been incorporated and the team has worked to overcome obstacles and barriers. However, the reviewer expressed concern about the final objective of determining a financial model for sustainability and replicability because the charger and vehicle costs are not being factored in.

Reviewer 2:

The reviewer found that providing vehicles and charging to distinct user groups in a single project—tourists, low-income, and non-English speakers—and targeting the approach for each is quite remarkable. It will be interesting to see the extent to which this project can be replicated with Clean Cities coalitions in other areas of the country. The project is strongly aligned with the local community and has a focus on documenting lessons learned.

Reviewer 3:

The reviewer noted that the approach is well thought out and added that tasks are clear, to the point, and quite feasible. COVID-19 restrictions delayed the project, but it appears little needs to be changed on the timeline. The reviewer indicated that the presentation conveys steps that are easy to adjust to changes.

Reviewer 4:

This reviewer observed a generally well-designed project. A weakness is that the slow launch and challenges regarding EV charging station installation indicate that the project leads did not adequately plan a timeline and potential installation sites in a manner that permitted a timely demonstration launch.

Reviewer 5:

The reviewer commented that the Project Approach section provides a satisfactory methodology to accomplish the project objectives and supporting the integration of advanced transportation technologies and practices. The approach is divided by project periods, each containing relevant tasks and activities. Good detail is provided on the Milestone slides regarding the planned tasks and activities and progress to date. The presentation makes several references to the three distinct user groups but never defines them. Also, it was unclear to the reviewer if vehicle and charger costs are included in the project budgets and how these costs could affect replication efforts.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer found good progress toward achieving project goals. The presentation highlighted progress related to site location selections and preparation, vehicle delivery, charging station installations, and initial data collection. Project launch and data collection appear to be on track. No significant concerns have been identified.

Reviewer 2:

This reviewer reported that three out of five vehicles have been launched, and three out of five charging stations have been installed. Results and findings are limited at this time based on the recent launch of the program to the public at three of five sites. The presenter acknowledges some delays from the initial schedule due to COVID-19 restrictions; however, the project seemed to the reviewer to be on-track for gathering results in the coming months and following through on the described deliverables.

Reviewer 3:

The reviewer described project accomplishments as good and on track. Even given setbacks with COVID-19 restrictions, the team was able to install three of the five chargers. Finding site hosts can be a significant barrier, and the team has identified hosts for all sites. The reviewer reported that the tool has been developed and added that new capabilities in BP 2 are defined and will enhance value. The reviewer expressed concern about community interest, given the number of responses to a survey. Sometimes, community interest can grow by having a visible network and charging locations.

Reviewer 4:

The reviewer noted the project has had numerous accomplishments including at least one vehicle that is now available to the public. One significant weakness is the fact that only nine responses were received for the survey, representing a very inadequate sample size for this aspect of the research.

Reviewer 5:

The reviewer chose "Good" on Question 3 because of the COVID-19 delay. In fact, the progress made since Slide 6 (Milestones) was created—electric vehicle supply equipment (EVSE) installation—is impressive. It looks like milestones are being met quickly now that states are opening back up and people are moving about. The reviewer described the number of returns on the survey as disappointing and hoped that there will be more people completing the survey in the future.

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 remarked that partners represent a broad cross-section of the community and were described as making "invaluable contributions" throughout the project. The PI appears to have done a good job of eliciting feedback and input from this team to inform all stages of the project. The presenter also did a thorough job of explaining the roles of key project team members with clear attention paid to assigning roles based on the strengths and capabilities of each partner.

Reviewer 2:

The reviewer commented that involvement of the key partners stands out in this presentation. Each partner appeared to be enthusiastic about bringing their assets, strengths, and services to this project.

Reviewer 3:

This reviewer observed that an effective project team of academia, community groups, public agencies, industry partners, and the local Clean Cities coalition has been assembled to carry out this project and provide 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:

Project collaboration appeared effective to this reviewer.

Reviewer 5:

Collaboration and partners are good; however, the reviewer suggested that the project may benefit from adding other community partners who are trusted within the community and could better reach the target audience.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the project has good potential to contribute to increasing transportation efficiency through the launch and demonstration of a financially sustainable, replicable model for EV carsharing in a rural community. The project will incorporate technological upgrades to remove barriers for low-income and non-English speaking community members by establishing alternate payment mechanisms and a Spanish version of the Envoy app.

Reviewer 2:

According to the reviewer, the project has a good opportunity to raise awareness about EVs within the community.

Reviewer 3:

The reviewer stated that there was no doubt that the project will contribute in the near future, particularly now that people are starting to move about. The level of impact on fuel diversity and transportation efficiency will not be great with just a few cars and neighborhoods. AFV champions will need to continue this project in the future, and projects like this will need to become popular nationwide to truly make a difference.

Reviewer 4:

The partnership with existing transportation options and the local government is a key element of project success. The reviewer indicated that data on the pricing strategies that are palatable to the community will be a key finding once it is ready; however, pricing strategies will need to be sensitive to local conditions for transportation costs in other areas of the country. This project has good potential, but its full impact is yet to be determined, pending finalization of results and its ability to be replicated.

Reviewer 5:

The reviewer indicated that the project impact may lie primarily in the thoughtful and thorough planning of best practice sharing and lessons learned distribution. Financial sustainability of the program appears questionable; the fact that charging station costs are not factored into the costs that need to be recovered by the financial model is particularly concerning.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

Funds appeared to be wisely used and well leveraged from this reviewer's perspective.

Reviewer 2:

The reviewer indicated that this project has the strong potential to develop a rural ridesharing model.

Reviewer 3:

Overall, the reviewer found this to be a well-designed, well-thought-out project. There could be some modifications to help increase participation and data collection. Regarding criteria for sustainability and replicability, one might want to consider what it means that cars and chargers were not included.

Reviewer 4:

The reviewer commented that use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is a critical strategy and activity to increase transportation system efficiency. Projects that serve as "living labs" are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems. Subsequently, it was hard for the reviewer to judge the merits of funding additional e-carsharing projects until this project has been completed to determine its effectiveness.

Reviewer 5:

The reviewer remarked that providing transportation options to lower income neighborhoods can also fall within the social services realm. Using AFVs for this service puts the project within the scope of VTO; the project still has the markings of a community and good neighbor effort.

Presentation Number: ti113
Presentation Title: Holistic and Energy-Efficient Rural County Mobility Platform (RAMP)
Principal Investigator: Sean Qian (Carnegie Mellon University)

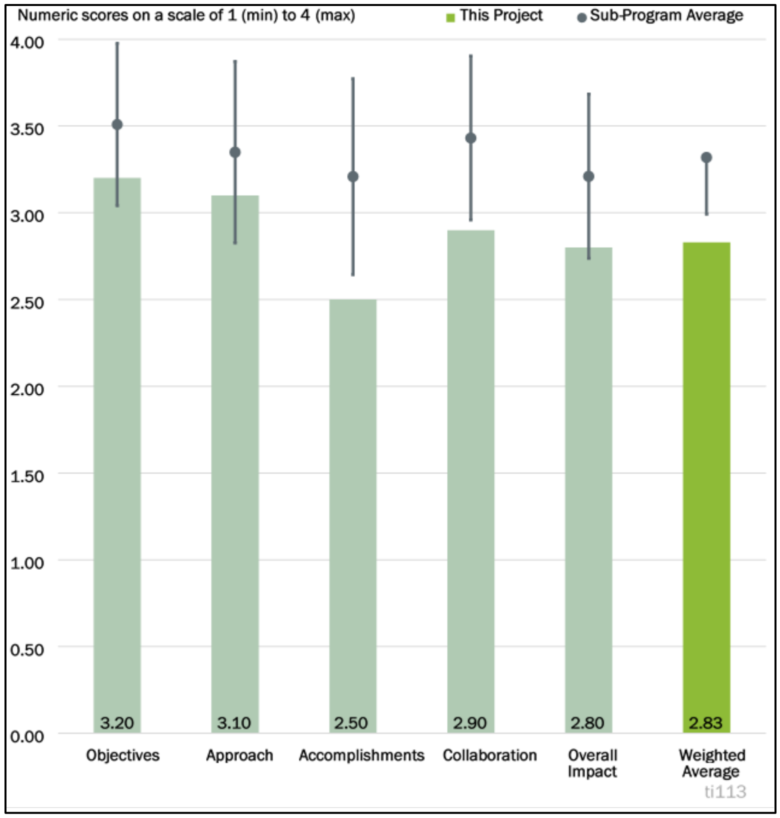


Figure 7-8 - Presentation Number: ti113 Presentation Title: Holistic and Energy-Efficient Rural County Mobility Platform (RAMP) Principal Investigator: Sean Qian (Carnegie Mellon University)

Presenter

Sean Qian, Carnegie Mellon University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

40% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 60% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project objective of developing and demonstrating affordable, accessible, sustainable, and replicable mobility service in a rural area supports the DOE objective of increasing transportation efficiency.

Reviewer 2:

This reviewer reported that this project aims to demonstrate a mobility services platform for an economically disadvantaged rural community that could be broadly replicable for other similar counties nationwide. The reviewer noted that transportation services in the project area are insufficient, inefficient, unaffordable, and inaccessible, resulting in most trips occurring in single-occupant vehicles and over long distances. This is further complicated by a lack of broadband service in the area. The project is examining CNG shuttle service, which aligns with alternative fuel goals of the program.

Reviewer 3:

The reviewer found that this project is primarily focused on the DOE objective of increasing transportation efficiency by providing alternatives to current transportation services in a rural community. The approach includes the use of volunteer drivers and a shuttle service.

Reviewer 4:

Addressing the transportation and mobility needs in a rural environment falls within VTO objectives to increase transportation efficiency. This reviewer stated that this project, once completed, will provide a tool from which to plan and launch smart transportation services. Using natural gas shuttles will provide fuel diversity, which also falls within VTO objectives.

Reviewer 5:

The reviewer noted that the Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing transportation efficiency. The project addresses several VTO TI goals, such as economic growth, affordability for business and consumers and reliability, and resiliency, through the development and demonstration of a mobility service in rural Greene County, Pennsylvania, which is supported by data collection, analysis, sharing, and public dissemination of results. Project objectives appeared to the reviewer to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer indicated that the project is focused on understanding the mobility needs of residents specific to their trips for food access, healthcare, work, and community services. The reviewer stated that the tasks focused on data collection are leveraging survey methods of an existing shuttle service at Waynesburg University (WU) and other existing datasets to generate a network model to assist in the analysis. The project leverages the volunteer culture of the community where many residents want to help their neighbors get where they need to go.

Reviewer 2:

The reviewer indicated that the project seemed well designed, though its feasibility will depend on the impending success of volunteer participation. Additionally, the project appears to be a novel concept for Greene County but it is unclear how novel the concept is nationwide.

Reviewer 3:

The reviewer found the project approach to be sound, and the overall objective for the transportation service leverages existing opportunities of volunteer drivers and a shuttle service into an integrated system designed to be more efficient than current operations.

The diagram on "Conceptual work flow for RAMP" on Slide 17 was extremely useful in understanding the concept as shown moving from "Day 1" to "Day 10." The reviewer indicated that it may also be beneficial to show WU on the diagram to better understand how this critical component from WU fits into the concept.

As mentioned during the presentation, overcoming legal and liability issues for volunteer drivers using their own vehicles to transport people (instead of food) is going to be a key, non-technical challenge to the approach. The reviewer asked whether there are any examples that the PI can use from transportation network companies (TNC), such as Uber, Lyft, etc., to overcome this challenge.

Reviewer 4:

The reviewer remarked that collection of data and creation of systems and models in the approach is appropriate. Once more progress is made on the project (and surveys received), there will be a better understanding of what else is necessary in the development of the platform. That the project seeks also to create a phone-based system as well as an online platform for ridesharing and shuttle services, indicated to the reviewer that the team is looking closely at the unique needs of rural communities.

Reviewer 5:

The reviewer reported that presentation slides covering the Project Approach and Milestones only covered the activities associated with BP 1. It can be assumed the other budget periods were not covered due to lack of progress, but it was difficult for the reviewer to access the project approach, effectiveness, and progress without the information related to the entire project. Finally, while the presentation stated the current cost of the trips was $26, the reviewer was unclear what the project is targeting for a reduced trip cost through this project implementation and when asked during the presentation, the PI did not have a specific answer on the target.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer commented that the presenter outlined significant project impacts due to declining demand for transportation services during COVID-19 closures, which impacted the team's ability to design the system, particularly for access to community services that were not necessarily available during COVID-19 restrictions.

The project survey has been designed, and the volunteer program is largely established. The team focused on understanding existing volunteer pools versus starting from scratch. The reviewer commented that the community has an interesting network established to pair volunteers to move food across the community to various food bank locations. The translation of this food movement operation into one that can also move people is a very interesting concept. Working through training, background checks, and insurance requirements to make that shift will be a challenge for the team.

Reviewer 2:

The reviewer noted that the project saw delays due to COVID-19 closures. The team is working on milestones. BP 1 shows progress with development of the simulation model. BP 2 milestones were not presented. As universities open up and people start to move about, progress will be made.

Reviewer 3:

This reviewer stated that the project has made satisfactory progress toward accomplishments of objectives and goals; however, the project is still very early stage.

Reviewer 4:

As mentioned in the presentation, the reviewer did not see many accomplishments being made due to COVID-19 restrictions.

Reviewer 5:

This reviewer reported that minimal progress has been made toward achieving project goals due to delays associated with the COVID-19 pandemic and that only 5% of the project is complete. It was unclear to the reviewer why this project was included for presentation due to the lack of progress beyond initial surveys and modeling.

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 observed a strong collaboration among the technical team on the surveying, modeling, and simulation aspects of the project. The technical team is ultimately hoping to match supply and demand for volunteer drivers and passengers through this project, which will require good collaboration and technical translation between this technical team and the community.

Reviewer 2:

The reviewer indicated that, so far, collaboration appeared to be going well with regular stakeholder meetings.

Reviewer 3:

Involvement of partners will soon ramp up with the country opening back up and universities back in session. The reviewer asserted that WU is a brilliant choice for this project as it can provide volunteer drivers, and as mentioned in the presentation, students also need shuttles to get around.

Reviewer 4:

The project team assembled appeared to the reviewer to provide an appropriate mix of expertise among team members, with academia, community organizations, local planning agency, a micro-transit provider, and the local Clean Cities coalition included. Team members appear to be qualified for this project work, and their working relationships appear to be appropriate for the project of this scope.

Reviewer 5:

The reviewer commented that the focus of effort to date demonstrates solid coordination regarding project research and analysis. Coordination success among the Project Principal Investigator (PI), municipal/community organization, and Waynesburg University during the implementation phase of work is to be determined.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer reported that the project is very early in implementation and remarked that the overall project impact is highly dependent on success of the volunteer aspect of this program. According to the presenter, 412 Food Rescue has demonstrated successful volunteer operations in the past; so, likelihood seems favorable.

Reviewer 2:

The reviewer indicated that this project has the potential to have a high impact in the Greene County region. Its ability to be replicated may be predicated on the described strong “volunteer culture” of this particular location and their existing familiarity with the food distribution volunteer model.

Reviewer 3:

This reviewer commented that the contribution to date is hard to assess because the project was delayed and work started just 6 months ago, although the team is working on milestones and the presenter brought the audience up to speed. According to the reviewer, the platform has the potential to contribute markedly to the planning of shuttle, rideshare, and other transportation efficiency efforts.

Reviewer 4:

The reviewer noted that the project has the potential to contribute to increasing transportation efficiency by quantifying the benefits of system-level strategies to improve mobility and energy efficiency. However, until the project has progressed to point of demonstration, it was difficult for the reviewer to evaluate the effectiveness of this research at this time.

Reviewer 5:

This reviewer remarked that the project has made little impact so far due to the lack of accomplishments. Also, very little detail was provided in the presentation related to specific upcoming work. The reviewer suggested it would be good if the upcoming work areas that are presented were tied to project tasks and schedule.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer found this to be a very interesting project with good potential to improve rural mobility in this specific location.

Reviewer 2:

The reviewer affirmed that DOE funds are being leveraged and used wisely.

Reviewer 3:

The reviewer stated that the project's methodology and partner choice are thoughtful, and the potential for a successful tool and pilot here is good. The reviewer expected there will be much more to present on this project at the next Annual Merit Review (AMR).

Reviewer 4:

The reviewer indicated that it is too soon to tell as no significant budget has been spent to date. However, cost share appears to be good.

Reviewer 5:

The use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is an important strategy and activity to increase transportation system efficiency. Subsequently, it was hard for this reviewer to judge the merits of funding similar projects until this project has been completed to determine its effectiveness.

Presentation Number: ti114
Presentation Title: Rural Open Access Development Mobility Action Plan
Principal Investigator: Sarah Conley-Ballew (Rural Action, Inc.)

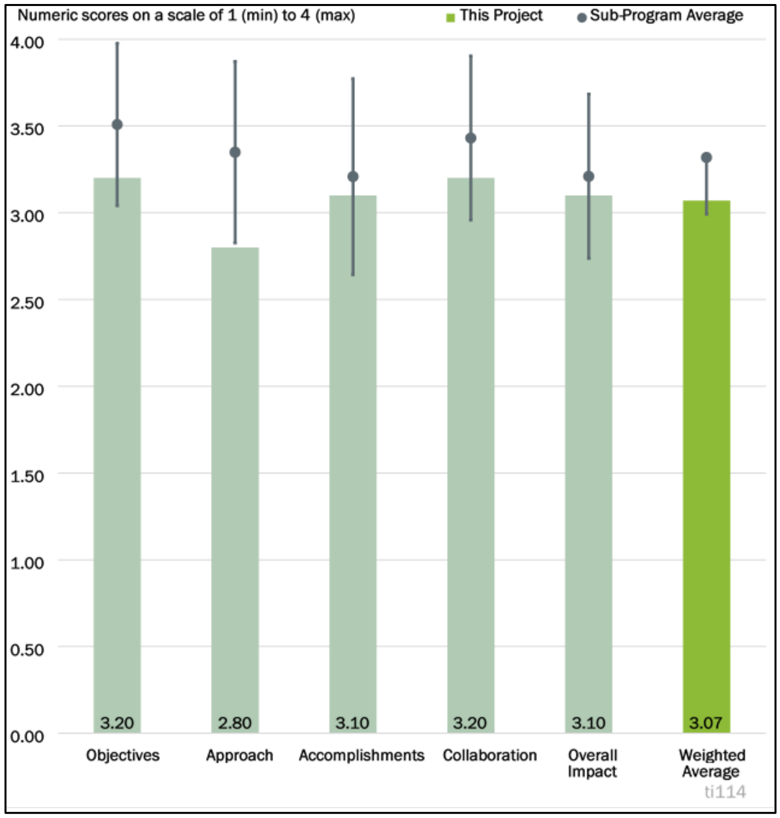


Figure 7-9 - Presentation Number: ti114 Presentation Title: Rural Open Access Development Mobility Action Plan Principal Investigator: Sarah Conley-Ballew (Rural Action, Inc.)

Presenter

Sarah Conley-Ballew, Rural Action, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

40% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 60% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer asserted that the project definitely supports DOE VTO objectives and will provide good insights into barriers and opportunities in rural communities. The reviewer added that the project would increase awareness of EVs in the region and help promote economic development through increased access.

Reviewer 2:

This reviewer asserted that the project's objective to develop and demonstrate an EV shuttle service in rural Ohio supports DOE objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency.

Reviewer 3:

The reviewer reported that the project is focused on closing rural mobility gaps and addressing EV readiness in rural areas. The project team will be evaluating strategies for EV and autonomous (AV) rural transportation and collecting best practices along with assessing reliability and resiliency of these services.

Reviewer 4:

This reviewer commented that developing an "affordable, accessible, sustainable, and replicable" transportation option for rural America is directly in line with VTO objectives to increase transportation efficiency. The project includes EV shuttles and an AV portion (Tesla automated driving in rural conditions), which is in line with VTO fuel diversity objectives.

Reviewer 5:

The reviewer noted that the Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing transportation efficiency. The project addresses several VTO TI goals, such as economic growth, affordability, reliability, and resiliency through the demonstration of EV and AV mobility service applications in rural environments (Appalachian Ohio) through qualitative and quantitative approaches. Project Objectives appeared to the reviewer to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer commented that the project is well defined and is making good progress. It was unclear to the reviewer how taxi and other fleets will be utilized and the information they will provide. The rural electrification study will provide good information for further electrification efforts in the area. One challenge is the uncertainty of whether EV and AV technologies are compatible with rural conditions, but this will provide good information for future project development.

Reviewer 2:

The reviewer stated that the project approach is divided into five tasks and three budget periods, with each budget period having a specific focus: project development, pilot demonstration, and data analysis and dissemination. While the first budget period is well on track, the second and third budget periods are behind schedule awaiting vehicle delivery. The full scope of the project was a bit unclear to the reviewer with respect to the multiple forms of transportation presented—the EV shuttle, the AV, the EV taxi/TNC pilot, etc.

Reviewer 3:

Although the project appeared feasible to this reviewer, deployment of the aftermarket retrofit electrified van has been delayed due to procurement issues. Testing a commercially-available Tesla vehicle on rural roads seems to be a novel activity for community/municipal organizations. The reviewer suggested that the value of data gathered from such testing to other rural communities should be identified in future reviews.

Reviewer 4:

The reviewer indicated that the project uses a simple and direct approach, tapping useful information from existing databases. Each budget period is clearly presented, and the approach is designed to easily be replicated in other rural areas. The reviewer noted that the AV portion of the project is not exactly in line with providing an EV shuttle to rural riders, but noted that the study will yield usable information.

Reviewer 5:

While the Approach and Milestone slides provided a list of planned tasks, activities, and progress to date, it was difficult for this reviewer to determine how the various pieces of this project come together. The exact role of the EV shuttle was unclear as was the purpose of using a Tesla for AV testing. The presenter made a reference to an EV taxi, but no details are provided.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer reported that the project has made significant progress: the study is complete; the direct-current fast charger (DCFC) has been installed; a forum took place to gather stakeholders to discuss rural mobility strategies; a shuttle vehicle has been purchased and being delivered; an AV test plan is in place; and the test run has been completed.

Reviewer 2:

The reviewer asserted that the draft report on EV penetration in rural Ohio is useful for understanding the types of vehicles being adopted in rural areas. The team hosted the first of three Appalachian Clean Transportation (ACT) Forums to engage with the target community and link them to subject matter experts. The public DCFC station has been installed and will have a dedicated charging port for the EV transit vehicle, which is still on order.

Reviewer 3:

This reviewer reported that satisfactory progress has been made toward achieving project goals. The project is 48% complete, and many of the BP 1 and BP 2 milestones and tasks have been completed, such as the installation of the DCFC and ordering of the EV shuttle, as well as starting the AV Test Plan and drafting of the Rural Electrification Report. The remaining work of BP 2 appears to be on track to finish on time. The reviewer identified no significant concerns.

Reviewer 4:

The reviewer noted that the project has made satisfactory progress in BP1/BP2, including installation of a DC fast charging station that will be used by the electric van shuttle.

Reviewer 5:

The reviewer noted that the project is on schedule (possibly ahead of schedule), and milestones were clearly presented for the three budget periods. The shuttle is due to arrive later this year and, if received when expected, will allow the project to continue as planned. To adequately measure the benefit of the EV shuttle pilot, the reviewer said that it will be necessary to estimate how many riders would have taken a gasoline- or diesel-powered vehicle if not for the shuttle (versus opting instead to walk or bike).

With respect to Slide 7, accomplishments indicate an ACT Forum presentation to be held this November, but the reviewer observed that the date may be incorrect as narrative indicates it already occurred (perhaps November 2020).

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 remarked that the project team has good representation from a variety of disciplines with project roles clearly delineated.

Reviewer 2:

This reviewer observed an effective project team of non-profits, community groups, public agencies, a national laboratory, and the local Clean Cities coalition has been assembled to carry out this project and provide an appropriate mix of expertise among team members. Team members are well suited to the project work, and their working relationships appeared to be appropriate for the project of this scope.

Reviewer 3:

This reviewer commented that collaboration between municipal and non-profit organizations appears to be solid within this project.

Reviewer 4:

The reviewer asserted that the partners' roles vary, with Clean Fuels Ohio, Rural Action, and the Ohio Department of Transportation (ODOT) doing most of the "heavy lifting". The reviewer stressed that it is imperative that these partners, and Hocking-Athens-Perry Community Action (HAPCAP) and the City of Athens, continue their enthusiastic participation once the shuttle arrives and the pilot begins.

Reviewer 5:

There are good project partners and effective collaboration, according to the reviewer. The project could benefit from including a utility partner.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

Although not yet developed, the library of best practices being developed during this project—including the identification of bottlenecks for EV and AV adoption and fleet forums to increase the confidence of rural fleet managers to pursue these technologies—shows good promise. According to this reviewer, the final Rural Mobility Action Plan report, Playbook, and Technology Transfer Plan will be welcome additions to the toolbox for rural states in addressing these challenges.

Reviewer 2:

This project's structure is designed for ease of replication in other rural communities. The reviewer noted that the setting in which the shuttle will be operating is not unlike that in thousands of communities. If it is simple and successful, the initiative will be put forth elsewhere many times.

Reviewer 3:

The reviewer indicated that this is a great project that will provide significant insights on transportation electrification in rural America.

Reviewer 4:

The reviewer stated that the project has the potential to contribute to increasing transportation efficiency by quantifying the benefits of system-level strategies to improve mobility and energy efficiency. At this point, the progress to date has not delivered any measurable results. However, once the project work has been completed, the reviewer indicated that it will be a more appropriate time to evaluate the effectiveness of this research.

Reviewer 5:

The reviewer indicated that the project has not yet made impactful contributions to increasing fuel diversity through alternative fuel use and increasing transportation efficiency. It is not clear what aspects of this project are novel beyond commercially available technologies.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer was looking forward to seeing the final deliverables of this project as the reviewer believed they will have good replicability for other rural areas struggling with sustainable mobility options for residents.

Reviewer 2:

The reviewer affirmed that this is a good project. Funding similar projects in other areas could be beneficial.

Reviewer 3:

According to the reviewer, the shuttle pilot project is exciting and holds promise for other communities. Replication has the potential to remove mobility gaps in many small towns. The AV portion still seems like a bit of a “tack on” to this effort, but will also provide useful information.

Reviewer 4:

The reviewer noted that use of DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is an important strategy and activity to increase transportation system efficiency. Subsequently, it was hard for this reviewer to judge the merits of funding similar projects until this project has been completed to determine its effectiveness.

Reviewer 5:

Although DOE resources appear to be leveraged well, this reviewer stated that the project is too early in progress to provide recommendations on funding similar, future work.

Presentation Number: ti115
Presentation Title: Electric First/Last Mile On-Demand Shuttle Service for Rural Communities in Central Texas
Principal Investigator: Elizabeth Munger (Lone Star Clean Fuels Alliance)

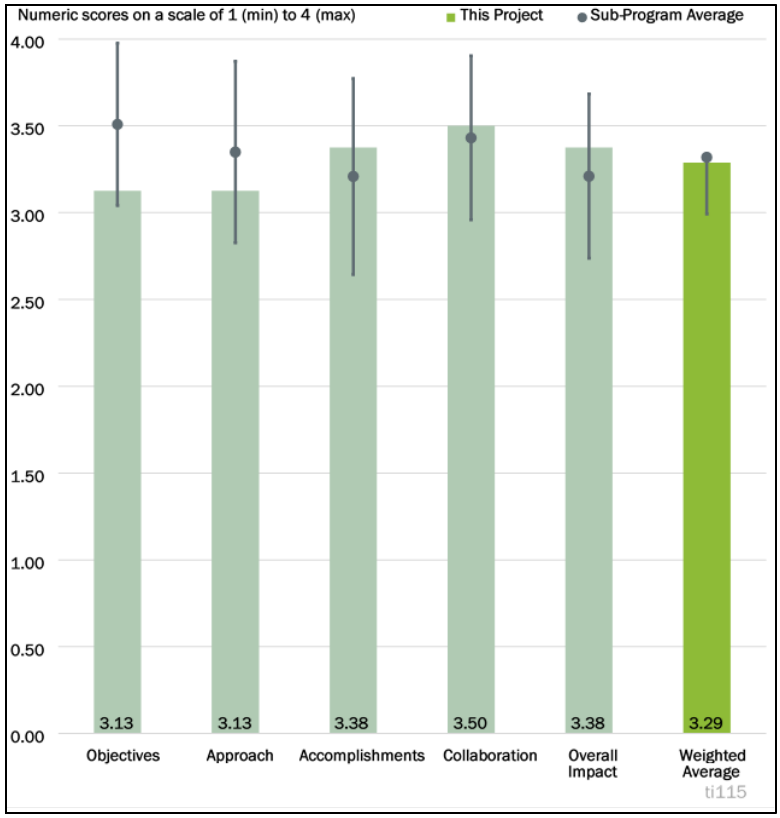


Figure 7-10 - Presentation Number: ti115 Presentation Title: Electric First/Last Mile On-Demand Shuttle Service for Rural Communities in Central Texas Principal Investigator: Elizabeth Munger (Lone Star Clean Fuels Alliance)

Presenter

Elizabeth Munger, Lone Star Clean Fuels Alliance

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

25% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 75% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer remarked that the project objective of developing and demonstrating affordable, accessible, sustainable, and replaceable LSEV first/last mile (FLM) shuttle applications aligns with DOE objectives.

Reviewer 2:

The reviewer stated that the project utilizes low-speed electric vehicles (LSEVs) for on-demand, first- and last-mile transportation to address limited understanding of these vehicles, limited data on their usage, and identification of barriers to more widespread usage. The project team aims to gather quantitative and qualitative research and to identify and disseminate best practices.

Reviewer 3:

The project's objective to "demonstrate and refine affordable, accessible, sustainable" transportation for first- and last-mile mobility needs falls directly under VTO's goal of increasing transportation efficiency, according to this reviewer. That LSEVs are available for demonstration ties into VTO's goal of fuel diversity.

Reviewer 4:

The reviewer remarked that Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency. The project addresses several VTO TI goals, such as national and energy security, economic growth, affordability for businesses and consumers, reliability, and resiliency through the demonstration of LSEV first- and last-mile shuttle applications for rural communities in Central Texas. Project Objectives appeared to the reviewer to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer asserted that the project approach is logical and supports stated goals. The reviewer noted that the team is leveraging existing datasets along with generating new data associated with users of the first- and last-mile service with data sharing happening in real time via the Livewire data platform.

Reviewer 2:

The reviewer found the approach to be simple and straightforward with all budget periods shown in the presentation. The project clearly outlines how data are collected and how the results will be disseminated.

Reviewer 3:

The Project Approach section provides a satisfactory methodology for accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The reviewer indicated that the approach is divided by project periods, each containing relevant tasks and activities. The Milestone slide provides adequate detail regarding the planned tasks and progress to date.

Reviewer 4:

This reviewer observed a well-designed and clearly feasible project approach. One important missing element of the rider survey is that riders are not asked what their e-cab trip is replacing. Without this baseline data, it is inconceivable that the researchers could calculate fuel displaced by the e-cab, a metric that seems essential to this work.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer observed that the project got off to a strong start with the ability to acquire vehicles and do community outreach prior to the pandemic. The project team provided nearly 800 rides to 955 passengers in the first four months of the project while taking into account COVID-19 social distancing protocols. Rides have increased since then. Data collection is already yielding some interesting findings after only a few months of service. The vehicles are highly visible in the community, and initial surveys suggest the community is developing a positive impression of this service along with larger concepts of EV and AV technology.

Reviewer 2:

This reviewer commented that—with the help of the acquisition of shuttles by Capital Area Rural Transportation System (CARTS), Bastrop's local transportation provider—the LSEVs are currently providing transportation throughout the city's center, allowing for project data to be gathered. The project is on time and the presentation provided the number of total trips to date and a map of route stops, which allowed the audience to see the progress. Provided the data show that riders would have used a gas or diesel vehicle for first- and last-mile transport and not walked or biked, the results will show this to be a more efficient transportation plan. The reviewer indicated that another benefit of this project is the addition of these shuttles to mobility options—another way to get around town—which can boost the local economy.

Reviewer 3:

Given 799 rides and 955 passengers in the first few months of operation, the reviewer asserted that this project's electric cab system has achieved considerable accomplishments.

Reviewer 4:

The reviewer observed good progress made toward achieving project goals. The presentation included five slides to highlight project progress, which included deployment of the eCab vehicle, service, and associated data collection along with user surveys. The remaining work of BP 2 appears to be on track to finish on time. The reviewer commented that no significant 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 observed an effective project team assembled that provides an excellent mix of expertise among team members, with a rural transit agency, national laboratory, non-profit community group, and Clean Cities coalition partners involved. Team members are well suited for this project work, and their working relationships appear to be appropriate for a project of this scope.

Reviewer 2:

The reviewer reported that the project lead and four partners each hold key positions in this project. The reviewer also stated that all partners are enthusiastic participants and bring this program together.

Reviewer 3:

According to the reviewer, the project team is strong and appears to be collaborating well.

Reviewer 4:

Collaboration was identified by this reviewer as an essential part of this project's success, particularly collaboration with CARTS, the Rural Transportation System operating the LSEV within its existing network.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The dedicated partners, the simple and direct tasks, and the fact that the vehicles are currently in use allowed the reviewer to start seeing the project benefits. There is no doubt that the project will continue to provide useful information and a replicable formula in the months to come.

Reviewer 2:

The reviewer asserted that the project is generating excellent qualitative and quantitative data on a highly specialized service that should be valuable for informing how these vehicles can be successfully utilized elsewhere.

Reviewer 3:

This reviewer stated that the project is making good, quantifiable progress toward its objectives and has solid potential to contribute to increasing fuel diversity through alternative fuel use.

Reviewer 4:

The reviewer stated that the project has good potential to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency by building knowledge associated with the development and implementation of LSEVs first- and last-mile shuttle applications for rural communities.

However, until the project is closer to completion, it was difficult for the reviewer to determine the potential of deploying LSEVs for first- and last-mile service.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer indicated that the project has made excellent use of DOE resources to date and is a well-coordinated research and demonstration endeavor.

Reviewer 2:

The reviewer noted that this project is generating very useful data and sharing it widely for maximum impact.

Reviewer 3:

The reviewer found this project to be exciting and had no doubt that LSEVs will soon be in rural settings based on this program. LSEVs are now popping up in small communities that are near bigger cities, so the interest is already there. Future funding of similar projects would be appropriate but with this momentum, it will not be necessary for long.

Reviewer 4:

This reviewer indicated that using DOE funding to identify activities that foster the adoption of energy-efficient mobility solutions is a critical strategy and activity to increase transportation system efficiency. The reviewer stated that projects that serve as “living labs” are important to test new ideas, collect data, and inform research on energy-efficient transportation technologies and systems.

Presentation Number: ti116
Presentation Title: East Zion National Park Electric Vehicle Shuttle System
Principal Investigator: Tammie Bostick (Utah Clean Cities Coalition)

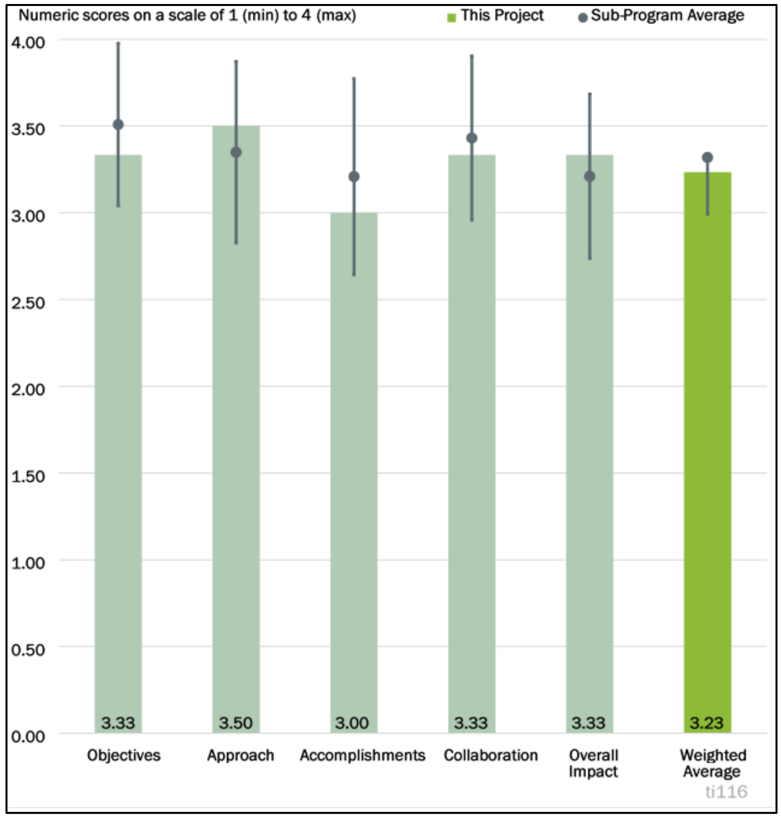


Figure 7-11 - Presentation Number: ti116 Presentation Title: East Zion National Park Electric Vehicle Shuttle System Principal Investigator: Tammie Bostick (Utah Clean Cities Coalition)

Presenter

Tammie Bostick, Utah Clean Cities Coalition

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer said that this is an important project for the following reasons: promoting consumer awareness and building support for the use of EVs among visitors to Zion National Park (ZNP); developing a relationship to promote the use of electric vehicles with the National Park Service (NPS); improving transportation efficiency and reducing vehicle emissions in ZNP; and encouraging the use of EVs in rural areas and destination points.

Reviewer 2:

This is a very visible project in a very popular and highly visited ZNP. The reviewer believed that currently a bus-shuttle system exists at Zion. The reviewer thought that it would be helpful to establish a baseline analysis for non-alternative fuel vehicles versus traditional-fueled buses. The objective could be to improve efficiency, emissions, capacity, customer experience, etc. Evaluating the performance of the vehicles in this difficult environment (steep grades, small tunnels, and four seasons) will make for very useful data for other demonstration and deployment efforts.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer reported that the project approach includes the assessing needs and barriers; developing a best strategies plan; mapping the system route and infrastructure for the shuttle; issuing the request for proposals

(RFP) for both the shuttle and infrastructure; developing shuttle stops; and fulfilling the project objectives via the actual demonstration. In addition, the reviewer commented that the full year of data collection as a result of the demonstration will lead to valuable information and "lessons learned" for other state and national parks looking to deploy electric shuttles/vehicles and associated infrastructure.

Reviewer 2:

As this reviewer previously stated, the project is very visible, well conceived, and should have substantial benefits in its geographical area. If the project requires a unique vehicle to handle the two-way tunnel challenge, it may not be scalable.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Accomplishments and progress to date are impressive with the preliminary shuttle route mapped, the RFP distributed to vendors, and the Best Practices Strategy Plan completed. It appeared to the reviewer that work is well underway for this project, and milestones and deadlines will be met.

Reviewer 2:

Although accomplishments to date include procuring vehicles, planning routes, identifying barriers, and building Hubs, the reviewer wanted to know how the remaining barriers are being addressed.

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 reported that various organizations involved in this project include representatives from the federal, state, and local perspectives. To date, the amount and degree of collaboration and coordination impressive. The involvement and participation of the National Association of State Energy Officials (NASEO) will help to give this project a national audience and will assist other state and national parks with similar efforts.

Reviewer 2:

Although many collaborators are listed, this reviewer noted that the process of collaboration was missing. The presentation mentions developing relationships and the importance of working with local, state, and regional governments. The reviewer asked whether there is a unique approach to doing this.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer suggested that the overall impact of this project will be substantial, especially in the area of replicability. If other state and national parks adopt this approach, it will reduce GHG and criteria air pollutants on a national scale. In addition, it will vastly improve the visitor experience and expose the public to EVs.

Reviewer 2:

This reviewer hoped that all the operational barriers can be eliminated and asserted that well-documented results and lessons learned will be useful for others.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer believed that this project is an excellent use of DOE government resources and will help to promote the use of EVs.

Reviewer 2:

The reviewer indicated that this project should have a large impact on the health of national parks and the visitor experience. If successful, the reviewer asserted that it can be scaled and replicated.

Presentation Number: ti117
Presentation Title: Electrifying Terminal Trucks in Unincentivized Markets
Principal Investigator: Kelly Gilbert (Metropolitan Energy Center)

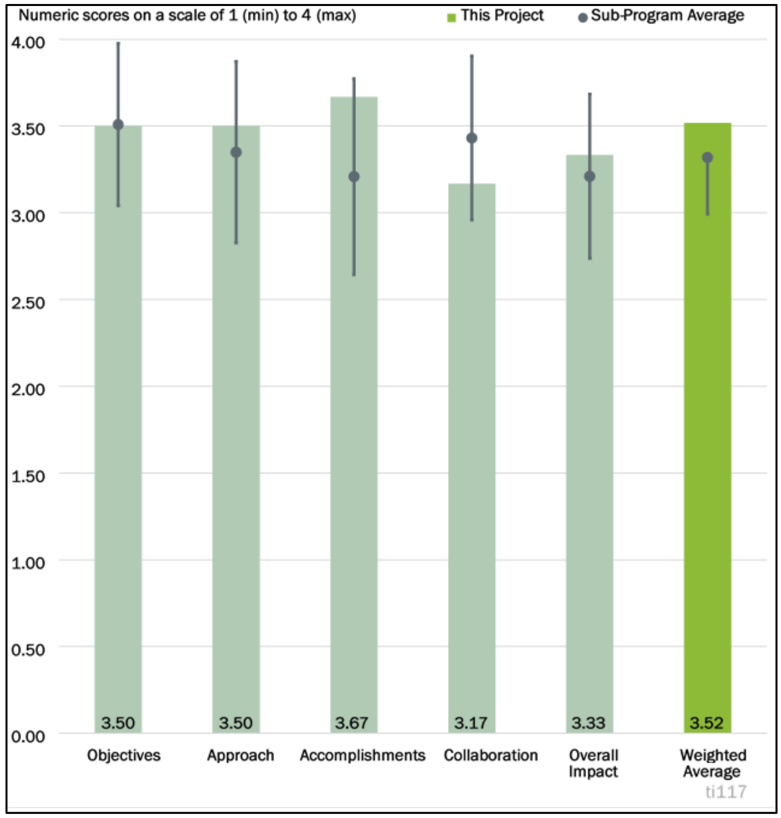


Figure 7-12 - Presentation Number: ti117 Presentation Title: Electrifying Terminal Trucks in Unincentivized Markets Principal Investigator: Kelly Gilbert (Metropolitan Energy Center)

Presenter

Kelly Gilbert, Metropolitan Energy Center

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer explained that freight emissions are a significant source of overall transportation-related air pollution. This project is focused on the electrification of freight yard terminal trucks, which usually are located near underserved communities. The project addresses many of the DOE VTO objectives and barriers, including promotion of fuel diversity and increasing transportation efficiency. The reviewer stated that documenting the cost savings and "lessons learned" associated with the project will assist other communities interested in the electrification of terminal fleets.

Reviewer 2:

The reviewer said that the objectives are well aligned with VTO's objectives of increasing fuel diversity through alternative fuel use.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer remarked that the application is very specific to demonstrate feasibility of electric freight yard terminal trucks. The approach is good in that it involves a large number of fleets having access to the demonstration trucks. Conducting workshops and demonstration surveys are very important.

Reviewer 2:

This reviewer commented that the project approach will help to achieve the project objectives. Further, the community outreach and data monitoring in FY 2021 will be key to ensuring success and helping to replicate the project in other areas of the country.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer praised the accomplishment and progress as excellent. The demonstration vehicles are being deployed and evaluated. Some results are already being generated.

Reviewer 2:

Project accomplishments to date are on track and in some instances ahead of schedule. The reviewer noted that 100% of the subrecipient contracts have been executed, the data collection process has been initiated, and 100% of the vehicles have been procured. There is no reason to believe that this project will not meet the stated accomplishments on time.

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:

According to the reviewer, there is excellent collaboration and coordination. Use of roundtables and surveys keeps the project focused and moving forward rapidly.

Reviewer 2:

Although the collaboration is good, the reviewer would have liked to see more collaboration with state environmental, energy, and transportation agencies.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer noted that the overall impacts and outcomes of this project should be very useful because it covers nine states in different geographical areas with various climates and user experiences. Both surveys being used for company and driver input will yield some valuable information that could be used in other applications across the country.

Reviewer 2:

The reviewer asserted that this project should generate a lot of data and experience that can show the true benefit of alternative fuels in these fleet applications.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

It appeared to the reviewer that DOE funding is being used efficiently and effectively with a good match from locals.

Reviewer 2:

The reviewer observed a good project with broad participation.

Presentation Number: ti118
Presentation Title: Heavy Duty EV Demonstrations for Freight and Mobility Solutions
Principal Investigator: Megan Stein (Clean Fuels Ohio)

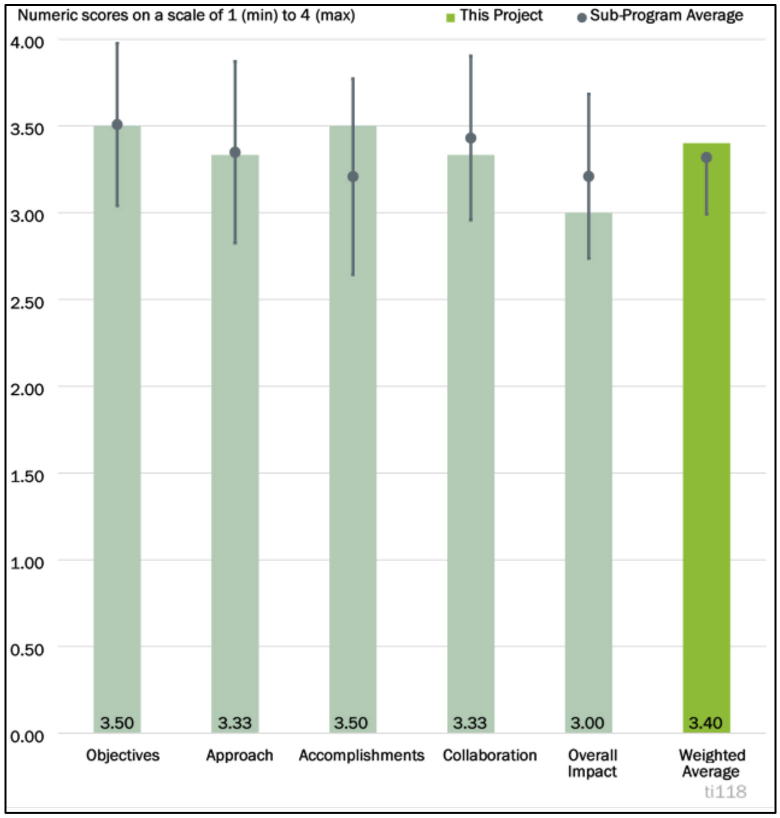


Figure 7-13 - Presentation Number: ti118 Presentation Title: Heavy Duty EV Demonstrations for Freight and Mobility Solutions Principal Investigator: Megan Stein (Clean Fuels Ohio)

Presenter

Megan Stein, Clean Fuels Ohio

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer remarked that one of the most critical issues surrounding the future of EVs is the electrification of medium-duty (MD) and heavy-duty (HD) vehicles, which is what this project addresses. The reviewer asserted that the deployment of MD and/or HD vehicles in fleets and proving the financial business case to fleet owners will address one of the largest gaps to the future of EV adoption.

Reviewer 2:

The reviewer noted that the project objectives support VTO objectives of increasing fuel diversity through the use of alternative fuels in a number of MD/HD truck applications.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer observed an excellent approach to obtaining and deploying information.

Reviewer 2:

The project approach appeared to the reviewer to meet the objectives and address barriers. The collection of data and development of a model will yield valuable information for use across the country. Utilizing the Clean Cities coalitions to connect fleet partners is a very good approach and will help to speed replication.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

This reviewer described project accomplishments and progress to date on this effort as impressive. The majority of milestones have been achieved, and the others are in progress. It appeared to the reviewer that this project is now in the data collection and model development phase with all vehicles having been deployed and in operation.

Reviewer 2:

Although the project has been affected by COVID-19 restrictions, the reviewer said that it is still making good progress and the progress is well documented. Getting upfront commitment for data from original use manufacturers (OEMs) is very smart.

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:

According to the reviewer, the presentation shows specific roles and data responsibilities for various collaborators.

Reviewer 2:

The collaboration with private industry, OEMs, and other Clean Cities coalitions is important. However, the reviewer opined that it would be beneficial to have some state and local partners involved as well as state transportation, energy, and environmental agencies.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project is very well organized as it moves toward data collection and analysis. The reviewer expected to see good results next year.

Reviewer 2:

The reviewer stated that the overall impact of this project should address the stated barriers and improve data collection and modeling for the electrification of MD/HD vehicles.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

It appeared to the reviewer that this project is a very good use of DOE resources and will result in valuable information, which can be shared with other Clean Cities coalitions and stakeholders across the country.

Reviewer 2:

The reviewer’s expectation was that good value will be delivered next year.

Presentation Number: ti119
Presentation Title: Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions
Principal Investigator: Brian Roy (Akimeka, LLC)

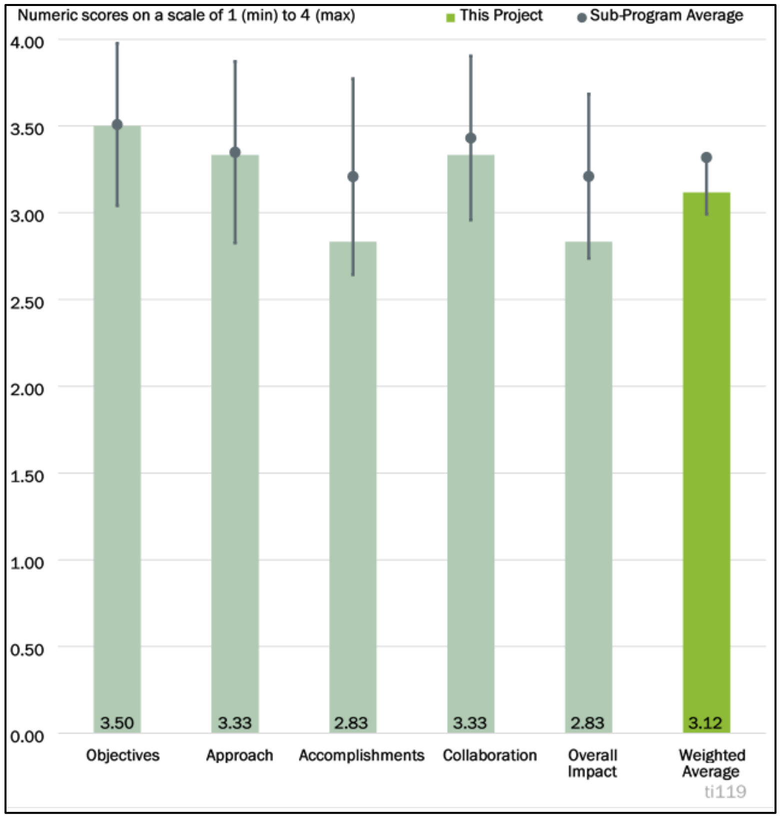


Figure 7-14 - Presentation Number: ti119 Presentation Title: Electric Vehicle Widescale Analysis for Tomorrow's Transportation Solutions Principal Investigator: Brian Roy (Akimeka, LLC)

Presenter

Brian Roy, Akimeka, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

According to the reviewer, the project seeks to establish a national database of EV and EVSE performance data to answer critical questions about how EVs and EVSE are being used in the real world.

Reviewer 2:

This reviewer indicated that the Project Objective and Overview slides describe the project's specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing transportation efficiency. The project addresses several VTO TI goals, such as national security, economic growth, affordability for businesses and consumers, reliability, and resiliency by collecting and analyzing real-world use data from 1,600 plug-in electric vehicles (PEVs) and 10,000 EVSE to support research at the DOE labs and other institutions. Project objectives also appeared to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer commented that the project approach section provides an effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. The project approach involves securing data partners, collecting raw data, transferring dataset quarterly to DOE labs, sharing summary results through an online interactive dashboard, and posting the dataset at the end of the project. The reviewer asserted that excellent detail is provided on the Approach and Milestone slides with regard to the planned tasks and activities and progress to date.

Reviewer 2:

The reviewer described the project approach as comprehensive and well structured. The presenter did a great job of explaining all phases of the project and how various partners are working together to achieve the project objectives. The reviewer also appreciated the inclusion of a project advisory committee.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

This reviewer reported that good progress has been made toward achieving project goals. The project has almost met its goal of collecting data from 10,000 EVSE; however, due to the pandemic, the project team is behind on its goal of including data from 76 PEVs. The presentation included five detailed slides to highlight the project progress. The remaining work of BPs 2 and 3 appeared to the reviewer to be on track to finish on time. No significant concerns have been identified.

Reviewer 2:

The reviewer indicated that the project is somewhat behind schedule regarding collection of certain data types due to COVID-19 restrictions; however, the combination of executed agreements plus leads for future agreements appear to put the project back on track for achieving the final milestones.

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 found that the project team is well structured and includes a good variety of diverse stakeholders. The collaboration with the CALSTART award in this same category is such that Akimeka is collecting light-duty data and CALSTART is collecting MD/HD data is significant and prevents duplication of effort. It is great to hear that the projects are actively collaborating to prevent inundating fleets with data requests and creating competing databases.

Reviewer 2:

This reviewer noted an effective project team assembled that provides an excellent mix of expertise among team members, with a charging network provider, national laboratories, industry advocacy organizations, and numerous Clean Cities coalition partners involved. Team members are well suited for this project work, and their working relationships appeared to be appropriate for a project of this scope.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer noted that the presentation was largely focused on the nuts and bolts of project initiation and data collection. However, impact of the seemingly mundane work of putting information into a database is tremendous for what that database will enable—namely, understanding real-world use and performance in this market to influence future decisions, designs, and policies that enable long-term success of the EV market.

Reviewer 2:

The reviewer remarked that the project has good potential to contribute to the following: increasing fuel diversity through alternative fuel use; and increasing transportation efficiency by collecting data on real-world operations of EVs and charging infrastructure to support research at DOE and other institutions. The reviewer noted that the lack of a national database of EVs and EVSEs has been a barrier to the electrification of the transportation system. The data collected in this project will inform decision makers, both from the private and public sectors, on the various strategies and priorities needed to deploy these technologies in an efficient and cost-effective manner.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer stated that this is an excellent project and a great use of the convening power of Clean Cities combined with the technical capabilities of the national laboratories to create insightful information that advances an alternative fuel market.

Reviewer 2:

The reviewer acknowledged that the use of DOE funding to collect, validate, and collate real-world use data and datasets from PEVs and EVSE to inform future research and deployment planning is appropriate. The data collected in this project will inform decision makers, both from the private and public sectors, on the various strategies and priorities needed to deploy these technologies in an efficient and cost-effective manner to assist in the market transformation needed to electrify our transportation sector.

Presentation Number: ti120
Presentation Title: Mid-Atlantic Electric School Bus Experience Project
Principal Investigator: Alleyn Harned (Virginia Clean Cities at James Madison University)

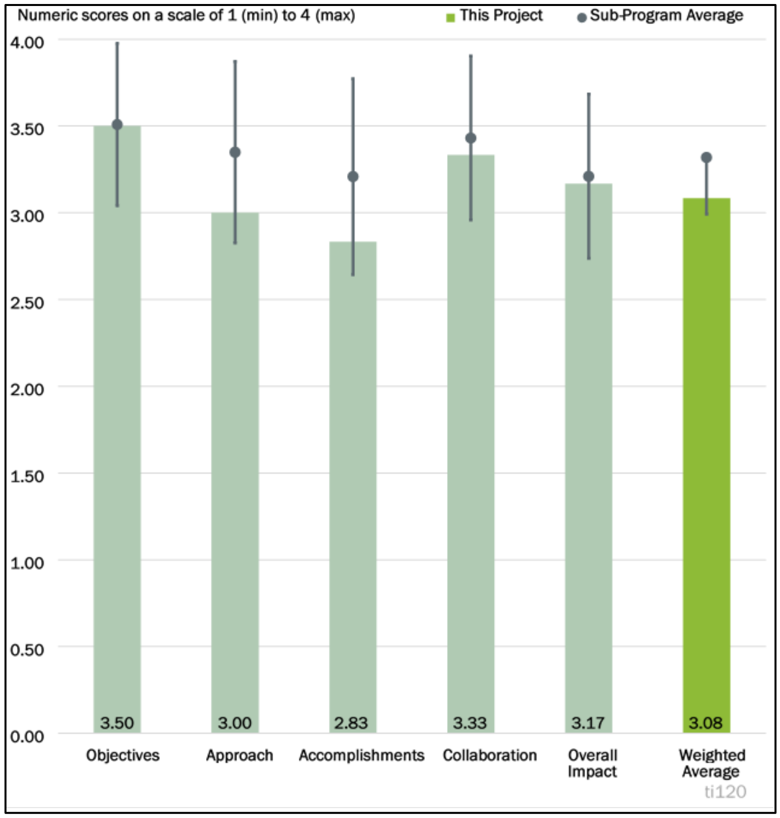


Figure 7-15 - Presentation Number: ti120 Presentation Title: Mid-Atlantic Electric School Bus Experience Project Principal Investigator: Alleyn Harned (Virginia Clean Cities at James Madison University)

Presenter

Alleyn Harned, Virginia Clean Cities at James Madison University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer said that the project supports DOE objectives in alternative fuels by educating school districts on electric school buses (ESBs), establishing ESB deployments, and communicating lessons learned from ESB deployments.

Reviewer 2:

This project is engaging in a multistate effort to get buses and educational tools out to users in regional demonstrations and deployments, document and analyze ESB deployment lessons learned, and distribute lessons learned to benefit future regional and national deployments. The reviewer asserted that this is an ambitious project in execution but narrowly and properly focused on one important area of alternative fuel adoption.

Reviewer 3:

The reviewer commented that the Project Objective and Overview slides describe the project’s specific objectives and barriers addressed, as well as how the project supports the DOE VTO objectives of increasing transportation efficiency. The project addresses several VTO TI goals, such as national energy security, economic growth, affordability for businesses, reliability, and resiliency by providing school districts in three states an opportunity to arrange an ESB demonstration in various school districts. Project objectives appeared to be generally effective for the planned scope.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

This reviewer explained that seeing is believing and that showcasing the many benefits of ESBs through real-world, onsite demonstrations is a solid way to increase the adoption and use of this technology.

Reviewer 2:

The project approach appeared to be straightforward and good to this reviewer.

Reviewer 3:

The reviewer noted that the project presentation slide covering the project approach and milestones provided very little detail or documented progress. It can be assumed that the lack of progress is due to delays associated with the pandemic, but the reviewer remarked that a revised timeline and milestones should have been included to assess the new schedule.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Despite tremendous barriers posed by COVID-19 restrictions, not least of which was the disruption of in-person schooling, the reviewer asserted that this project has accomplished a tremendous amount. Switching to virtual training through online webinars during the pandemic was a nimble adaptation and holding five real-world ride-and-drive demonstration events during this time is no small accomplishment.

Reviewer 2:

The reviewer commented that the project has been delayed due to COVID-19 restrictions, but progress is now being made. The team has held several demonstration events, web events, and webinars. Virginia is now committed to 100 vehicles, and Dominion Power is offering free fast charging and fast chargers for school districts participating in the project.

Reviewer 3:

This reviewer remarked that slow progress has been made toward achieving project goals, due to delays associated with COVID-19 restrictions. The project presentation does not contain any information related to how much funding has been spent to date. While the Project Accomplishments slide does indicate that some progress has been made, it was difficult for the reviewer to judge the progress to date without any milestones or schedule provided. Additionally, project goals (e.g., how many ESB demonstrations are being targeted) are not provided; so, once again, it was hard for this reviewer to determine progress.

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 indicated that collaboration and coordination is strong with 36 virtual team meetings having been held along with successful engagement with stakeholders and partners.

Reviewer 2:

This reviewer reported that the project team assembled appears to provide an appropriate mix of expertise among team members, with school bus OEMs, utilities, transportation advocacy groups, and Clean Cities coalitions included. Team members are well suited for this project work, and their working relationships appeared to be appropriate for a project of this scope.

Reviewer 3:

The project held 36 virtual team and stakeholder meetings and participated in four ESB Manufacturer Open House web events during the pandemic, keeping project partners engaged throughout and allowing significant progress to be made. The reviewer commented that the project assembled a broad group of partners on both the supplier and user side of the ESB market, allowing the expertise of each to contribute to reaching project goals.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

Especially considering the significant barriers imposed by the pandemic, the reviewer indicated that this project has accomplished a great deal and should end up having a tremendous impact on the adoption and use of ESBs in the region. The District of Columbia and four states have already announced ESB programs, at least partially as a result of this project.

Reviewer 2:

The project has already contributed to making an impact through the demonstrations and outreach events. According to the reviewer, the presentation did not really provide many specifics with respect to future planned research work.

Reviewer 3:

The project has good potential to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency by offering pilot demonstrations of ESBs in various school districts in Virginia, Maryland, and Pennsylvania. At this point, until the deployment of the project is up and running at full capacity and the anticipated results are documented, it was difficult for the reviewer to evaluate the effectiveness of this project at this time.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

According to the reviewer, this project represents an excellent use of DOE resources. The project has accomplished much already and has the potential for tremendous impact on the adoption and use of ESBs throughout the region by direct action and across the country by example.

Reviewer 2:

The reviewer affirmed that the resources are being used wisely and similar projects would assist in promoting ESB use across the country.

Reviewer 3:

This reviewer indicated that using DOE funding to demonstrate ESB deployment is an appropriate use of federal funds. As more school districts are moving toward the deployment of electric buses (either through mandates or by choice), it will be critical to incorporate strategies and approaches that will facilitate the transition of the fleet turnover of these buses from diesel to electric.

Presentation Number: ti121
Presentation Title: Medium and Heavy-Duty Electric Vehicle Deployment's Data Collection
Principal Investigator: Jasna Tomic (Calstart, Inc.)

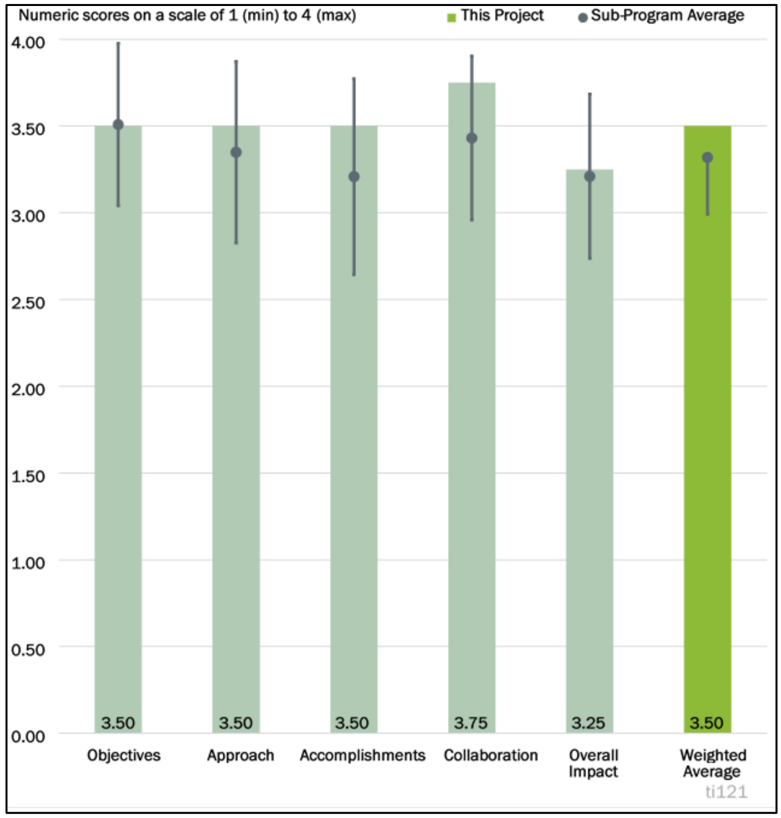


Figure 7-16 - Presentation Number: ti121 Presentation Title: Medium and Heavy-Duty Electric Vehicle Deployment's Data Collection Principal Investigator: Jasna Tomic (Calstart, Inc.)

Presenter

Jasna Tomic, Calstart, Inc.

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

According to the reviewer, the project seeks to address the lack of data on MD/HD EV deployments and to understand the utility and grid impacts of charging for this sector. Upon completion of this project, the database will be useful in identifying and eventually addressing barriers to EV adoption in the MD/HD sector.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer asserted that this project is appropriately scoped and structured. The three project phases to establish the framework, implement data collection, and analyze, share, and report on the collected data makes sense. The PI did a thorough job of planning for the project. The reviewer explained that the ability to get a wide variety of MD/HD vehicles from diverse geographic areas included in the database will be very challenging, especially getting a statistically significant sample in order to draw sound conclusions. Additionally, the national laboratory advisory group was a strong contributor in early phases of the project.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The project accomplishments through BP 1 were very strong with a large number of fleets agreeing to contribute data. The structure of the data collection platform itself, along with the data parameters being collected, is also strong. The quantity of data being added to the platform in BP 2 is not as strong; however, the pipeline of additional fleets considering participation plus the involvement of Clean Cities coalitions to assist with fleet outreach should help increase data collection numbers going forward. The presenter noted some challenges the team has been addressing regarding fleet participation, and a continued steady yet flexible approach to continue bringing on new fleets seemed prudent to this reviewer.

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 stated that project roles are well defined and appropriate, and that the PI has done an excellent job of structuring and advancing the overall project. Participation from the national laboratories has helped to refine which data are collected and how they will be shared broadly with the research community. Participation from Clean Cities has helped the project team achieve additional diversification of data within its database, and the reviewer suggested that the PI should continue to leverage those relationships to grow the database.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer noted that the ability to collect statistically significant numbers of vehicles from diverse geographic areas is a huge challenge for the project team. While collecting any data (and clean, usable data) is better than collecting no data, the team will need to continue to vigorously pursue additional fleet participation for this to be as impactful as the complimentary light-duty database being developed by Akimeka. The ability to collect clean and relevant data is also important, but quantity will also be highly valuable.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

This reviewer observed an interesting project that bridges research, national laboratory expertise, and the reach of Clean Cities coalitions. No single entity would be able to do this project on its own, and the reviewer saw this as a model for how DOE should aim to collect research data on AFV deployments going forward.

Presentation Number: ti122
Presentation Title: Supporting Electric Vehicle Infrastructure Deployment Along Rural Corridors in the Intermountain West
Principal Investigator: Tammie Bostick (Utah Clean Cities)

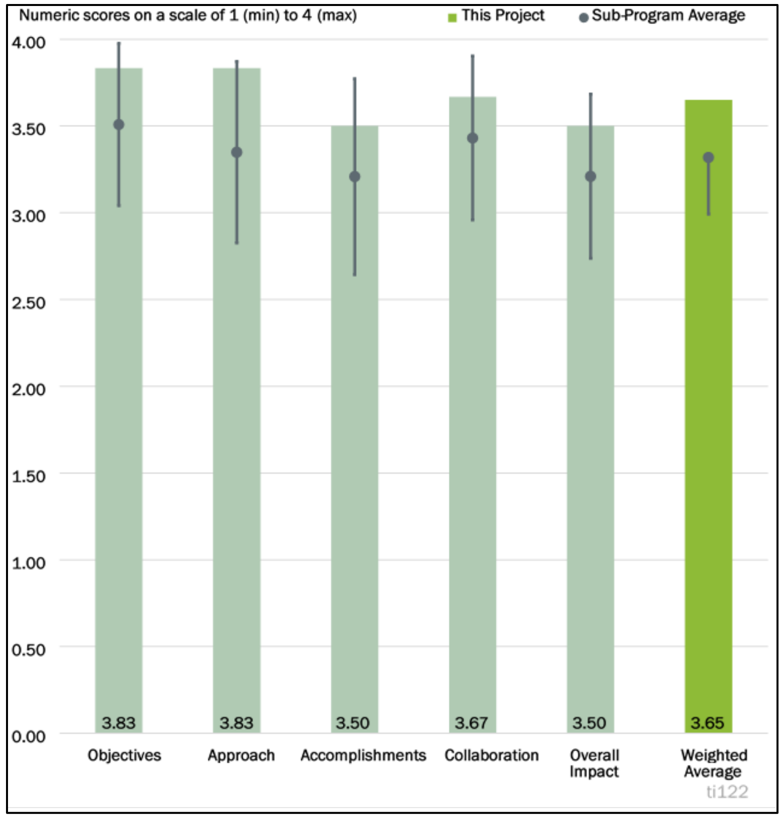


Figure 7-17 - Presentation Number: ti122 Presentation Title: Supporting Electric Vehicle Infrastructure Deployment Along Rural Corridors in the Intermountain West Principal Investigator: Tammie Bostick (Utah Clean Cities)

Presenter

Tammie Bostick, Utah Clean Cities

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the project supports DOE VTO objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency. This project addresses a big barrier for EVSE installation for states in the Intermountain West, mainly the problem of covering a substantial amount of Interstate and corridor mileage with EV infrastructure every 50 miles. The reviewer described use of off-grid solar and FreeWire technologies as an innovative solution for installing EVSE in areas where there is little or no electricity. Overcoming this barrier will determine the success of this project in building regional and cross border EV corridors in the Intermountain West.

Reviewer 2:

According to the reviewer, the effort meets many DOE VTO objectives and will help establish EV fueling along rural corridors by providing EV customers with confidence when traveling. The reviewer added that having some of the locations in high visibility areas will help to raise EV awareness. The report on demand charges will be valuable for addressing a key barrier for station economics.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer said that the team has a well-defined and effective approach, beginning with a needs assessment and engaging with utilities across the region to address barriers. Planned future work is significant and attainable given the timeframe and funding levels.

Reviewer 2:

The approach supports the objectives and supports and compliments the Regional Electric Vehicle West effort being led by NASEO. In addition, the reviewer noted that the rural focus of this project is extremely timely with the priorities of the Biden Administration and will provide valuable information, lessons learned, and insight to other rural areas around the country looking for assistance with the installation of EVSE facilities.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Significant project progress has been made from this reviewer's perspective. Collaboration among partners is strong, and the team is leveraging the partnerships to develop resources and promote awareness of work products. Engaging utilities early in the project was essential, according to the reviewer, and has proven beneficial to developing new solutions and reducing barriers.

Reviewer 2:

The reviewer commented that EV corridors that have been established in both Utah and Nevada indicate a very good start to connecting other corridors in the Intermountain West. The team has developed a website, branding assessment, and educational materials to raise awareness and for use by stakeholders. Accomplishments to date and planned activities demonstrate effective progress toward meeting overall goals and objectives. In addition, this project is informing the development of an EV rural toolkit as part of the U.S. Department of Transportation (DOT) Rural Opportunities to Use Transportation for Economic Success (ROUTES) Program.

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 there is great collaboration and coordination on this project. There are 75 partners involved, which will provide a wide range of support for the project. In addition, support from national organizations like NASEO and regional organization like the Western Governors' Association, will help to convey findings and outcomes to a wide audience of stakeholders throughout the country.

Reviewer 2:

This reviewer noted that the project put together a great team with key partners. The reviewer had been worried that utilities were not listed in the partner list, but the PI explained their involvement, which seems appropriate. Hopefully, the team can further leverage the utilities to help promote awareness and disseminate results. The reviewer suggested that another key partner that the team should work with is National Rural Electric Cooperative Association (NRECA), as they will be essential for further raising awareness of successes and lessons learned. NRECA could also provide introductions to statewide electric cooperative associations, specifically the North Carolina Electric Membership Corporation (NCEMC). NCEMC is working with North

Carolina electric cooperatives on EVs and is finding it challenging. Collaboration with the PI and the project team could prove beneficial and would further leverage federal funding dollars.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer found that the overall impact of this project is significant, which will help to overcome barriers being experienced by other states interested in deploying EV infrastructure. The information, lessons learned, and knowledge gained from this project will help other states interested in establishing EV corridors and connecting corridors across state boundaries. Overall, the project will help to encourage EV infrastructure deployment and in turn the uptick of EVs in the country.

Reviewer 2:

The is a great project, according to the reviewer, who hoped that the team will work with NRECA and other electric cooperative associations to further disseminate information. It also might be beneficial if the team worked with other state coalitions (e.g., Florida) and corridor efforts (Electric Highway Coalition).

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

It appeared to this reviewer that DOE resources are being leveraged and used wisely and efficiently in this project. The reviewer encouraged DOE to fund other projects like this one, especially when the project addresses a specific barrier to EV adoption and/or the deployment of EV infrastructure.

Reviewer 2:

The reviewer affirmed that there is good use of funding.

Presentation Number: ti123
Presentation Title: Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility
Principal Investigator: Megan Stein (Clean Fuels Ohio)

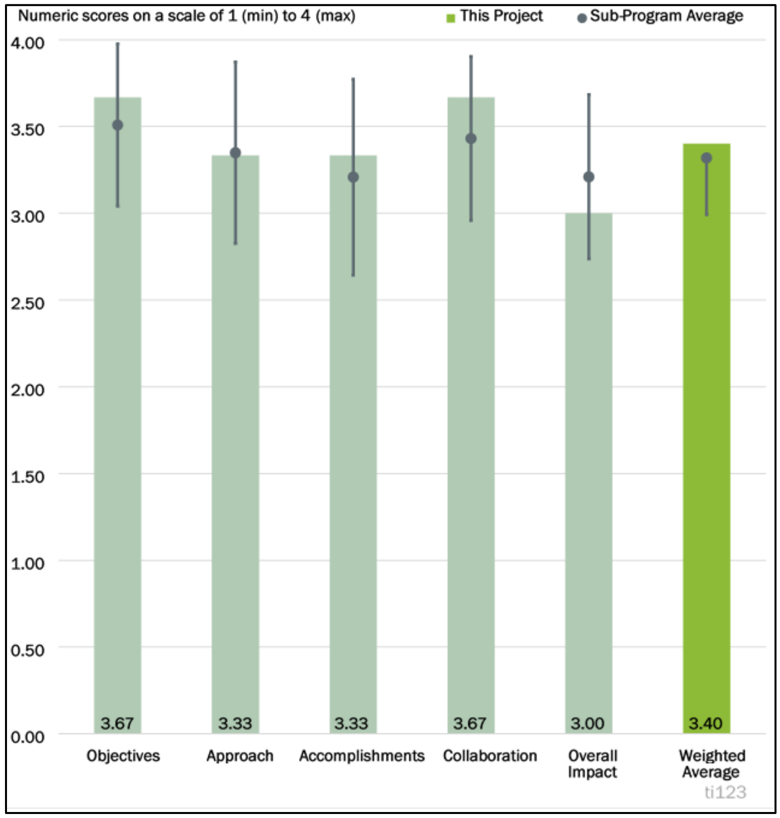


Figure 7-18 - Presentation Number: ti123 Presentation Title: Decentralized Mobility Ecosystem: Market Solutions for 21st Century Electrified Mobility Principal Investigator: Megan Stein (Clean Fuels Ohio)

Presenter

Megan Stein, Clean Fuels Ohio

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer stated that the project supports the DOE objective of fuel diversity by locating, installing, and assessing the use of three EV mobility hubs in central Ohio.

Reviewer 2:

The reviewer found the project to be very well aligned with VTO objectives of increasing fuel diversity through the use of EVs in the greater Columbus area.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The approach is a well-thought-out plan that addresses acquisition, vehicle deployment, ordering, hub deployment, and data analytics. The reviewer noted that the project focuses on existing stakeholders, transportation service fleets, and major parking providers.

Reviewer 2:

The reviewer observed a strong approach using data-driven methods to identify appropriate locations for EV charging hubs. The approach currently does not include an investigation into alternative business models for EV hub sustainability (e.g., the fee and/or pricing structure for users of the hub). The reviewer asked whether this is something that can be included into future work.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Overall, the reviewer indicated that the project seems to have made good progress with all BP 1 milestones achieved and BP 2 milestones in progress. Development of the mobility hub geospatial planning tool is an achievement that could have application to other locations that are analyzing the best locations for EV mobility hubs.

Reviewer 2:

The reviewer remarked that the deployment of EVs and EVSE is well underway, the Project Advisory Committee is in place and meeting, and the geospatial planning tool has been developed and demonstrated.

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 the team appeared to be working well together. In addition to the team members, a Project Advisory Committee has been established and is meeting on a quarterly basis.

Reviewer 2:

The reviewer noted excellent collaboration between Columbus Yellow Cab (CYC), Mobikit, and the City of Columbus. Clean Cities coalition Replication Partners are very important for broadened deployment.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

According to the reviewer, the team is making good progress with CYC.

Reviewer 2:

This reviewer stated that the project has already made an impact through the development of the EV mobility hub location tool and the deployment of one EV mobility hub at the Yellow Cab location. The planned future research seemed reasonable to the reviewer. However, there does not seem to be any type of assessment or evaluation of the effectiveness of the mobility hubs, including the hub location tool and the reservation system. As mentioned previously, there also does not appear to be any development of business plans for mobility hub sustainability or pricing models.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer indicated that the project would provide significant information for other cities.

Reviewer 2:

The reviewer affirmed that DOE resources are being used wisely. Similar projects are appropriate but should continue to explore mobility hubs that serve a variety of populations, such as commercial fleets, campuses, rest stops, shopping locations, attractions, etc.

Presentation Number: ti124
Presentation Title: Developing an Electrified Vehicle Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region
Principal Investigator: Pingen Chen (Tennessee Tech University)

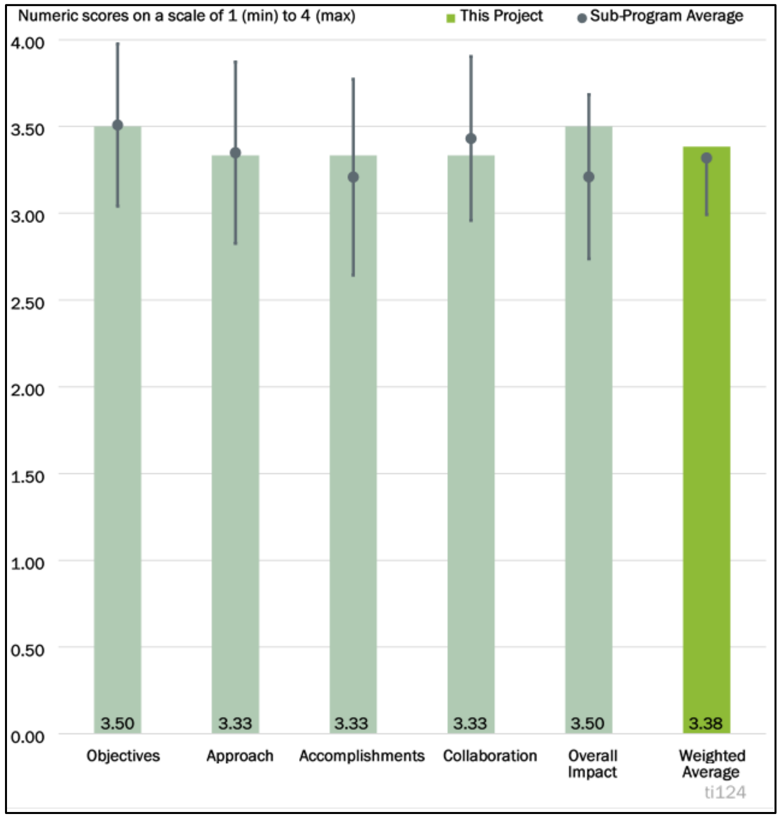


Figure 7-19 - Presentation Number: ti124 Presentation Title: Developing an Electrified Vehicle Demonstration Testbed in the Upper Cumberland Region of Tennessee, an Economy Distressed Rural Region Principal Investigator: Pingen Chen (Tennessee Tech University)

Presenter

Pingen Chen, Tennessee Tech University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The 2-week test drive of the EVs and hybrid-electric vehicles allows for a real-life experience, and the reviewer indicated that such a trial is what will move the needle toward EV adoption. The data gathered will provide a clearer view of EV operation and use in a rural setting. Both are in line with VTO objectives of increasing fuel diversity and transportation efficiency.

Reviewer 2:

The reviewer commented that the project supports DOE objectives and directly addresses barriers related to EV adoption in rural communities. The project is exposing rural communities to EV and allowing individuals to use an EV as their personal vehicle for a 2-week period. The project is also conducting outreach within the community.

Reviewer 3:

According to the reviewer, the project directly supports VTO objectives to increase fuel diversity through the use of alternative fuels and increasing transportation efficiency in rural areas.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer stated that the tasks are direct and appropriate. The formula is simple, with BP 1 and 2 milestones similar, almost identical. The presentation was impressive in the area of "Establishing Public Charging," emphasizing that to accelerate adoption of EVs in a rural setting by offering test drives, EVSE installation would need to be there.

Reviewer 2:

According to the reviewer, the approach is good to give a "hands-on," 2-week experience of using an EV for accomplishing travel needs and to conduct outreach on EVs. The reviewer had a question on the approach related to the 2-week volunteering using the EV at no cost (as shown on the flyer image on Slide 10) and stated that this could have some minor impact on the questionnaire results. The reviewer wanted to know whether the volunteers are given some estimate of what their charging expenses would have been during the 2-week period and what typical expense for a gasoline-powered vehicle would have been.

From the presentation, the approach is for using the electric bus at Upper Cumberland Human Resource Agency during the project was not clear to the reviewer. For example, the reviewer asked if the bus will be used on regular routes, for demonstration purposes, or some combination of both.

Reviewer 3:

The reviewer indicated that this is a traditional approach to creating a demonstration public charging network and conducting EV demonstrations and evaluation.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

The reviewer observed that the 2-week demonstration periods seem to have generated a lot of good data and market exposure.

Reviewer 2:

The reviewer said that the project has made very good progress so far—deployment charging stations, hosting outreach events, and providing EVs to a number of volunteers for 2 weeks each.

Reviewer 3:

With the vehicles and charging stations currently operational, the reviewer remarked that the project can continue its course with analysis of data and continuing education and outreach. It was not obvious how this project will "reduce rural transportation costs," as indicated on Slide 3-Impacts. In fact, a new F250 with an XL plug-in electric upfit would initially be costly for many, and the reviewer was unsure what the breakeven point would be for the long-distance commuter.

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 found excellent overall collaboration between OEMs, EVSE providers, and universities.

Reviewer 2:

Based on the excellent progress and accomplishments to date and looking at the role of the various team members as shown on Slide 17, it appeared to this reviewer that the collaboration and coordination are going very well.

Reviewer 3:

Although the project relies on its partners for demonstrations and analysis, and while Slide 17 shows their tasks, the reviewer did not recall mention of them all in the presentation.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

This reviewer described the data contributed as a result of this project (as shown in presentation slides) as excellent.

Reviewer 2:

The reviewer remarked that the project is generating exactly what the team set out to do—rural information on EVs.

Reviewer 3:

This reviewer indicated that the project has already contributed through exposing the community to EVs during outreach events, deploying charging stations, and allowing volunteers to use an EV as their vehicle for 2-week periods. For future work, additional information could be provided on how the electric bus is going to be used in the project because this was not clear to the reviewer in the presentation. Also, the project team mentioned that it may need to adjust the approach to make sure that there are enough volunteer EV users from the most remote locations in the project area. So, adjustments to the current approach may be necessary.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer affirmed that DOE funds are being used wisely and DOE should continue to sponsor similar projects in the future. This project could definitely encourage those in rural communities to consider purchasing an EV in the future.

Reviewer 2:

The key to the adoption of EVs or any advanced technology vehicle is exposure. This program puts the vehicles out there in the hands of potential owners. The reviewer suggested that there is a need for more programs like this if furthering the fuel diversity objectives of VTO is to continue.

Reviewer 3:

This reviewer observed a good project, although this is a difficult part of the market in which to generate interest and enthusiasm about EVs.

Presentation Number: ti125
Presentation Title: EcoCar Mobility Challenge
Principal Investigator: Kristen Wahl (Argonne National Laboratory)

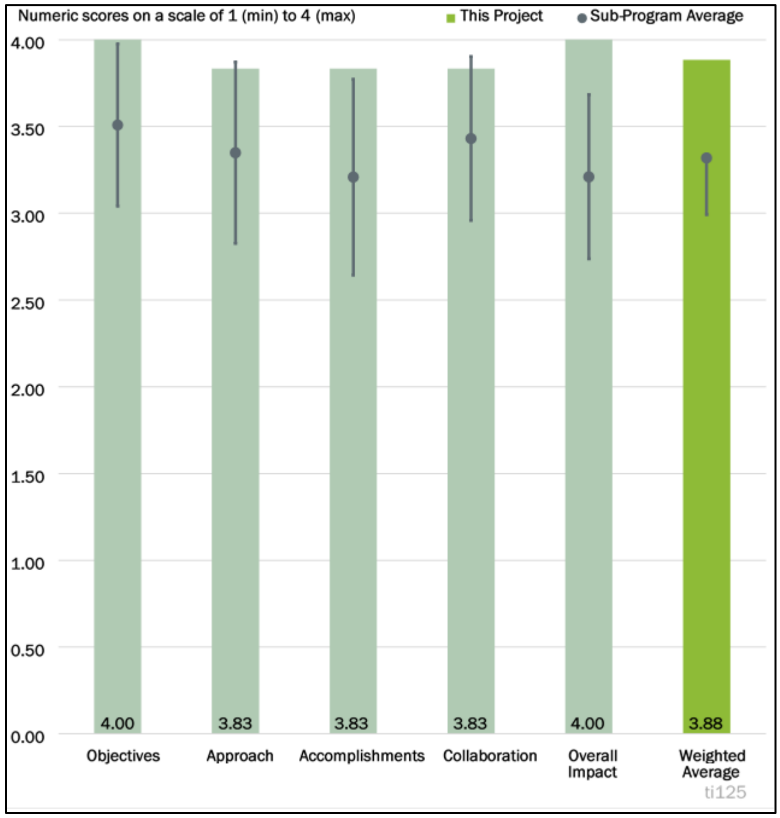


Figure 7-20 - Presentation Number: ti125 Presentation Title: EcoCar Mobility Challenge Principal Investigator: Kristen Wahl (Argonne National Laboratory)

Presenter

Kristen Wahl, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

0% of reviewers felt that the use of resources might be used wisely, 0% of reviewers felt that the use of resources were not being used wisely, 100% of reviewers felt that the use of resources were being used wisely, and 0% of reviewers did not indicate an answer.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The project objectives seek to prepare students for a career in design and implementation of advanced technology vehicles. The reviewer commented that the project is key to the promotion of more efficient transportation and tomorrow’s vehicle and fuel options.

Reviewer 2:

The reviewer stated that the EcoCAR Mobility Challenge and its predecessors have a long history of success in bringing new thinking to the development of AFVs, as well as fostering and encouraging the next generation of clean vehicle engineers and advocates.

Reviewer 3:

According to the reviewer, creating and educating new engineers and scientists for this new transportation future is essential to the industry and society.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer found the multi-year approach to creating real vehicles with world-class mentors to be outstanding.

Reviewer 2:

This reviewer reported that the project supports classes, curricula, hands-on labs, and competitions through technical goals. When COVID-19 restricted the implementation of the tasks associated with these goals, the reviewer indicated that the team adapted by launching a virtual learning series and allowing students to be evaluated at regional sites.

Reviewer 3:

The reviewer indicated that providing a hands-on challenge, industry experts for tutoring, and the resources to succeed is a goldmine for developing the next generation of engineers and vehicles, and benefits the vehicle manufacturers and future car buyers just as much as it does the students.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives.

Reviewer 1:

Although the program was slowed by the COVID-19 pandemic, this reviewer asserted that it achieved significant results from all teams.

Reviewer 2:

This reviewer commented that the pandemic did not appear to interfere significantly with year 3 goals. Slide 6 – Milestones identifies the pathway, and although the presenter indicated that some tasks were delayed, the overall program made it through fairly unscathed.

Reviewer 3:

The reviewer stated that EcoCAR has faced significant obstacles due to the pandemic, but creatively found ways for the teams to continue progressing on the design of their vehicles. A series of 16 educational videos was developed to train teams to self-inspect vehicles when travel and social distancing restrictions prevented in-person inspections and were not permissible. Identifying individual test sites for each team to have its vehicle evaluated was a key accomplishment this year, and the competition remains on track for wrapping up in year 4.

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 observed that the presenter put great emphasis on the partners and their dedication to the program's success. "Headline Sponsor" General Motors is perhaps the most notable, given the number of students it has hired out of the program.

Reviewer 2:

This reviewer explained that EcoCAR brings together a huge number of partners and stakeholders and does an excellent job of keeping them all engaged and contributing at a high level. The reviewer indicated that adapting to a virtual environment without delaying the overall project timeline, showed the strength and flexibility of this program.

Reviewer 3:

The reviewer asserted that there was outstanding collaboration and coordination within teams and industry experts.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The overall impact of the EcoCAR Mobility Challenge will likely be felt for years, according to this reviewer, as the next generation of vehicle engineers continues to grow and develop skills fostered by this project. EcoCAR has impacted more than 2,000 students to date, enriching them and the workforce with valuable experiential training.

Reviewer 2:

The reviewer indicated that this program has been promoting education and opportunities in the advancement of fuel diversity and advanced technology vehicles for 5 years with extraordinary results.

Reviewer 3:

The reviewer asserted that this program is creating the young engineers who are our future.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer remarked that EcoCAR is an excellent use of resources. Project management at Argonne has honed its program through years of trial and error, and the program provides an unparalleled level of experience and training to these students. Contributions of the manufacturer and component supplier stakeholders is significant and adds tremendous value to this project.

Reviewer 2:

The program is a proven success and an integral part of training tomorrow's designers, inventors, alternative fuel, and fuel efficiency champions. The reviewer hoped that curricula and specialized degrees would soon be offered in many more colleges and universities as a matter of course.

Reviewer 3:

The reviewer suggested that this program should continue each year.

Acronyms and Abbreviations

3G	Third generation
4G	Fourth generation
ACT	Appalachian Clean Transportation
AFV	Alternative fueled vehicle
AMR	Annual Merit Review
ATRI	American Transportation Research Institute
AV	Autonomous vehicle
BP	Budget Period
CARTS	Capital Area Rural Transportation System
CNG	Compressed natural gas
COVID-19	Coronavirus disease 2019
CYC	Columbus Yellow Cab
DCFC	Direct-current fast charger
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
e	Electric
EERE	Office of Energy Efficiency and Renewable Energy
ESB	Electric school bus
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
FLM	First/last mile
GHG	Greenhouse gas
GTI	Gas Technology Institute
HAPCAP	Hocking-Athens-Perry Community Action
HD	Heavy-duty
LSEV	Low-speed electric vehicle
MD	Medium-duty
NASEO	National Association of State Energy Officials
NCEMC	North Carolina Electric Membership Corporation
NGV	Natural gas vehicle
NPS	National Park Service

NOAA	National Oceanic and Atmospheric Administration
NRECA	National Rural Electrification Association
ODOT	Ohio Department of Transportation
OEM	Original equipment manufacturer
PEV	Plug-in electric vehicle
PI	Principal Investigator
RDD&D	Research, development, demonstration, and deployment
RFP	Request for proposals
SNAP	Rideshare software interface
TI	Technology Integration
TNC	Transportation network company
VTO	Vehicle Technologies Office
WU	Waynesburg University
ZNP	Zion National Park

8. Vehicle Analysis

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The VTO Analysis subprogram provides critical information and analyses to prioritize and inform Vehicle Technologies research portfolio planning through technology-, economic-, and interdisciplinary-based analysis, including target-setting and program benefits estimation. Projects continue to support analytical capabilities and tools unique to DOE's national laboratories. For data activities, trusted and public data are critical to Vehicle Technologies efforts and are an integral part of transportation and vehicle modeling and simulation. For modeling activities, the subprogram supports the creation, maintenance, and utilization of vehicle and system models to explore energy impacts of new technologies relevant to the Vehicle Technologies Office portfolio. Finally, for analysis activities, integrated and applied analyses will bring together useful findings and analysis of the energy impacts of transportation systems through the integration of multiple models including vehicle simulation and energy accounting of the entire transportation system. The result creates holistic views of the transportation system, including the opportunities and benefits that advanced vehicle technologies create by strengthening national security, increasing reliability, and reducing costs for consumers and businesses. Overall, Analysis activities explore energy-specific advancements in vehicles and transportation systems to inform Vehicle Technologies' early-stage research and offer analytical direction for potential and future research investments.

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
van021	Transportation Energy Evolution Modeling (TEEM) Program	Zhenhong Lin (ORNL)	8-3	3.56	3.67	3.78	3.39	**3.62**
van028	Electric Vehicle (EV)-Grid Analysis Modeling	Srinath Ravulaparthy (LBNL)	8-10	3.67	3.58	3.33	3.42	**3.55**
van034	Medium- and Heavy-Duty Vehicle Choice Modeling and Applied Analysis	Alicia Birky (NREL)	8-15	3.57	3.57	3.64	3.43	**3.56**
van035	Assessing Vehicle Technologies Benefits in a Transportation Energy Ecosystem	Vincent Freyermuth (ANL)	8-21	3.00	3.21	3.43	3.21	**3.19**
van036	Distributions of Real-World Vehicle Travel	Dave Gohlke (ANL)	8-28	3.50	3.57	3.50	3.36	**3.52**
van038	The Department of Energy's (DOE) More Comprehensive Total Cost of Ownership (TCO) Franework	Dave Gohlke (ANL)	8-34	3.72	3.83	3.61	3.67	**3.76**
van039	Electric Vehicles at Scale	Michael Kintner-Meyer (PNNL)	8-41	3.44	3.13	3.56	3.38	**3.29**
van040	Energy Impacts of Electrified Passenger Air Transport	Dominik Karbowski (ANL)	8-48	3.29	3.29	3.29	3.33	**3.29**
van041	Location History	Venu Garikapati (NREL)	8-54	3.21	2.79	3.00	2.86	**2.93**
Overall Average				**3.45**	**3.42**	**3.48**	**3.32**	**3.42**

Presentation Number: van021
Presentation Title: Transportation Energy Evolution Modeling (TEEM) Program
Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

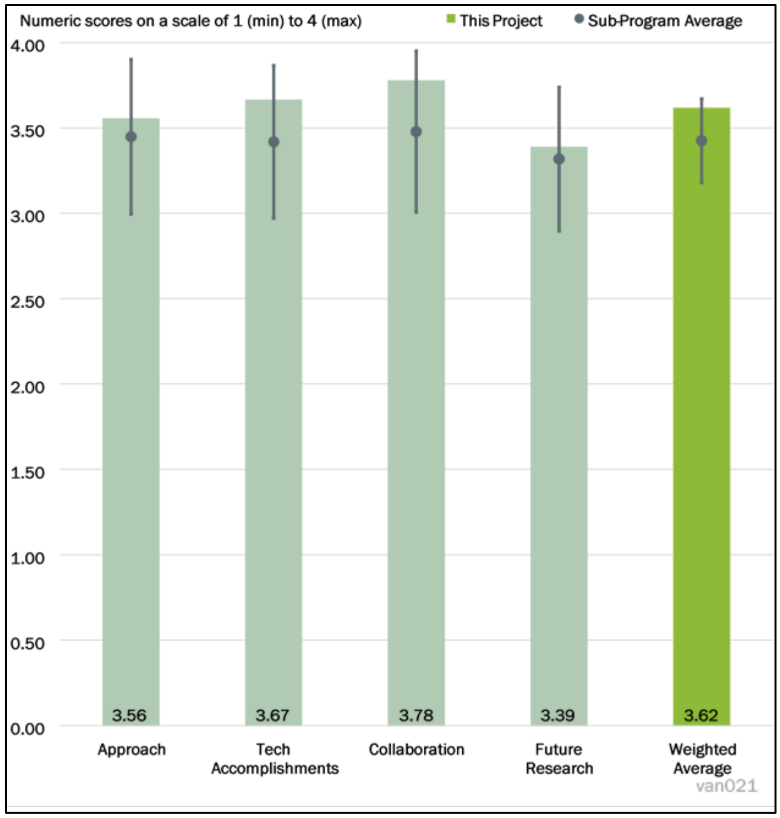


Figure 8-1 - Presentation Number: van021 Presentation Title: Transportation Energy Evolution Modeling (TEEM) Program Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

Presenter

Zhenhong Lin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of nine reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 89% of reviewers felt that the resources were sufficient, 11% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer applauded the research team for helping advance transportation decarbonization across the United States. The reviewer noted that the tools have been used in multiple decarbonization and policy studies and provide the rigor and ease-of-use that a lot of decision-makers seek. The reviewer stated that there simply are not enough similar tools that are publicly available.

Reviewer 2:

The reviewer said that the project team’s approach to exploring these issues is sound, and that it utilizes existing VTO modeling resources and expands/improves where necessary. The reviewer added that integrating a few of the models (Market Acceptance of Advanced Automotive Technologies [MA3T]; Greenhouse gases, Regulated Emissions, and Energy use in Transportation [GREET]; and VISION) is an excellent way to assess carbon neutrality scenarios without having to develop a new modeling framework.

Reviewer 3:

Although the stated TEEM goal includes addressing issues related to equity as well as employment, it was unclear to the reviewer how these are addressed in research.

Reviewer 4:

The reviewer mentioned that in general the project team has done a good job applying best practices in its modeling. The reviewer expressed two concerns. The reviewer explained that the first is the extent to which modeling uncertainty is passed through each of the sub-models. The reviewer asked how the uncertainty in the mode choice model is passed through to other models, and how sensitive, for example, the results on Slide 8 are to uncertainty in underlying models. The reviewer's second concern is that it might be worth attempting to validate the upper bound of the projection scenarios based on upper limits of expected production capacities, as the scenarios seem very ambitious.

Reviewer 5:

The reviewer stated that the objectives were clearly explained, and that the use of tools including MA3T, GREET, and VISION was explained and appropriate for the task. The reviewer added that carbon neutrality analysis was clear, and that meaningful scenarios were presented. The reviewer suggested more clarity in the description for internal combustion engine vehicles (ICEVs) and "other" categories to articulate where gasoline and diesel fall. The reviewer clarified that ICEV was described as gasoline and "other" as diesel and natural gas (NG) ICE and said that this is not intuitive and should be clearly defined.

Reviewer 6:

The reviewer noted that the approach is sound, but that it could have more emphasis on sensitivity analysis and uncertainty in some of the factors driving adoption. The reviewer remarked that the data driving the model are based on empirical data that may be less relevant going forward in a rapidly changing system. The reviewer indicated that the regional considerations and Truck choice model are valuable additions.

Reviewer 7:

Overall, the reviewer observed a well-reasoned approach that addresses barriers. The reviewer expressed slight confusion over the 2050 carbon neutrality analysis regarding the conclusions drawn—"Policy forcing and PHEV force out may be necessary." The reviewer stated that, while the results are an accomplishment, the approach incorporated scenarios that did not seem tied to potential and/or likely future policy scenarios. The reviewer indicated that any policy work that includes assumptions about future policy scenarios should be explicit about the basis.

Reviewer 8:

The reviewer noted that the project approach could be refined/improved to better align with project goals in assessing barriers to adoption or identifying mechanisms for reducing these barriers. Carbon neutrality policy results are interesting but rely on existing model outputs, and do not address underlying data issues or seem to endogenize any feedback effects of these pricing strategies on travel demand. The reviewer remarked that choice modeling for trucks should consider vocational differences to better reflect operational demands on purchase decision-making. The reviewer commented that the approach could also be improved by considering the impacts of reductions in criteria pollutant emissions near roadways with respect to regional air quality attainment targets. The reviewer remarked that the charging infrastructure model should include regional arterial and local traffic and should address additional/restorative investments required in historically disadvantaged communities. The reviewer indicated that it is unclear how the proposed Transportation Energy Evolution Modeling (TEEM) approach assesses equity in the context of adoption.

Reviewer 9:

The reviewer stated that the research builds on eight previous models that explore things like vehicle and transportation mode choice, battery electric vehicle (BEV) performance, charging infrastructure, and industry actions. The reviewer commented that recent studies have focused on the impacts of fast charging on BEVs, from both a performance side (in terms of capacity fade from fast charging) and impacts on adoption. The reviewer indicated that it is not clear whether the range considered is the vehicle highway range, or a general range with more city driving (where efficiency improvements and regenerative braking have a substantial role in increasing the vehicle range). The reviewer remarked that more detail could be given about how the models were updated in the most recent years.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Numerous accomplishments are recorded by the presenter and it appeared to this reviewer that good progress has been made.

Reviewer 2:

The reviewer stated that the project team outlines several research products and model improvements.

Reviewer 3:

The reviewer remarked that the project team has numerous publications (including many collaborative efforts) and updates to models to include truck choice models and overall GHG impact analyses.

Reviewer 4:

The reviewer indicated that the team has accomplished quite a lot in just 1 year.

Reviewer 5:

The reviewer noted that progress is on schedule and deliverables are being met.

Reviewer 6:

The reviewer remarked that the performers have made progress and are on track to meet goals.

Reviewer 7:

The reviewer said that the scope is large, but the milestones are on track. The reviewer remarked that the project team has a very productive record of publications, and that the inclusion of emerging mobility, charging infrastructure, mobility choice, and multimodal travel models is important. The reviewer commented that equity was listed, but could be expanded beyond employment considerations.

Reviewer 8:

The reviewer commented that the project is on schedule according to the milestone table, and that it has several excellent accomplishments, including linking up multiple modeling frameworks across different labs to complete a carbon neutrality analysis, publishing a paper on workplace charging, assessing the value of extreme fast charging, and further developing the TruckChoice model. The reviewer added that integrating MA3T, GREET, and VISION is a technical accomplishment on its own, but that it would have been interesting to hear more specifics about the carbon neutrality assumptions and results. The reviewer found that it is difficult to gauge the rigor of the carbon neutrality scenario assumptions and methodology and suggested that additional explanation/proof would be helpful in assessing the completeness of the related tasks. The reviewer remarked that there are some similar gaps in the explanation for the other projects, and that it seems like the project may be a bit spread thin working on multiple, not clearly linked, fronts.

Reviewer 9:

The reviewer asserted that that the TruckChoice model is desperately needed in the public space.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project team has collaborated with many companies and other researchers on studies of different aspects of transportation.

Reviewer 2:

The reviewer indicated that the Principal Investigator (PI) is actively collaborating with a wide range of stakeholders, including other national laboratories, academia, and industry.

Reviewer 3:

The reviewer remarked that there appears to be excellent collaboration across multiple entities on this project.

Reviewer 4:

This reviewer reported that the presenter indicates a significant amount of collaboration between industry, academia, government, and lab organizations in support of a variety of topics within the TEEM models.

Reviewer 5:

The reviewer reported that the collaborations are meaningful and reasonable, and suggested including some fleets to provide industry relevance and feedback.

Reviewer 6:

The reviewer observed that the presentation nicely mapped out the many connections and collaborations and how they are related. Slide 14 was helpful.

Reviewer 7:

The reviewer remarked that the PI and the project team do an excellent job collaborating across the government, industry, and academia.

Reviewer 8:

The reviewer stated that Oak Ridge National Laboratory (ORNL) projects are tied well to multiple collaborators. It was difficult for this reviewer to assess the efficacy/role of collaborators; based on outcomes, they seem to play an equal and appropriate level of involvement. The reviewer added that one of the noted barriers is data availability for heavy-duty (HD) electrification, which seems like it may be a problem for a number of researchers within the VTO portfolio, and suggested that perhaps coordinating or leveraging existing partnerships could help solve that. The reviewer said that it is great to see the emphasis on publications and software being made publicly accessible.

Reviewer 9:

The reviewer observed a large project team. Given the range of international participation, the reviewer suggested that it would be good to see how this work is being translated or applied in other contexts.

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 state project ended.

Reviewer 1:

The reviewer remarked that future research is planned well.

Reviewer 2:

The reviewer looked forward to the public release of as many of the models in TEEM as possible.

Reviewer 3:

The reviewer reported that future research plans appear sound.

Reviewer 4:

The planned next steps seemed logical to the reviewer, but more detail would have been helpful. The reviewer suggested expanding on the impact of different policy avenues.

Reviewer 5:

The reviewer noted that the future research plan is good. The reviewer was interested to see further work with the MA3T TruckChoice model applied to medium-duty (MD) and HD commercial vehicles. The reviewer encouraged consideration of selected off-highway equipment after commercial vehicles (CV) are modeled. The reviewer stated that a question was raised about making a version of the model available to the public for use, but that there are no plans to do so formally, but the team can make it available on a special request basis. The reviewer encouraged making a public version available.

Reviewer 6:

The reviewer suggested that the project team should consider placing additional focus on infrastructure costs and planning in low income and historically disadvantaged communities. The reviewer noted that the scope of impacts should be refined/expanded with respect to air pollution impacts, potentially linking cost-effectiveness with pollution-related health cost impacts. The reviewer suggested further work on the implications of coronavirus disease 2019 (COVID-19) and growth in last-mile goods movement as well as its implications on cost effectiveness and adoption.

Reviewer 7:

The reviewer found the study objectives for the plug-in hybrid vehicle (PHEV) and BEV study to be somewhat ambiguous. The reviewer asked if the project team will focus on cost, environmental impacts, and/or emissions. The reviewer remarked that the presentation also touched on the ability to examine jobs as one area of study, although how this is incorporated into the existing models is somewhat unclear. The reviewer suggested that the equity models seem to need additional modeling capabilities.

Reviewer 8:

The reviewer stated that the future research that is part of the current project (Quarter [Q] 3 and Q4 milestones) was not clearly explained. The reviewer added that other future research items appear to be reasonable modeling pursuits, but that it is not clear whether these were specifically requested by VTO or if they are ideas from the PI.

Reviewer 9:

Proposed work, as described, was somewhat vague to this reviewer, who noted difficulty in determining if future work is planned effectively.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer indicated that yes, this work supports DOE energy-specific advancement objectives in vehicles and transportation systems and informs VTO's direction for potential and future research investments.

Reviewer 2:

The reviewer noted that this study does address policy-relevant planning questions with respect to climate and emissions reduction targets as well as technology development.

Reviewer 3:

The reviewer remarked that simple models examining different adoption patterns and their estimated environmental impacts are an important toolset to have.

Reviewer 4:

The reviewer asserted that the project clearly works toward developing data-driven, advanced transportation analysis tools (e.g., TEEM, MA3T, TruckChoice, and REVISE) to answer critical questions and create insights about energy use and other metrics.

Reviewer 5:

The reviewer indicated that there are multiple contributions through a variety of models that can be used by different organizations to model a wide variety of impacts of future vehicle technologies.

Reviewer 6:

The reviewer said that, yes, the work provides a better understanding of the scenarios for deployment of alternative propulsion systems in achieving GHG objectives.

Reviewer 7:

The reviewer commented that the work is very relevant to the VTO mission and beyond. Further, the presentation laid out the relevance very nicely and tied together various pieces with the broader goals.

Reviewer 8:

The reviewer observed that the work by TEEM is directly relevant to the work of the U.S. Department of Energy (DOE), offering insights into the energy transition and market adoption.

Reviewer 9:

No comment was indicated 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 stated that significant project funding has been provided, but that it supports a large team with several collaborative initiatives.

Reviewer 2:

The reviewer indicated that the project supports multiple models that need continuous improvement, along with new collaborative analyses using those tools.

Reviewer 3:

Sufficient project resources were observed by this reviewer to achieve the stated milestones. Progress has been made in a timely manner to date and should be expected to continue with given resources.

Reviewer 4:

The reviewer observed that, given the accomplishments of just 1 year, the proposed future work appears feasible to be completed in the following year under the current budget plan.

Reviewer 5:

The reviewer remarked that no barriers were identified.

Reviewer 6:

The reviewer said that the level of funding seems about right for the project scope and significance.

Reviewer 7:

The reviewer indicated that the resources are adequate and appropriate.

Reviewer 8:

The reviewer noted that there is an increasing need for publicly available tools to help policy makers and decision-makers at the local, state, and federal levels. The reviewer would have liked to see an expansion and acceleration of the modeling tools in TEEM, if possible.

Reviewer 9:

The reviewer reported that resources appear sufficient to meet the stated milestones, but that it seems like there are also several other tasks going on in parallel (not in the milestones). The reviewer added that this could be a misunderstanding based on the presentation being slightly disjointed; if not, then there is a risk that the team could become overwhelmed with tasks adjacent to the milestones.

Presentation Number: van028
Presentation Title: Electric Vehicle (EV)-Grid Analysis Modeling
Principal Investigator: Srinath Ravulaparthy (Lawrence Berkeley National Laboratory)

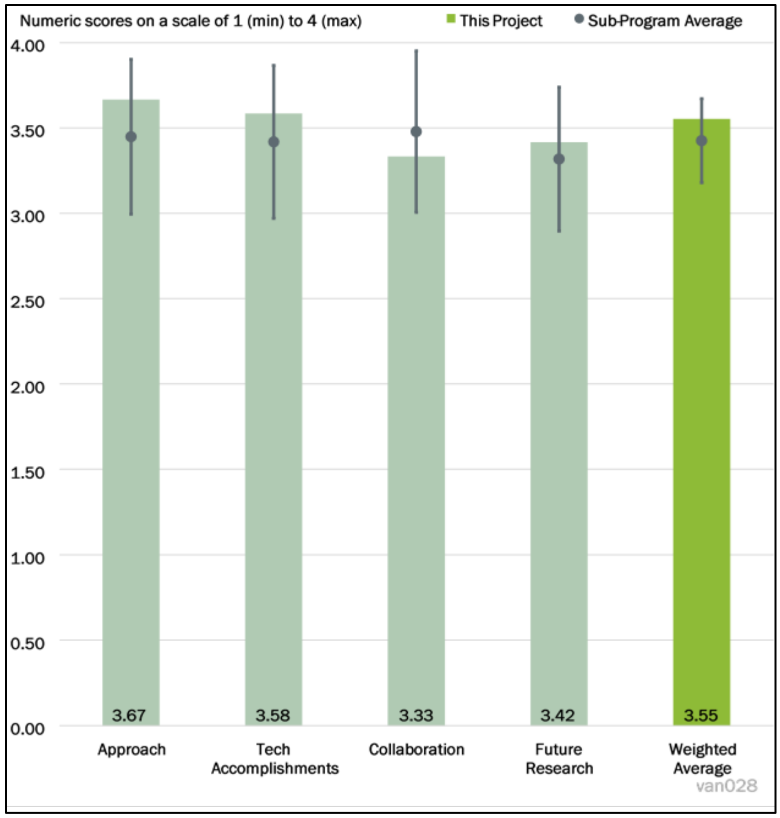


Figure 8-2 - Presentation Number: van028 Presentation Title: Electric Vehicle (EV)-Grid Analysis Modeling Principal Investigator: Srinath Ravulaparthy (Lawrence Berkeley National Laboratory)

Presenter

Srinath Ravulaparthy, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer observed a well-designed and well-planned project. Inclusion of micromobility in the GEM model is novel and has value for communities considering modal shift opportunities.

Reviewer 2:

The reviewer stated that the project has two parallel components—freight truck electrification and micromobility—each with a grid impact analysis. The reviewer added that the team's approach—using the Greenhouse gas Emissions Model's (GEM) Truck Electrification component to scale up truck advanced technology impacts and GEM's micromobility component to assess potential modal shifts—sufficiently bridges the gap between the data (truck advanced technology assumptions and National Highway Travel Survey [NHTS] travel data) and national-level environmental and cost impacts. The reviewer said that the inclusion of GEM's grid modeling capabilities further addresses the technical barriers to accurately model such a complex system by ensuring that transportation impacts are not estimated in isolation.

Reviewer 3:

The reviewer noted that the project is ambitious, but that the methodology is straightforward, and the team has thus far done a good job executing the project.

Reviewer 4:

The reviewer observed that this is a good approach to include micromobility vehicles in addition to shared and freight trucks.

Reviewer 5:

The reviewer reported that the project has a straightforward approach to answering important questions about both emerging mobility and understudied modes, and their potential interactions with the grid. The reviewer added that the GEM model is uniquely positioned to tackle these questions, and that there is high value in building out the relevant components.

Reviewer 6:

The reviewer stated that the bottom-up modeling work is deeply granular, and that it offers a robust approach that clearly provides nuanced results.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that Q1 and Q2 milestones are marked complete, and that the remaining milestones are marked as on schedule. The reviewer noted that the heavy-duty vehicle (HDV) accomplishment slides show results from the battery technology/capacity scenarios, but that it would have been helpful to see the actual battery assumptions and range results that were developed to meet the Q1 milestone. The reviewer stated that these are of particular interest in studies of freight truck electrification, as the freight truck market is fragmented, and it is difficult to develop simple "average battery specs" that apply across the board. The reviewer added that the accomplishment clearly suggests the project is on track to meet the future milestones, as the milestones do not require the battery technology/capacity/range scenarios to be vetted. The reviewer observed that the micromobility accomplishments clearly show completion of the Q2 milestone and progress toward the final (Q4) milestone, although, again, it would be helpful to see the reasoning behind some of the scenario assumptions. The reviewer reported that it is great that the team has published results and is working to make GEM more available to the public to encourage transparency and reproducibility of the results.

Reviewer 2:

The reviewer said that, to date, the progress is very good, and applauded making the model openly available on GitHub.

Reviewer 3:

The reviewer reported that the research team has made progress and the plan is on schedule. Additionally, accomplishments related to computational efficiency improvements are noteworthy.

Reviewer 4:

The reviewer stated that the progress is on schedule.

Reviewer 5:

The reviewer said that the project is on track and has produced interesting results to date. The reviewer highlighted that most of the work to date has been on building out the new model components, and looked forward to the published results for HDV and micromobility.

Reviewer 6:

The reviewer asserted that the performers are hitting project milestones on time, and that results for both HDV and micromobility are provided. The reviewer recommended that takeaways be included on the accomplishments slides in the future. The reviewer noted that it is great to see micromobility modeled in

GEM, and that it is particularly interesting, given modal shift opportunities. The reviewer stated that the HDV charging load is equally important; however, the implications of the results are unclear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted good collaboration across the team.

Reviewer 2:

This reviewer remarked that collaboration between LBNL and UC Davis appears to be sufficient for project success.

Reviewer 3:

The reviewer reported that the team is collaborating with other national laboratories as well as academia. The reviewer stated that the approach has been developed with an eye to others who may use the work. The reviewer said that the GEM model has been made open source to allow for users to customize scenarios.

Reviewer 4:

The reviewer expressed that the collaboration between Lawrence Berkeley National Laboratory (LBNL), University of California at Davis (UC Davis), and Marain Inc. is clearly effective, as it leverages the expertise of all participants and is well coordinated. The reviewer was glad to also see that an open-access version of GEM has been published and includes a user tutorial.

Reviewer 5:

The reviewer stated that the collaboration with universities and national laboratories is mentioned. This reviewer would have liked to see more collaboration with fleets or industry to gather relevant feedback and perspective on the issues related to deployment in the micromobility space and other applications.

Reviewer 6:

The reviewer observed that the collaboration with the University of California, Davis (UC Davis) and Marain was not discussed beyond the quad chart slide. The reviewer suggested that it would be beneficial to summarize the different collaborators' roles and responsibilities.

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 state project ended.

Reviewer 1:

The reviewer observed that future work—beyond meeting the remaining milestones—was not very clearly explained. However, what was stated appears to imply that ride-hail electrification could be added; and that modeling results will be validated and vetted to ensure the results are "finalized." The reviewer said that these are logical next steps.

Reviewer 2:

The reviewer remarked that the proposed future research continues to focus on emerging mobility and would be a worthwhile effort. The reviewer added that the multimodal integration is an especially interesting avenue to explore.

Reviewer 3:

The reviewer noted that the current research is well planned, and that the proposed future research is in keeping with that.

Reviewer 4:

Proposed work is appropriate and effectively planned in a logical manner from this reviewer's perspective. Researchers should consider targeting distribution of information related to micromobility research to the urban transportation planner sector.

Reviewer 5:

The reviewer indicated that, overall, the future work plan seems solid. The reviewer expressed concern about the specific choices for scenario analyses, as there are quite a lot of variables that will be incorporated into this framework, and it is unclear whether any generalizable findings will result, given the potentially large amount of scenario analyses that might be needed.

Reviewer 6:

The reviewer said that freight movement is focused on long haul. The reviewer suggested that consideration be given to MD package delivery and autonomous package delivery (drones) for last-mile delivery, as these are expected to be entry points for semi-autonomous and autonomous vehicles, as well as electrified powertrain systems. The reviewer encouraged that, for completeness, some study of the adoption rates of e-bikes, forecasts and scenarios for deployment, and the role that they could play in the micromobility sector.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that the project supports overall DOE objectives in that it aims to extend DOE vehicle technologies benefit analysis to include the upstream costs and benefits of EVs to the grid.

Reviewer 2:

The reviewer noted that this project is primarily focused on using data to build, maintain, and expand DOE VTO modeling capabilities to generate impactful analysis, particularly analysis of transportation electrification impacts on the grid.

Reviewer 3:

The reviewer said that, yes, this project has a lot of relevance for real-world decisions made by state and local governments, e.g., how to plan for the needed future charging infrastructure.

Reviewer 4:

The reviewer observed that this program is relevant to the overall objectives.

Reviewer 5:

The reviewer noted that this project is very relevant to DOE objectives, with good focus on high-priority areas that will be broadly useful for decision-makers as well as other modeling efforts.

Reviewer 6:

The reviewer stated that, yes, this work is deeply relevant to the overall objectives of DOE. The reviewer added that, as electric vehicles (EVs) become more prevalent, they will inherently play a role in the grid. Quantifying the costs and benefits allows VTO to better articulate the value of its technical work or make different decisions based on the outcomes of modeling.

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

Reviewer 1:

Resources appeared sufficient to this reviewer for the project to achieve stated milestones in a timely fashion.

Reviewer 2:

The reviewer reported that the resources are sufficient considering the scale of the project.

Reviewer 3:

The reviewer said that the resources are adequate.

Reviewer 4:

The reviewer indicated that the resources appear to be sufficient, although the presenter mentioned that the original PI has moved on.

Reviewer 5:

The reviewer had no additional comments on resources as the budget seems sufficient.

Reviewer 6:

The reviewer noted that no resource constraints were identified.

Presentation Number: van034
Presentation Title: Medium- and Heavy-Duty Vehicle Choice Modeling and Applied Analysis
Principal Investigator: Alicia Birky (National Renewable Energy Laboratory)

Presenter

Alicia Birky, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

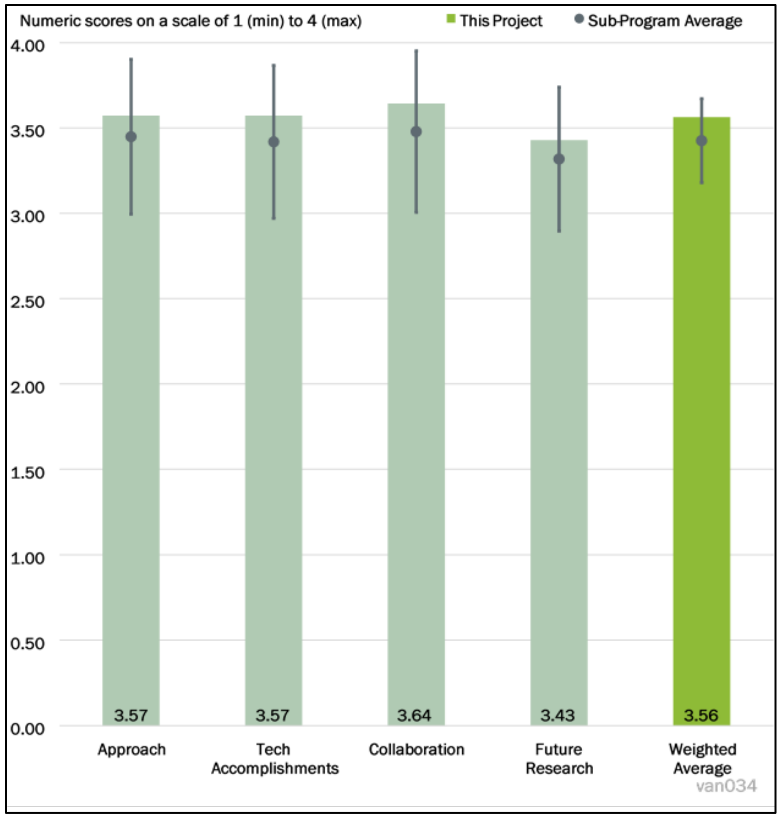


Figure 8-3 - Presentation Number: van034 Presentation Title: Medium- and Heavy-Duty Vehicle Choice Modeling and Applied Analysis Principal Investigator: Alicia Birky (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project incorporates multiple modeling approaches to estimate the adoption of alternative powertrains in the MD and HD sectors. The reviewer added that the pilot models have focused on Class 8 vehicles because of their share in overall energy use. The reviewer mentioned that the use of multiple modeling strategies is one way to hedge against the uncertainties associated with how vehicles are adopted in the MD and HD segments, which are under-studied relative to light-duty vehicles (LDVs). The reviewer noted that there is some mention of perhaps combining the approaches from both TRUCK and Automotive Deployment Options Projection Tool (ADOPT), although the exact method for doing so is uncertain. The reviewer indicated that the performance parameters for the new technologies (BEV and fuel-cell electric vehicle [FCEV]) have generally improved in recent years, and it seems like there is more collaboration between the offices, which helps to improve the input assumptions. The reviewer observed that, for the BEV segment, it seems like the useable state of charge (SOC) window is a bigger factor in changing the overall cost of BEVs in the long term (approximately 2040–2050) than the cost of the batteries, which may be something to explore. The reviewer said that the process for developing scenarios is generally a bit limited given a significant reliance on Annual Energy Outlook (AEO) assumptions.

Reviewer 2:

The reviewer indicated that the approach to handling the MD and HD VTO benefits analysis—using the legacy modeling framework while developing a new and potentially more capable framework that is consistent with that used in the LDV analysis—is reasonable and appropriately navigates the opposing risks of redundant work (parallel models) and using a model that is not ready (ADOPT). The reviewer added that the team clearly understands how complex the freight truck market is, and is implementing an approach and methodology (i.e., a focus on adding Class 8 tractors to ADOPT first, rather than all trucks) that can be thoroughly executed in the project timeframe without unworkable data availability issues. The reviewer mentioned that it was also scoped to ensure that the model adds the largest energy consumer first, and that the approach includes Future Automotive Systems Technology Simulator (FASTSim) to help relate specific component-level technologies to the national-level benefits in TRUCK/ADOPT.

Reviewer 3:

The reviewer reported that the benefits estimation tool (ADOPT) is well suited to the MD and HD truck applications. The reviewer noted that the approach is sound in assessing total cost of ownership (TCO) and other benefits to decarbonization technology, and in enhancing modeling capabilities within the TRUCK choice model.

Reviewer 4:

The reviewer indicated that the approach and ADOPT framework were clearly laid out, and care was taken in the development of a new approach alongside the existing model. The reviewer expressed some concerns regarding the ability of this approach to adequately inform decarbonization pathways in the long term due to the lack of data and reliance on older data that does not seem representative of new technologies and emerging trends in the sector. The reviewer remarked that the program scenario has low BEV penetration compared to other modeling efforts.

Reviewer 5:

Project is well-designed and well planned, representing strong analytical work in the MD and HD sectors.

Reviewer 6:

The reviewer noted that the approach to performing the various objectives is well reasoned and addresses barriers.

Reviewer 7:

The reviewer remarked great use of multiple models to incorporate HD trucks into the ADOPT framework. The reviewer expressed concern (as with many of these projects) about passing uncertainty through to model outputs. The reviewer added that there can be large uncertainty from choice models, and it is important to enable the modeler to pass that uncertainty through to further downstream outputs of the analyses, like emissions impacts. The reviewer encouraged scenario analyses where it is asked what needs to happen to achieve a climate goal, like fully zero-emission vehicles (ZEV) in HD applications by 2050. The reviewer asked if there is any scenario where this might be even remotely feasible, and stated that this could be assessed using these tools.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the project appears to be on track to meet all milestones. The reviewer mentioned that the modifications to ADOPT have enabled Class 8 tractor vehicle choice modeling in a similar fashion to the LDV methodology (as targeted in the approach), and that further research has identified a potential "next group" to add to the model (Class 4-6). The reviewer added that TRUCK modifications have expanded its flexibility to continue as a comprehensive MD and HD benefits analysis tool until ADOPT is fully set up. The reviewer noted that the team has completed the 2020 benefits analysis, including all of the inter-office coordination on input assumptions (VTO and Hydrogen and Fuel Cell Technologies Office [HFTO]) as well as the modeling and validation of results. The reviewer remarked that this is a substantial accomplishment, given the amount of model improvement and modification that is going on in parallel.

Reviewer 2:

The reviewer noted the project has made good progress toward overall project goals, with numerous accomplishments presented within the project's Fiscal Year (FY) 2020 analysis results.

Reviewer 3:

The reviewer observed that the project team made very reasonable assumptions given limited data.

Reviewer 4:

The reviewer stated that progress appears to be on track, and that interesting scenario results were presented.

Reviewer 5:

The reviewer indicated that the project is on track to update the MD/HD capabilities of ADOPT. The reviewer added that the ability to run LD and HD scenarios in the same interface, generate consistent LD and HD benefits analysis, and improve the quality of the MD/HD results by adding additional market segments is a significant accomplishment. The reviewer reported that other project goals, including maintaining and enhancing legacy models and generating benefits analysis results, are on track and are generating significant improvements.

Reviewer 6:

The reviewer noted that the project team has made good progress to expand the MD and HD segments of the TRUCK and ADOPT models, and that the focus on specific market segments as a pilot study is a good choice. The reviewer noted that there is documentation of model updates, but that analysis from the models is ongoing and the scope has shifted given the administration's priorities.

Reviewer 7:

The reviewer remarked that progress is on track and looked forward to the draft technical paper describing MD/HD ADOPT updates and enhancements. The reviewer noted the following and asked the questions below:

- Slide 10 refers to the validation of results. Please expand on the extent of the validation and the process for validating. Is there a comparison to real-world data for validation purposes?
- Slide 11 shows sources of data for Class 4–8 adoption rates, but these sources are old. Are there more recent data on which to assess adoption rate in the MD and HD segments?
- Slide 14 shows an inflection near 2040, later described as related to the hydrogen (H_2) fuel price. Please add this explanation to the report.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the modeling team has experience from other vehicle choice models and has partnered with the Bioenergy Technologies Office (BETO) and HFTO to incorporate technology parameters. The project is also part of other, broader HDV efforts.

Reviewer 2:

The reviewer observed great collaboration.

Reviewer 3:

The reviewer remarked that there are good collaboration partners, including 21st Century Truck Partnership stakeholders.

Reviewer 4:

The reviewer observed that the project is inherently deeply collaborative, requiring the input of DOE's technology program managers, as well as of DOE partnerships. The reviewer added that the performers are clearly coordinating effectively considering progress to date.

Reviewer 5:

This reviewer reported that the project represents collaboration within DOE Sustainable Transportation units—VTO, Hydrogen and Fuel Cell Technologies Office, and Bioenergy Technologies Office—and also represents a connection to the 21st Century Truck Partnership.

Reviewer 6:

The reviewer stated that the team has regular meetings with collaborators and solicits input. It was somewhat unclear to the reviewer, however, what the connections are between this effort and others in the MD and HD spaces, including other scenario modeling, adoption modeling, and improving cost and other assumptions.

Reviewer 7:

The reviewer noted that this project would not be successful without tight integration and collaboration with VTO, HFTO, and BETO Program Managers and what can, at times, be somewhat conflicting goals in terms of market penetration. The reviewer remarked that the National Renewable Energy Laboratory (NREL) team expertly walked this line for the 2020 analysis. The reviewer remarked that it would be interesting if the team could do scenarios for each office's "dream" case, rather than trying to balance all of the offices' targets. The reviewer reported that the likelihood of simultaneous success for the three offices' competing long-term MD and HD goals—full electrification (VTO), an H_2 economy (HFTO), and biodiesel/other (BETO)—is slim.

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 state project ended.

Reviewer 1:

The reviewer noted that the planned future research is logical and has clear decision points.

Reviewer 2:

The reviewer indicated that the presenter shares a clear and thorough description of appropriate future research, with a recognition of data availability weakness concerns.

Reviewer 3:

The reviewer indicated that the specific future tasks were laid out by year in a clear manner. The reviewer observed that further research into the various MD and HD segments is valuable, but that the importance of this work to long-term decarbonization analysis is unclear. The reviewer encouraged more policy scenarios integrated with technology.

Reviewer 4:

The reviewer asked, regarding benefits analysis, what the economic/policy conditions under consideration are. The reviewer asserted that there are a couple of possible policy impacts (and there is probably more guidance with administration priorities), but that the economic condition models are a bit more uncertain. The reviewer asked if these conditions focus on the rate at which technologies improve, costs fall, or something else. The reviewer added that these are also important to include for the FY 2022 scenario developments. When it comes to modeling, the reviewer asked if there are opportunities to bin similar vehicle types into categories to streamline the model expansion process.

Reviewer 5:

The reviewer expressed concern regarding the limited data availability that was noted, which could be a big barrier to the success of this project.

Reviewer 6:

The reviewer encouraged more details on the factors affecting adoption rate for the new technologies model and the cost trends that could influence adoption.

Reviewer 7:

The reviewer started that the remainder of FY 2021 tasks is logically mapped out, although it is not clear how the team plans to balance all three offices' unique (and not always entirely overlapping) approaches to decarbonizing the MD and HD space. As mentioned elsewhere in this review, the reviewer suggested separately modeling each office's approach, assuming that the three have not collaborated in terms of mapping out different modes or truck types. The reviewer added that the team has incorporated an appropriate decision point regarding the development progress of ADOPT, at which point TRUCK will continue being used if ADOPT is not ready later in FY 2021.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer commented that the researcher presents a clear correlation between project activities and DOE VTO Analysis goals.

Reviewer 2:

The reviewer stated that the modeling approach is already in use for LDVs and could be integrated into broader analyses of transportation emissions.

Reviewer 3:

The reviewer indicated that the PIs provided a slide explicitly cross walking the goals of their project to the Vehicle Analysis Program's overarching goals. The reviewer reported that the project aims to improve VTO's suite of modeling tools (specifically TRUCK, HDStock, ADOPT) to enable more accurate and comprehensive assessment of the potential benefits from broader VTO technology programs.

Reviewer 4:

The reviewer noted that the combination of FASTSim and ADOPT is beneficial for multiple aspects of techno-economic modeling.

Reviewer 5:

The reviewer observed that this is a good study of relevant alternative technologies to support decarbonization in the MD and HD truck sectors.

Reviewer 6:

The reviewer mentioned that the project has high relevance to VTO priorities. Generally, the MD and HD sectors need more attention, and the focus here on benefits analysis will help move things forward.

Reviewer 7:

The reviewer indicated that this work is directly relevant to DOE objectives—estimating the benefits of technological investments through energy and emissions 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 indicated that the project supports multiple modeling efforts, and has ambitious goals for improving the scenarios analyzed.

Reviewer 2:

The reviewer noted that the staff resources are sufficient and fully capable of completing the work, and added that both PIs have years of experience in these specific models and VTO benefits analysis more generally.

Reviewer 3:

The reviewer had no additional comments on resources as the budget seems sufficient.

Reviewer 4:

Given the diversity of this sector, the reviewer suggested that fleshing out the details across segments is a big task that likely warrants the high cost.

Reviewer 5:

The reviewer observed appropriate resources.

Reviewer 6:

The reviewer noted sufficient resources for the project to achieve its stated milestones in a timely fashion.

Reviewer 7:

The reviewer remarked that several barriers exist but do not appear to be related to resources. The reviewer suggested more collaboration with industry, including technology developers, to address the need for additional information related to cost-effective solutions.

Presentation Number: van035
Presentation Title: Assessing Vehicle Technologies Benefits in a Transportation Energy Ecosystem
Principal Investigator: Vincent Freyermuth (Argonne National Laboratory)

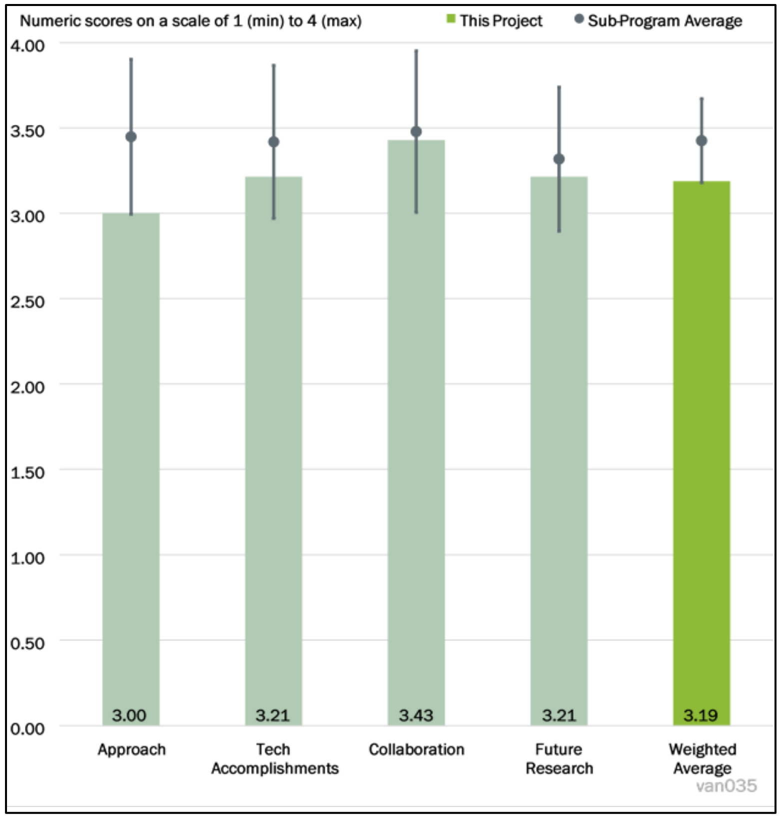


Figure 8-4 - Presentation Number: van035 Presentation Title: Assessing Vehicle Technologies Benefits in a Transportation Energy Ecosystem Principal Investigator: Vincent Freyermuth (Argonne National Laboratory)

Presenter

Vincent Freyermuth, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the approach was clearly described and appropriate to the task. The reviewer remarked that the use of the Planning and Operations Language for Agent-based Regional Integrated Simulation (POLARIS) model suits the analysis objectives, and that the selection of vehicle and powertrain configurations are appropriate for the MD and HD truck applications noted. The reviewer observed, that while too early for large-scale deployment, consideration of FCEVs would be appropriate, and suggested it as a future addition, recognizing that this is not an issue for plug-in charging infrastructure.

Reviewer 2:

The reviewer indicated that the POLARIS model is very valuable for understanding the broader system-level effects and network interactions. The reviewer added that the main question would be if the level of detail and computing resources needed are worth the added granularity, especially as the results might be city specific.

Reviewer 3:

This reviewer described the project as well designed. Regarding objective 2—EV Penetration and Utilization of Charging Stations—the study's definition of "Street Charging" does not seem to relate to real-world charging application or current charging infrastructure proliferation.

Reviewer 4:

The reviewer stated that both objectives—MD/HD cost of driving minimization impact to market share and PEV penetration impact to charging stations—utilize robust methodologies. The reviewer suggested, however, that the framing and approach of the PEV penetration impact work led to somewhat less interesting results. The reviewer noted that the outcomes of constrained, compared to unconstrained, charging align with expectations. The scenarios of low/high ownership and home chargers add little nuance to our understanding of penetration and charging dynamics.

Reviewer 5:

The reviewer stated that the model includes good data on energy consumption for different vehicle types using Autonomie. The reviewer suggested that a weakness of the model is the lack of detail on the charging speed, which would have a substantial impact on the cost of charging, but also may be extremely relevant for drivers (especially commercial drivers). The reviewer remarked that a queuing function to schedule charging at public stations would help with some modeling of the electricity load, but the way that costs are calculated does not incentivize any fast charging, which does not seem to match with observed behavior. The reviewer suggested that because the objective of this work is to examine how charging contributes to an overall energy system, it would be useful to adapt the model to look at different charging speeds, especially for public charging.

Reviewer 6:

The reviewer said that, as the presenters noted, the research involves a large number of simulations, which is computationally quite expensive. However, the reviewer remarked that some of the main results from these simulations are somewhat intuitive, so it is unclear what new insights are being gained from these exercises. The reviewer suggested that concluding that home charging is the most desirable alternative for EV owners, for example, and that, when constrained, those drivers will charge out of home is not particularly surprising. The reviewer raised concerns about the benefits of these exercises given the computational cost. The reviewer added that there did not appear to be a choice model backend to the model, which is problematic in terms of modeling adoption patterns. Also, the reviewer noted that there are limited behavioral aspects in the simulations, and that missing these aspects may significantly limit the validity of the simulation results.

Reviewer 7:

The reviewer stated that the project appears to be targeting a "micro" VTO benefits analysis, where rather than using nationally representative drive cycles to estimate energy and costs, the team is using simulated drive cycles in Chicago. The reviewer mentioned that the approach to meeting the main problem statement and questions (Slide 3)—use an agent-based, high-resolution model (POLARIS) to simulate "real-world" behavior on a micro-scale—is reasonable. The reviewer added that the team uses Autonomie to generate different technology impacts by vehicle mode/type, which allows them to penetrate that micro-market and assess the energy and cost impacts.

The reviewer suggested that the steps following the generation of energy and cost impacts for Objective 1 are not as well reasoned and may not be representative of how fleets make purchase decisions. The reviewer indicated that the approach takes the model outputs and generates an "optimum powertrain distribution" based entirely on minimizing cost (i.e., vehicle purchase based entirely on an estimated cost of driving). The reviewer suggested that the issue is that this cost of driving was calculated based on a single route and duty cycle—some fleets purchase vehicles for dedicated routes and duty cycles, but most require some level of mission flexibility and would not buy, for example, a Class 8 electric refuse truck because it is the cheapest to operate on a specific 25-mile route. The reviewer observed that flexibility is critical for fleets, particularly when vehicles are in and out of the shop frequently (need a substitute while out) and/or routes change. When it comes to Objective 2, the reviewer highlighted that the approach—run an unconstrained scenario to inform charging infrastructure deployment, then run a constrained scenario with that infrastructure in place—is reasonable. The reviewer recommended that the team replace the somewhat vague "Machine Learning for Energy Consumption" step description with a more informative description.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the milestones are on track, and valuable technical progress has been made. The reviewer added that the light-duty (LD), MD, and HD results are interesting and make an important contribution.

Reviewer 2:

The reviewer asserted that both objectives—MD/HD cost of driving minimization impact to market share and PEV penetration impact to charging stations—are on track, and initial findings are interesting. The reviewer reported that the barriers are noted and, based on current progress, are likely to be overcome.

Reviewer 3:

The reviewer noted that technical tasks appear to have been well implemented.

Reviewer 4:

The reviewer indicated that the team has produced some estimates of vehicle adoption, and has established some assumption frameworks about the availability of at-home and public charging stations. However, the reviewer noted that the model of vehicle shares by fuel type is dependent on a simplified cost model that does not account for fast charging or other non-energy costs (or benefits) associated with EVs. The reviewer added that the model for the charging network does not include a time resolution, either for charging speed or for scheduling the charging of multiple vehicles looking to use the same charger. The reviewer observed that a queuing protocol was mentioned, but that additional details were not provided about how cars would make use of the shared resources.

Reviewer 5:

The reviewer mentioned that it would be interesting to get a broader view of the forces driving change in this market, and that considerations are given to regulatory drivers, policy, economics of technology advancement, TCO, or other. The reviewer added that charging categories were described as home and street charging, but noted that there are other categories that could be considered separately, such as workplace charging, fleet-domiciled vehicle charging, public DC fast charging, etc., to provide greater fidelity to the charging scenarios considered. The reviewer remarked that Slide 21 mentions that the share of highly electrified powertrains could be higher than assumed in previous studies and suggested that an explanation of the reasons why would be helpful. The reviewer encouraged the team to clarify the battery cost assumptions and forecast for battery cost decreases over time (based on volume increases or technology advancements).

Reviewer 6:

The reviewer stated that the team has successfully met past milestones and is on track to meet the remainder for both objectives. Regarding Objective 1, the reviewer suggested that there should be more explanation around the assumed vehicle class composition and simulated drive cycles in order to answer whether it is worth all of the additional computational power to generate and simulate these scenarios rather than simply relying on nationally representative values. The reviewer added that agent-based models like these provide an incredible amount of resolution in exchange for an incredible amount of input data. The reviewer suggested that, if validated and vetted input data are not available to fuel such a model and, thus, generating the data will be based on national averages, it is hard to see the added value of such a modeling framework. The reviewer suggested that additional thought or research could be dedicated to fleet and vehicle-miles traveled (VMT) distributions, and to the drive cycles. The reviewer said that there is also some overlap here with the comments on the approach above, but that the "share of electrified powertrains" based on cost-of-driving (Slide 10) is likely not a particularly accurate estimate of real-world response to the model's cost outputs. The reviewer reiterated their earlier point that fleets make purchase decisions based on their entire operations, not on single trips or routes. The reviewer suggested that the team should also include backup slides with the most important assumptions clearly displayed, e.g., battery cost projections for low and high technology cases. Regarding Objective 2, the reviewer reported that results of this analysis were fascinating, and that seeing the model respond to public charging constraints (agents "deciding" to charge at home rather than detour) was a helpful insight.

Reviewer 7:

Solid progress has been made, but it appeared to the reviewer that there is significant future work required and only one-third of the project budget remaining.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer reported good collaboration and coordination.

Reviewer 2:

The reviewer indicated that there is a good collaboration with national laboratories, the 21st Century Truck Partnership, and others.

Reviewer 3:

The reviewer commented that the collaboration across labs and the coordination with stakeholders is evident.

Reviewer 4:

The reviewer said that the cooperation and collaboration are outstanding as they include a diverse use of inputs and numerous stakeholders. The reviewer suggested a dialogue with the work at Pacific Northwest National Laboratory (PNNL) on charging availability (EVs at Scale).

Reviewer 5:

The reviewer observed that the team has some good collaborations with other organizations working to electrify the HD vehicle sector. However, the reviewer remarked that some additional partnerships, perhaps with local utilities, would be helpful if the goal is to work on transportation within the electricity/energy ecosystem. The reviewer mentioned that understanding the network of transmission lines and distribution feeders within the region studied is extremely important.

Reviewer 6:

Only project collaboration with the 21st Century Truck Partnership was observed by this reviewer; future work should seek to collaborate with other academia or lab teams.

Reviewer 7:

The reviewer stated that there does not appear to be much collaboration with partners in the MD and HD modeling, aside from pulling some input assumptions from DOE staff. The reviewer noted that the collaboration with NREL (Electric Vehicle Infrastructure Projection Tool [EVI-Pro]) appears to be working quite well and is producing interesting technical 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. Note: if the project has ended, please state project ended.

Reviewer 1:

With respect to Objective 1, the reviewer commented that future research is logically planned out, and that the team's aim to compare results of the relatively simplistic cost of driving market penetration models with standard VTO tools (e.g., TRUCK and ADOPT) is good. When it comes to Objective 2, the reviewer reported that future research includes several important considerations. The reviewer reiterated that the team should not use the term, "machine learning [(ML)] models," as a description for a process (as this could mean anything from fitting a trendline to implementing a neural network).

Reviewer 2:

The reviewer noted that there is a good plan for future research, particularly for the analysis of individual classes and applications, and the comparison of results with market penetration predictions. The reviewer recommended that in future work the team should consider workplace charging as separate from street or public charging.

Reviewer 3:

Proposed future research seemed significant to this reviewer and presents many variables to add to the study. Researchers should consider utility-provided load management scenarios in future work.

Reviewer 4:

The reviewer observed that the proposed future research seems appropriate. The reviewer encouraged more work on charging station type, location, and usage across MD and HD segments. The reviewer stated that the home charging piece is the most interesting, and wondered if the installation cost of home chargers matters, and if anything can be learned from these results from a policy perspective.

Reviewer 5:

The reviewer indicated that, for the MD and HD work, the proposed future research is well reasoned and planned. The reviewer added that, for EV penetration work, the proposed future research is similarly logical. However, the reviewer highlighted that the incorporation of behavioral models and station queuing emphasis, while important work, is predicated on a dataset and framing that seem slightly limited. The reviewer suggested questions that the researchers may want to ask: For example, how would a decision-maker interpret the results of this work for planning purposes? In a constrained low home charging situation, where do owners opt to charge? In turn, what is the feedback loop of charging availability on PEV purchasing?

Reviewer 6:

The reviewer observed that the project has produced some results regarding the possibility for fleet electrification, but that, overall, the results for the energy system services side are still somewhat lacking, and the path forward suggests using some workarounds to get around some fundamental challenges of the approach. The reviewer suggested that charging speed is very important to both the cost of charging and the impact on the electricity system, but noted that it is not included in the current model. The reviewer added that the move to include queuing is important to accurately estimate how charging infrastructure could be shared, but that it does not address the challenges associated with providing fast charging access at scale, especially if commercial vehicles are included.

Reviewer 7:

The reviewer expressed concern that the proposed future work might take longer to implement than the 1-year time frame left as it will involve considerable computational power as well as new, complex logic incorporated into the simulations.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the researcher presents clear correlation between project activities and DOE VTO Analysis goals.

Reviewer 2:

The reviewer stated that the questions this project aims to address are important, as local impacts to electricity grid infrastructure could have a substantial impact on the cost or availability of fast charging resources.

Reviewer 3:

The reviewer said that, yes, the project does in that it evaluates the impacts of existing VTO technologies.

Reviewer 4:

The reviewer responded that the project supports the objectives as stated on Slide 3.

Reviewer 5:

The reviewer asserted that the project has high relevance and uses a framework that allows for a detailed analysis of emerging vehicle modes and use patterns. However, the reviewer commented that the direction going forward should continue to carefully examine the project relevance. The reviewer wondered if other factors beside operating cost, alone, could influence route choice, and stated that it is unclear where policy fits in and how exactly the scenarios translate to the real world. The reviewer also wondered how battery size, range, and other vehicle attributes could play into the results on MD and HD. The reviewer cautioned that these could change quite a bit in the future scenarios.

Reviewer 6:

The reviewer said that, yes, assessing benefits of VTO investments in more nuanced ways is directly in line with DOE objectives.

Reviewer 7:

The reviewer mentioned that the team should clearly identify where this project fits into the VTO Analysis program’s specific goals and mission statement to save time for the reviewers. The reviewer highlighted some of the language from the Vehicle Analysis (VAN) goals, and how this project fits:

- “Provide critical information and analysis to inform VTO research portfolio planning ... including program benefit estimation.” This project appears to be targeted at estimated program benefits, and that is relevant.
- “Provide essential vehicle modeling and simulation and applied analysis ... integrate multiple models to yield useful findings.” (Autonomie, POLARIS, EVI-Pro).

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 for the project to achieve its stated milestones in a timely fashion.

Reviewer 2:

The reviewer said that the resources are adequate.

Reviewer 3:

The reviewer remarked that no barriers or resource constraints were identified.

Reviewer 4:

The reviewer stated that the PI is knowledgeable about Argonne National Laboratory's (ANL) vehicle analysis tools and appears to be capable of using them to complete the remaining milestone tasks.

Reviewer 5:

The reviewer observed that the project budget is sufficient, but suggested that resources could be redistributed to focus more on the electricity/energy systems side of the challenge.

Reviewer 6:

The reviewer observed that there are sufficient resources for the stated goals, but that the value of these detailed runs needs to be balanced with the high computing effort.

Reviewer 7:

The reviewer reiterated that the only concern is on the timeline. The reviewer noted that it is possible that the resources are sufficient, but also that more time may be needed to complete all of the proposed future tasks. This reviewer also suggested that this might require a slightly larger budget.

Presentation Number: van036
Presentation Title: Distributions of Real-World Vehicle Travel
Principal Investigator: Dave Gohlke (Argonne National Laboratory)

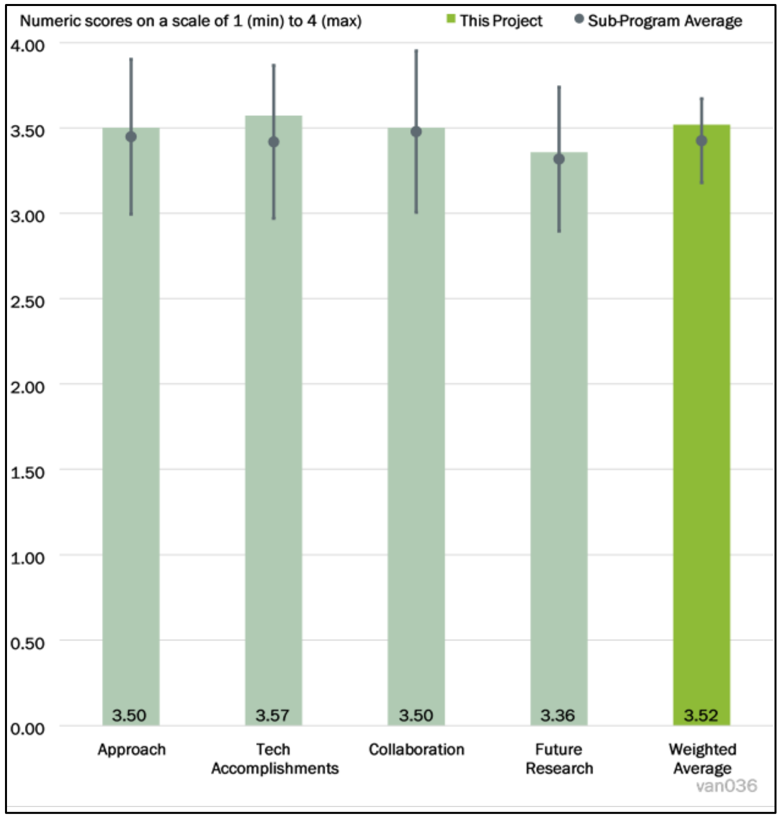


Figure 8-5 - Presentation Number: van036 Presentation Title: Distributions of Real-World Vehicle Travel Principal Investigator: Dave Gohlke (Argonne National Laboratory)

Presenter

Dave Gohlke, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers felt that the resources were sufficient, 14% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the work is on track and has clear objectives, and reasonable outputs.

Reviewer 2:

The reviewer stated that the approach is appropriate, as it is starting with LDV, continuing into MD and HD fleet commercial vehicles, and mentioned that the TCO and levelized cost of driving (LCOD) perspective is real.

Reviewer 3:

This reviewer remarked that the research team has made significant progress with a relatively small project budget. Publication of results has not yet occurred; however, the presenter describes clear near-term plans to do so.

Reviewer 4:

The reviewer noted that the project appears well designed and feasible for LD. However, the reviewer said that, given the lack of MD and HD data, it is unclear how much progress can be made in the timeframe.

Reviewer 5:

The reviewer remarked that the study develops and refines methods for quantitative comparisons of alternative vehicle fuel and powertrain technologies, including a novel approach to modeling vehicle scrappage. The reviewer noted that the robust data on vehicle activity, particularly for MD and HD vehicles and for traffic on local streets, in addition to representative average VMT estimates for ZEVs, are well identified data gaps for travel and emissions modeling. The reviewer observed that it is somewhat unclear how this study addresses these barriers to VMT data. The reviewer suggested that additional focus could also be paid to how household or sociodemographic characteristics impact LCOD, in addition to emissions impacts for historically disadvantaged communities.

Reviewer 6:

The reviewer stated that there are a lot of interesting data associated with the project. The reviewer mentioned that the results and study for the upcoming Transportation Research Board (TRB) meeting are an interesting start, but future plans remain somewhat unclear. The reviewer suggested that, for the TRB study, it might make sense to look at locations where emissions inspections are required (usually in urban/suburban areas, but not rural, which may be a factor in vehicle age as well). The reviewer noted that finding transaction or sales data seems like a key challenge to estimating how vehicle driving patterns change over the vehicle lifetime.

Reviewer 7:

The reviewer reported that the project goal is to develop more granular LDV operational characteristics (VMT, LCOD, survival) using real-world data, where available, to improve VTO's understanding of how advanced vehicle technologies will enter and impact different segments of the market. The reviewer explained that the approach—using historical NHTS survey data to develop VMT distributions for use in several follow-on analyses—is reasonable, given the fact that NHTS is one of the few public datasets with this level of information about vehicle registrations and operation. The reviewer said that this means the project results will be easy to reproduce. The reviewer cautioned that the downside (noted by the PI in Slide 16) is that it only covers a very limited timeframe (days) out of the year, and it may not be representative of average full-year driver behavior and vehicle operations. The reviewer suggested that the PI/team should consider obtaining at least a year of more granular non-survey data like IHS Polk registrations to validate the VMT distributions presented, particularly because they underpin all of the project's analysis and are being proposed for use in other VTO models and analyses. The reviewer added that there was mention of using additional data sources (Slide 16) and suggested that the PI should explicitly list the sources that were used and generally how the data were fused and/or synthesized.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reiterated that the project is on track and yielding interesting and valuable results for all portions (VMT, LCOD, fleet metrics, and vehicle survivability). The reviewer highlighted that the survivability graphic is particularly useful and intriguing as it directly notes and addresses challenges and barriers.

Reviewer 2:

The reviewer noted the progress in VMT, LCOD, fleet metrics, and scrappage. The reviewer expressed interest in scenario analysis based on an investigation of variables related to technology deployment, cost down of technology as production volume grows, disruptive technologies as technical breakthroughs are achieved, and the effect of remanufacturing and recycling, etc.

Reviewer 3:

The reviewer stated that significant results are shown from the modeling exercise, in addition to the methods proposed. The reviewer added that more information on the data gathering process and data sources for VMT would be helpful in providing a more robust evaluation of this category.

Reviewer 4:

With a relatively small project budget, the research team has made significant progress from this reviewer's perspective. Publication of results has not yet occurred, but the presenter describes clear near-term plans to do so.

Reviewer 5:

The reviewer mentioned that the project is meeting initial targets for analysis and publications for FY 2021, but future research questions are still a bit undefined.

Reviewer 6:

The reviewer noted that the project is on schedule with all milestones. The reviewer remarked that the main project goal—heterogenous travel behavior characterization, or VMT distributions—appears to have been achieved (Slide 6). The reviewer mentioned that this is a great accomplishment, and should enable the remainder of the project milestones to be reached. The reviewer added that the follow-on analyses using the new VMT distributions are very interesting and relevant to the issue at hand (i.e., the impact of assuming LDV use is homogenous). The reviewer suggested that the LCOD and energy consumption impact analysis seem somewhat simplistic, and that hopefully the LCOD will include maintenance costs for the survivability analysis. The reviewer indicated that the survivability correlation matrix is fascinating, although it would have been beneficial to have more explanation on how the PI intends to develop a scrappage model based on VMT/LCOD, particularly given the data difficulties. The reviewer suggested that it might be interesting to collaborate with NREL on how the heterogenous VMT assumption impacts energy consumption estimates. The reviewer said that the TRUCK model (for MD and HD vehicles) could be a template for the LDV energy consumption impact analysis, as it uses several VMT cohorts, where different powertrains can penetrate each cohort at different rates based on the cost/benefit calculation for that cohort.

Reviewer 7:

The reviewer observed that the progress appears to be on track, and looked forward to seeing the publications. The reviewer cautioned that data availability is a critical barrier, especially for MD and HD, and that the milestones presented did not specify deliverables for LD compared to MD and HD.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the project team is well integrated with other partners and projects on TCO and other efforts.

Reviewer 2:

The reviewer noted that the work has already fed into other projects (e.g., TCO), and that there is a clear connection to additional users and audiences.

Reviewer 3:

Cross-lab (ANL, NREL, LBNL, ORNL) coordination and collaboration on this project was described by this reviewer as a strength.

Reviewer 4:

The reviewer stated that a significant number of partner laboratories are identified for the project team, but that no information was provided on specific partner roles and activities.

Reviewer 5:

The reviewer observed that there was not much discussion around how the PI collaborated with other national laboratories, but that many of the results from this project and VAN038 (same PI) are interdependent and involved regular communication with the other labs listed in the quad chart and those on the TCO project.

Reviewer 6:

The reviewer remarked that the collaboration is good. The reviewer encouraged outreach to other industry stakeholders, original equipment manufacturers (OEMs), fleets, industry groups, etc., to keep analysis relevant to the interests of users and to the decision criteria related to forecasting adoption rates of candidate technologies.

Reviewer 7:

The reviewer reported that there are clear inputs into the TCO framework. The reviewer added that the VMT and scrappage assumptions are used in many travel models, and that there may be other potential points of 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that the proposed future research is a logical progression from where the accomplishments left off and follows the plan laid out in Slide 4.

Reviewer 2:

This reviewer stated that proposed future research may benefit to answer more direct policy questions related to encouraging heavy-emitting MD and HD vehicle scrappage turnover.

Reviewer 3:

The reviewer stated that the proposed future research plan addresses a needed gap. The reviewer said that more details on how the research team will approach data acquisition could be provided. The reviewer added that it would be helpful if this project could provide a comparative analysis with other emerging mobility data sources, including location-based services data.

Reviewer 4:

The reviewer observed that the challenges and barriers raised bring up interesting areas for possible analysis, but that the research plans for estimating VMT for HD vehicles and trends that vary with vehicle ownership are a bit undefined.

Reviewer 5:

The reviewer remarked that studying VMT and scrappage is good, as well as MD/HD fleets. The reviewer suggested emphasizing the items noted above regarding remanufacturing, recycling, repair, etc., in the useful life of the vehicle and in the second life of batteries and technologies. The reviewer added that it is important to consider life-cycle analysis (LCA) evaluation of alternative technologies in understanding the economic impact of these technology rollouts.

Reviewer 6:

The reviewer reported that the presentation could have been more detailed in how barriers will be addressed. The reviewer cautioned that, given the project timeframe, waiting for the Vehicle Inventory and Use Survey (VIUS) or other data might not be the best approach.

Reviewer 7:

The reviewer stated that the proposed future research considers barriers and challenges adequately and has an appropriate timeline and plan. The reviewer was especially interested in future work on changes in ownership and, particularly, anything related to alternative powertrains.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer observed that the study outputs support performing robust analysis of the costs of alternative fuel and ZEVs, as well as potentially enhancing existing mobile source activity models.

Reviewer 2:

The reviewer stated that understanding how different types of vehicles are actually driven is important to the overall goal of estimating energy consumption and emissions from the transportation sector, beyond just estimating the makeup of the vehicle fleet.

Reviewer 3:

The reviewer expressed that the project is essential to understanding how new technology will support the ambitions of environmental and economic improvement goals.

Reviewer 4:

The reviewer reported that the project is directly relevant to DOE objectives, and that this work adds nuanced understanding to metrics that are frequently used in modeling and analysis in order to make major technology and public policy decisions.

Reviewer 5:

The project clearly correlates with overall DOE objectives from this reviewer's perspective.

Reviewer 6:

The reviewer asserted that this work contributes important analysis that is needed for a variety of research avenues. The reviewer stated that it would be interesting to see what impacts would result from the addition of newer data that are more representative of future mobility trends, especially because new technology and vehicle applications have the potential to drastically change VMT and scrappage patterns.

Reviewer 7:

The reviewer noted that this work aims to explore one of the key assumptions that goes into all of VTO's energy consumption projection models—annual VMT per vehicle schedules. The reviewer added that it could more clearly pinpoint where advanced vehicle technologies will be most attractive. The reviewer indicated that the fusion of large public datasets will improve VTO's understanding of the LDV market.

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 more funding should be directed toward enhancing fleet and activity data for MD and HD vehicles with sufficient spatial and temporal resolution to support analysis of impacts at the community scale.

Reviewer 2:

The reviewer noted that the project has fairly open goals of data analysis and has appropriate resources given overlap with other collaborators.

Reviewer 3:

The reviewer indicated that resources are sufficient for the project to achieve the stated milestones in a timely fashion.

Reviewer 4:

The reviewer mentioned that the PI is capable of achieving the stated milestones.

Reviewer 5:

The reviewer observed that no resource barriers were identified.

Reviewer 6:

The reviewer stated that the resources seem sufficient for the level of analysis and timeframe.

Reviewer 7:

The reviewer remarked that the resources are adequate.

Presentation Number: van038
Presentation Title: The Department of Energy's (DOE) More Comprehensive Total Cost of Ownership (TCO) Framework
Principal Investigator: Dave Gohlke (Argonne National Laboratory)

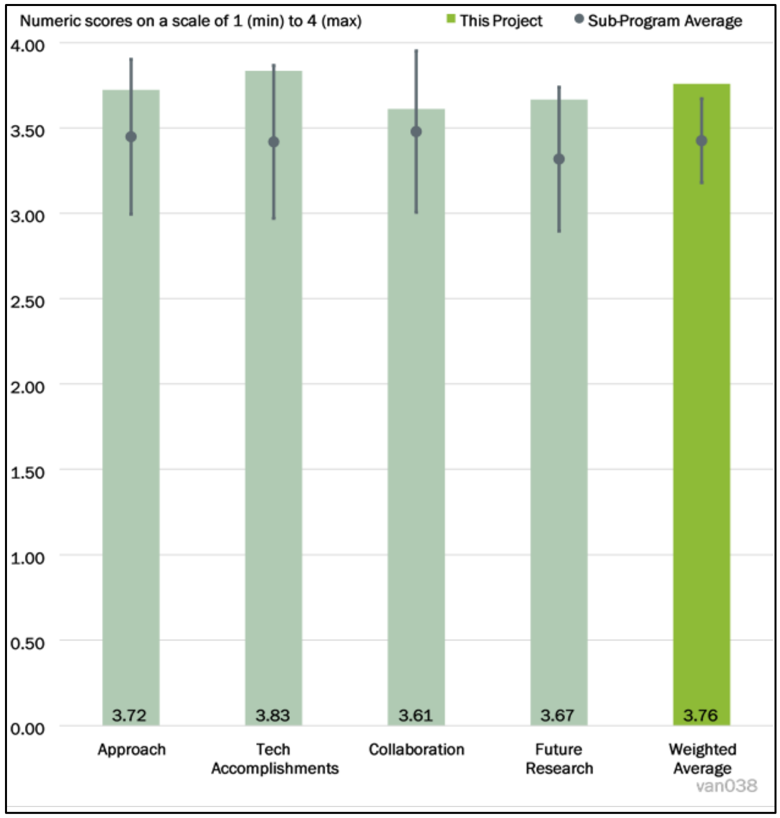


Figure 8-6 - Presentation Number: van038 Presentation Title: The Department of Energy's (DOE) More Comprehensive Total Cost of Ownership (TCO) Framework Principal Investigator: Dave Gohlke (Argonne National Laboratory)

Presenter

Dave Gohlke, Argonne National Laboratory

Reviewer Sample Size

A total of nine reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 89% of reviewers felt that the resources were sufficient, 11% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer reported that good, reliable, data-driven TCO analyses are difficult to find. Yet, every policymaker and decision-maker wants to know about it. The reviewer applauded the good work and highlighted that this analysis does an excellent job of breaking down different cost factors and doing so more thoroughly than seen elsewhere.

Reviewer 2:

The reviewer stated that the project has a good approach to TCO modeling and to LCOD for LD, MD, and HD vehicles.

Reviewer 3:

This reviewer noted the research team had a strong approach to addressing technical barriers with a well-designed and well-planned undertaking.

Reviewer 4:

The reviewer observed that the project combined outputs from previous models on the technical side of operating EVs with data about other expenses. The reviewer added that the use of focus groups with industry partners was a good strategy for verifying the data collected for the other factors that go into TCO.

Reviewer 5:

The reviewer mentioned that this approach was well designed and well executed, as it identified barriers and clearly overcame them. The reviewer added that the scope was challenging, yet well prioritized.

Reviewer 6:

The reviewer noted that the project develops and refines a method for assessing TCO of vehicles. The reviewer added that the project provides several important technical contributions related to refining TCO inputs, most notably related to maintenance costs for MD and HD vehicles. The reviewer mentioned that the payload capacity and penalty assessment for zero-emission trucks is also an important contribution. The reviewer said that potential weaknesses are the reliance on modeled outputs and the high variability in fuel/capital costs.

Reviewer 7:

The reviewer agreed that the approach is sound, but hoped that this effort can continue in the future to better capture costs related to future trends in vehicle technology and usage. The reviewer said that, with most of the available data from privately owned ICE vehicles, it will be important to flesh out new cost factors as PEVs gain market share and as batteries, infrastructure and behavior continue to evolve.

Reviewer 8:

The reviewer indicated that the approach to developing a methodology for DOE VTO to compare economics of vehicle operation across multiple technologies is well designed. The reviewer stated that it leverages past DOE VTO work by using the same metrics (TCO and LCOD) and leaning heavily on the substantial repository of past national lab research (i.e., lab collaboration). The reviewer said that the approach includes a wide range of vehicle classes and powertrains over a long timeframe to provide some relative comparisons within and across the entire on-road vehicle fleet. The reviewer noted that the inclusion of all on-road classes is a sizable feat, but that the multi-lab team assembled is likely the best available to investigate. The reviewer observed that data availability issues make it difficult to say that this effort (as stated on Slide 4) was 100% feasible. The reviewer mentioned that, while possible to estimate some of the knowledge gaps, the project approach should have more clearly stated that some of the assumptions would be best guesses based on data that may be outdated, not fully representative, and/or incomplete (particularly the MD and HD components).

Reviewer 9:

The reviewer reported that this project was well organized and well thought through in terms of the technical barriers. The reviewer believed that the largest limitation was in getting better data to improve each of the sub-modules within the overall TCO. To that extent, the reviewer added that the overall framework is rather modular, so the team should be able to quickly incorporate improvements as better data become available. The reviewer indicated that each of the sub-modules has small components that could be improved, such as including vehicle mileage in the price depreciation models (again, limited by data availability).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer applauded the great progress and the launch of the report.

Reviewer 2:

The reviewer explained that the most valuable aspects of this research are those that ensure other parties can utilize the findings of this work beyond VTO staff. This includes publications and development of software tools for third parties to make their own total cost of ownership calculations.

Reviewer 3:

The reviewer noted a good balance of reports, journal publications, and open-source modeling tools that others can use.

Reviewer 4:

The reviewer observed that progress was completed on schedule.

Reviewer 5:

The reviewer stated that the work is on time and largely complete, with reporting remaining.

Reviewer 6:

The reviewer noted that the team conducted industry workshops and delivered a report, software, and a voluminous literature review. The reviewer reported that this project did an outstanding job of meeting milestones and providing valuable deliverables. The reviewer looked forward to seeing follow-on work and decisions that rely on the efforts.

Reviewer 7:

The reviewer stated that the project has produced a significant body of technical reporting, publications, outreach, and tools. The reviewer added that the project team was obviously very productive, given the project timeline. The reviewer suggested that more activity data on MD and HD vocational vehicles would benefit this project.

Reviewer 8:

The reviewer indicated that the project was completed with time to spare, and that the results were recently published in a valuable report. The reviewer added that a literature review and the publicly available tool were also completed. The reviewer remarked that the technical results were presented for several of the cost components, which were interesting additions given the gaps in previous work. The reviewer said that, given that early market entrants and low sample size could skew results for PEVs, it would be helpful to somehow indicate the distribution in these categories for context. For example, on BEV maintenance costs, the reviewer asked how many BEV models are driving the result, whether they are representative of the BEVs on the market today, and if they are applicable to future BEVs.

Reviewer 9:

The reviewer said that the methodology (the metrics for which were included in the TCO calculation) was briefly but sufficiently explained and is more comprehensive than any past effort. The reviewer reported that the team completed a significant amount of work, both a literature review and data analysis, in order to drop data into each of the equation's components. The reviewer stated that the report will be a valuable starting (and perhaps ending) point for many stakeholders working on transportation energy consumption models and others. The reviewer suggested that it would have been helpful to include data sources for the charts and assumptions throughout the presentation. The reviewer added that data are likely the most difficult piece of this project, but that they were not covered in much detail. The reviewer noted that results were presented as if they were nationally representative and comprehensive without specifically offering much supporting evidence. The reviewer indicated that admitting the difficulties upfront (perhaps a table with all of the datasets used and identifying the gaps that were filled with assumptions) would not devalue the project results, but would more accurately communicate how little we actually know about some of these topics. The reviewer stated that VTO could then get a clearer vision of which gaps could be slowly whittled away with research dollars and which need to be filled with scenario analyses. The reviewer added that, in a similar vein, it would be beneficial to include whiskers on some of the bar charts (maybe inner quartile range), if possible, to demonstrate the uncertainty underlying much of this.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there is excellent collaboration among experts at several national laboratories and emphasized the great work observed.

Reviewer 2:

The reviewer noted good involvement from the project team on research reporting and a relatively small amount of funding spread over a large project team.

Reviewer 3:

The reviewer remarked that there is good collaboration across multiple labs, and that the use of industry workshops was helpful in collecting and verifying the data.

Reviewer 4:

The reviewer remarked that everything seems to be well aligned with regard to the project team.

Reviewer 5:

Solid cross-lab coordination between ANL, Sandia National Laboratories (SNL), LBNL, NREL, and ORNL was noted by this reviewer.

Reviewer 6:

The reviewer mentioned that this work is of interest to many and that the project team had a good representation of several relevant lab groups. The reviewer added that the team collaborated with industry and others via workshops and interviews, which appeared to be an honest attempt to get and incorporate feedback from many different perspectives.

Reviewer 7:

The reviewer observed that this work represents a massive collaboration effort across numerous national laboratories incorporating diverse stakeholders, which is a testament to both the project management and communication abilities of both the performers and DOE.

Reviewer 8:

The reviewer had no concerns with regard to collaboration with this project, although there are fewer collaborators than some longer running projects (hence the “good” rating in Question 5). The reviewer stated that once the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool gets re-parametrized, a lot of collaboration can be claimed through that tool.

Reviewer 9:

The reviewer encouraged more collaboration with industry and fleet stakeholders. The reviewer stated that this would be a good source of information to address remaining challenges and barriers (Slide 16), especially for understanding cost projections for evolving technology and the economics associated with new technology 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer reported that the project has ended.

Reviewer 2:
The reviewer noted that the project ended March 31, 2021.

Reviewer 3:
The reviewer indicated that the project has ended.

Reviewer 4:
The reviewer reported that the project has ended.

Reviewer 5:
The reviewer said that the project has ended.

Reviewer 6:
The reviewer commented that proposed future research seems broad and should be more defined if additional funding is applied to the work.

Reviewer 7:
The reviewer encouraged continued research toward understanding the economics and potential pathways of technology development. The reviewer stated that of particular interest is the contribution from battery life, including issues such as recycling, remanufacturing, second life reuse, or scrap. The reviewer added that the TCO model can be enhanced by considering operational factors., such as the cost of downtime (including lost revenue and penalties).

Reviewer 8:
The reviewer remarked that no specific steps were identified to address noted data gaps. The reviewer suggested that additional economic barriers for historically disadvantaged communities, including lack of infrastructure or local built environment conditions, should be considered in the context of TCO and LCOD.

Reviewer 9:
This reviewer had no comments.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:
The reviewer noted that the project supports a more robust comparative estimate of alternative fuel vehicle economics.

Reviewer 2:
The reviewer said that this is a good step toward understanding the costs beyond vehicle purchase and fueling that drive decisions in EV adoption, especially for MD and HD vehicles, where there are additional labor impacts on charge time to consider.

Reviewer 3:
The reviewer asserted that this project supports DOE's ability to compare economics of vehicle operation across multiple technologies in a balanced manner.

Reviewer 4:
The reviewer mentioned that this project supports DOE VTO objectives across the board by informing the baseline assumptions for many of the cost/benefit and consumer choice modeling frameworks currently in use. The reviewer added that it also fostered collaboration between several experts across the DOE labs and ensured that results were published and publicly available for all stakeholders (reproducible results that can be built and improved upon).

Reviewer 5:

The reviewer agreed that having a solid model of TCO for various vehicle types is a critical component of other related models that need an estimate of vehicle TCO. The reviewer added that it also serves as a reference for other research by other entities, so there are considerable broader impacts for others to build upon with this model.

Reviewer 6:

The reviewer indicated that this is an essential tool toward understanding the economics of technology advancement and deployment.

Reviewer 7:

The reviewer reported that this work is important across a range of different research avenues and is a great addition.

Reviewer 8:

The reviewer said that, yes, this project is deeply relevant to the objectives of DOE as it fills a large gap in the state of knowledge regarding TCO for vehicles (and does so in a consistent way) and will help improve energy and technology modeling and decision making.

Reviewer 9:

The reviewer stated that, yes, this project is relevant because it addresses the barrier of lack of information on TCO. using a rigorous, data-driven analysis.

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 funding appears to be insufficient to support future work as this is reported to be the end of this project's funding, with no continuing work planned.

Reviewer 2:

Sufficient project resources were observed by this reviewer to achieve the stated milestones in a timely fashion.

Reviewer 3:

The reviewer stated that the funds supported a large project team and yielded a significant body of work.

Reviewer 4:

The reviewer noted that the project budget was justified by the number of collaborators.

Reviewer 5:

The reviewer reported that the team is capable of completing the work; it is published and done.

Reviewer 6:

The reviewer remarked that this project was completed on schedule and met the desired tasks. The reviewer added that it appears that the budget was adequate.

Reviewer 7:

The reviewer said that the resources were used within the project timeframe and that the project was completed on time.

Reviewer 8:

The reviewer observed that the resources for the project were appropriate.

Reviewer 9:

The reviewer had no comments.

Presentation Number: van039
Presentation Title: Electric Vehicles at Scale
Principal Investigator: Michael Kintner-Meyer (Pacific Northwest National Laboratory)

Presenter

Michael Kintner-Meyer, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

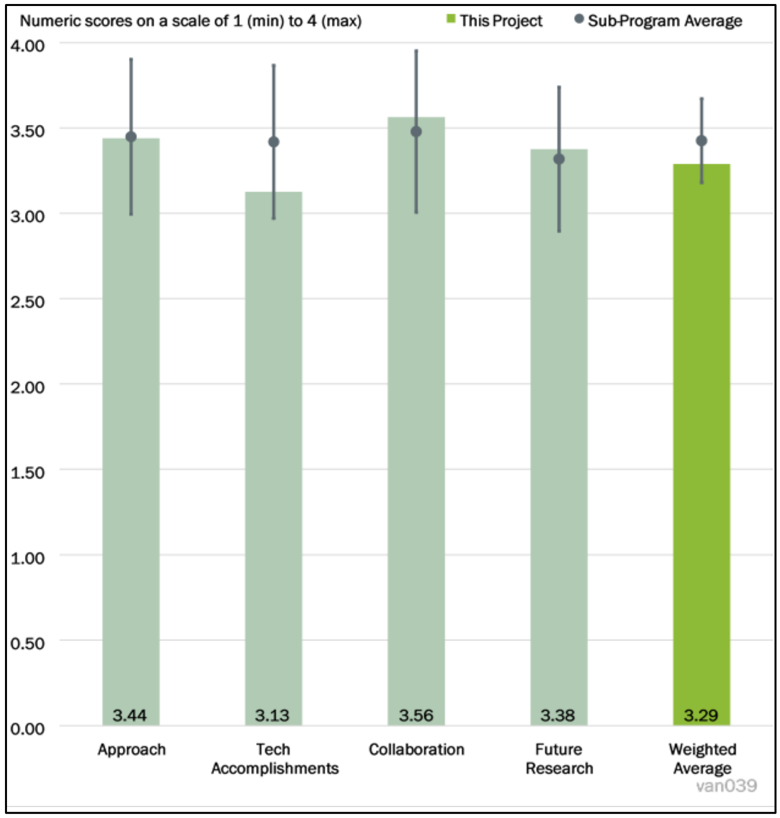


Figure 8-7 - Presentation Number: van039 Presentation Title: Electric Vehicles at Scale Principal Investigator: Michael Kintner-Meyer (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer highlighted that this is a detailed and deeply granular project, and that the approach is fascinating and well designed.

Reviewer 2:

The reviewer stated that the study develops a robust and novel approach to linking EV deployment with grid operations and electricity distribution. The reviewer added that the outputs of this work will potentially be of great value to utilities and support broader goals for developing infrastructure to meet electrification goals.

Reviewer 3:

The reviewer noted a well-designed and feasible project. The socio-economic EV adoption forecast methodology addresses barriers by providing household-level and feeder-level forecasts.

Reviewer 4:

The reviewer indicated that the approach is relevant to the study in California, and suggested that it may be helpful to expand to investigating trends, barriers, and enablers in other states.

Reviewer 5:

The reviewer noted that the project is well positioned to model impacts on the grid distribution feeder level. The reviewer remarked that some additional modeling may be necessary to estimate charging behavior. The reviewer suggested that the project team should also be cognizant of any broad differences in the distribution systems of high-income neighborhoods, where EV adoption rates have been higher than in lower income neighborhoods or neighborhoods with more multifamily housing. The reviewer highlighted that the differences in population density could prove more challenging to the grid than would be captured in models that estimate adoption based on historical trends, which cover a time period when most EV early adopters have been higher income and have owned homes.

Reviewer 6:

The reviewer indicated that the overall project approach—develop an EV adoption model that can feed a grid model to determine EV impacts on local grid infrastructure and use that modeling framework to explore the potential value of smart charging management—is well designed. The reviewer added that the grid impact exploration is feasible, given PNNL's expertise in this space as well as the large amount of data they have available on grid infrastructure. The reviewer noted that building an EV adoption tool that operates at the distribution-circuit and customer levels to get more localized load curves seems somewhat less feasible. The reviewer suggested that the availability of high-quality data that meet the needs of such a model (e.g., household income, vehicle registrations, home charging capability, and all by home) would be a limiting factor. The reviewer asserted that it is not clear that the model development aspirations are feasible without making quite a few assumptions, which works against the main stated goal of the tool to minimize uncertainty. The reviewer posed a few key unanswered questions:

- How does the tool forecast EV adoption without a forecast of household income, home prices, home characteristics, and vehicle registrations? Does it assume that they all remain at historical levels?
- How does the tool estimate EV adoption from household income and charging availability? What mathematical relationship is assumed?
- Given a set "ZEV" goal, how does the tool determine which neighborhoods adopt the EVs? What if all of the EVs needed to meet a state goal are sold in a single high-income Zone Improvement Plan (ZIP) code?

The reviewer suggested that it might have been less work and perhaps more feasible for the team to use existing VTO models to estimate local EV adoption. The reviewer stated that if the tool is actually intended to be a method for distributing a pre-conceived number of EVs, per the language in Slide 7 about forcing California Energy Commission (CEC) and Southern California Edison (SCE) sales goals and calibrating the model to other targets, then these gaps are less relevant, but that the team should have clearly stated that intention up front if it is the case.

Reviewer 7:

The reviewer thought that, in general, this was a good project, but cautioned against making future projections based on current adoption trends. The reviewer noted that most EVs have been adopted by wealthier car buyers, and that future adoption patterns may be very different from historical adoption patterns. The reviewer stated that things like whether they have a dedicated parking spot or if their neighbors bought an EV may be better predictors than income in the future, and encouraged these sorts of considerations to be incorporated into future analyses.

Reviewer 8:

The reviewer noted that this line of inquiry is important and the approach is novel. The reviewer remarked that there is some question as to whether the historical data used to inform the adoption model will be adequate for longer term scenarios, where adoption patterns and behavior could be very different. The reviewer explained that the scenarios may be able to account for the uncertainty, but was not sure if that is the case. The reviewer added that, if using current data that is largely based on wealthy early adopters, then there might be some equity concerns in that this approach may in fact help to improve distribution first in the places that reflect patterns from primarily early adopters. The reviewer suggested that perhaps there is an opportunity to consider how policy could change adoption behavior. The reviewer stated that it is also unclear if the project was well designed to be able to inform utilities nationally because it might not work for other locations and utilities.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team displayed good progress toward study goals and development of the EV adoption model, and that the open-source tool development sounds promising, particularly regarding the linkage with the project partner.

Reviewer 2:

The reviewer asserted that the technical modeling is great and appreciated the local level insights, e.g., which transformers may blow sooner rather than later due to local EV adoption.

Reviewer 3:

The reviewer noted some challenges associated with non-disclosure agreements (NDA) and data sharing agreements, but that contracts have been signed. The reviewer indicated some preliminary estimates of transmission line/other hardware failures as a result of EV adoption.

Reviewer 4:

The reviewer observed that the first milestone was met, but that the remaining milestones were all delayed due to NDA signing delays. The reviewer said that the team appears confident that the work can be completed by the project end date (September 2021), but that there seems to be a substantial amount of work remaining. The reviewer added that the technical accomplishments so far are good. The reviewer indicated that the case study demonstrates on a basic level how the EV adoption model works and how it reports results, although more explanation is warranted, as discussed in the approach question response. The reviewer commented that more detailed results are shown for the grid impacts, which are promising and represent clear steps toward meeting the future milestones.

Reviewer 5:

Although challenges pertaining to NDA processing have delayed completion of project deliverables, this reviewer reported that technical accomplishments and progress have been made with regard to the New High-Resolution Socio-Economic LDV EV Adoption Model.

Reviewer 6:

The reviewer mentioned that the progress is behind schedule due to delays in signing NDA with the California Department of Motor Vehicles (DMV) and SCE.

Reviewer 7:

The reviewer observed that this project has experienced significant delays, which seem to be mostly external. The reviewer stated that there is some question as to whether all project deliverables can be completed on time given the compressed schedule.

Reviewer 8:

The reviewer said that the project has been delayed due to progress on NDA. The reviewer noted that it was signed in May, but that the project is behind by approximately 3–4 months. The reviewer added that, while the performers have demonstrated that they will be able to deliver quality work and make up for some lost time, they considered the delays as a barrier to a higher rating.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there is clear evidence of strong coordination and collaboration between the lab and a utility partner.

Reviewer 2:

The reviewer mentioned that SCE and PNNL appear to be working quite closely on this project. The reviewer reported that SCE is providing the grid data required to complete the analysis, and PNNL is building an open-source tool that could potentially improve its EV forecasting.

Reviewer 3:

The reviewer remarked that there is good collaboration.

Reviewer 4:

The reviewer indicated that the team is working closely with the utility, which enhances the impact of this research. The reviewer added that the open-source tool will help make the research accessible more broadly. The reviewer suggested that there may be other avenues for coordination with other research groups doing EV adoption forecasting.

Reviewer 5:

The reviewer applauded the excellent work in building a relationship with SCE and encouraged more concretely tying/translating it to smaller utilities. Although a plan is discussed in future work, this reviewer expressed interest in seeing specific utilities and relationship building.

Reviewer 6:

The reviewer stated that the project represents a high-value private sector data provision partnership that requires strong coordination and relationship building. VTO coordination with the Office of Electricity would be beneficial for this project.

Reviewer 7:

The reviewer noted the good relationships with SCE, and some challenges getting other California data that impacted the project schedule. The reviewer added that having access to feeder data is helpful to verify the results and compare to actual infrastructure.

Reviewer 8:

The reviewer suggested considering additional collaboration partners in order to gather additional input and remove possible bottlenecks or constraints for input information and data. The reviewer encouraged broader regional coverage outside of California as additional 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that the proposed future work appears to be well thought out and adequate.

Reviewer 2:

The reviewer said that the proposal of technology transfer and making the work more accessible to multiple utilities, including scaling the methods and approach to smaller public utility districts (PUDs), is fantastic.

Reviewer 3:

This reviewer concurred with the presenter’s oral comments that a version of this model could ideally be developed via technology transfer so that utilities of all sizes could take advantage of the learnings and apply them to their grids.

Reviewer 4:

The reviewer remarked that future work might also consider the value of additional distributed storage, vehicle-to-grid integration, or managed public charging on grid operations and costs. The reviewer suggested that MD and HD vehicle adoption, particularly in fleets, should be a key focus of future work, given existing and planned targets in the region. The reviewer added that it would be useful to see an evaluation of the impacts of distributed storage investments either behind or in front of the meter on EV adoption.

Reviewer 5:

The reviewer stated that the approach is effective and accounts for possible variability in the future scenarios. The reviewer mentioned that the timeline might be a bit compressed, given the holdup from the data NDA challenges.

Reviewer 6:

The reviewer reported that future research aligns with the remaining milestones, and jumps off from the completion into a technology transfer stage. The reviewer said that it seems like the EV adoption tool may be in need of more development, and suggested that the team should consider working with other VTO modelers to further improve the methodology.

Reviewer 7:

The reviewer indicated that future plans would help address some constraints on the work to date. The reviewer suggested that additional consideration be given to workplace charging and domiciled charging for last-mile delivery applications. The reviewer posed the following questions:

- How does the study recognize any effects of the possibility that BEVs become the low-cost consumer choice at the end of the decade?
- Has consideration been given to an LCA approach for evaluating alternative technologies?
- What about policy implications for ICE bans, ZEVs, etc.?

The reviewer noted that mention was made about a lack of information regarding consumer charging preferences. The reviewer suggested referring to the Fuels Institute study and other references included in the report, which may be of some assistance.

Reviewer 8:

The reviewer reported that future research goals are logical next steps, but that it is somewhat unclear how the items align with the milestones laid out, especially considering the project delays.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that understanding EVs at scale impact on the distribution grid across the United States correlates directly to DOE objectives of ensuring grid reliability.

Reviewer 2:

The reviewer reported that the project is well aligned with reducing barriers and identifying infrastructure upgrades necessary to enable high rates of electrification in surface transportation systems.

Reviewer 3:

The reviewer mentioned that this work expands VTO's limited research into grid-side impacts of and barriers to EV market penetration.

Reviewer 4:

The reviewer said that the distribution system planning practices do not reflect the local characteristics of EV adoption, and that this modeling initiative is the first that addresses this need.

Reviewer 5:

The reviewer noted that this work is relevant to objectives.

Reviewer 6:

The reviewer remarked that this project addresses important questions relevant to DOE objectives on EVs and the grid.

Reviewer 7:

The reviewer said that, yes, this work provides data and an approach that is directly relevant to DOE's mission.

Reviewer 8:

The reviewer stated that, while the project is somewhat limited by using historical (first-adopter) data as the model input, the grid modeling is detailed and helps in understanding the infrastructure upgrades necessary to support widespread EV adoption with home charging. The reviewer added that final reports should make note that there may be other impacts depending on EV adoption in higher density neighborhoods with more multi-family housing or public charging infrastructure.

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 more funding and time are needed to really build out this approach so that it is broadly applicable.

Reviewer 2:

The reviewer noted sufficient project resources to achieve its stated milestones in a timely fashion.

Reviewer 3:

The reviewer mentioned that significant funding has been awarded, but that extensive data have been acquired and modeling is likely computationally intensive. The reviewer added that the remaining budget seems sufficient.

Reviewer 4:

The reviewer said that the project budget is sufficient to support the DOE side, as SCE is also contributing resources to support the project.

Reviewer 5:

The reviewer stated that staff and computational resources appear to be sufficient.

Reviewer 6:

The reviewer had no further comments on budget as it appears to be adequate.

Reviewer 7:

The reviewer indicated that the resources are reasonable.

Reviewer 8:

The reviewer noted the constraints in the availability of cluster commuting and technology transfer funding.

Presentation Number: van040
Presentation Title: Energy Impacts of Electrified Passenger Air Transport
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

86% of reviewers felt that the project was relevant to current DOE objectives, 14% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

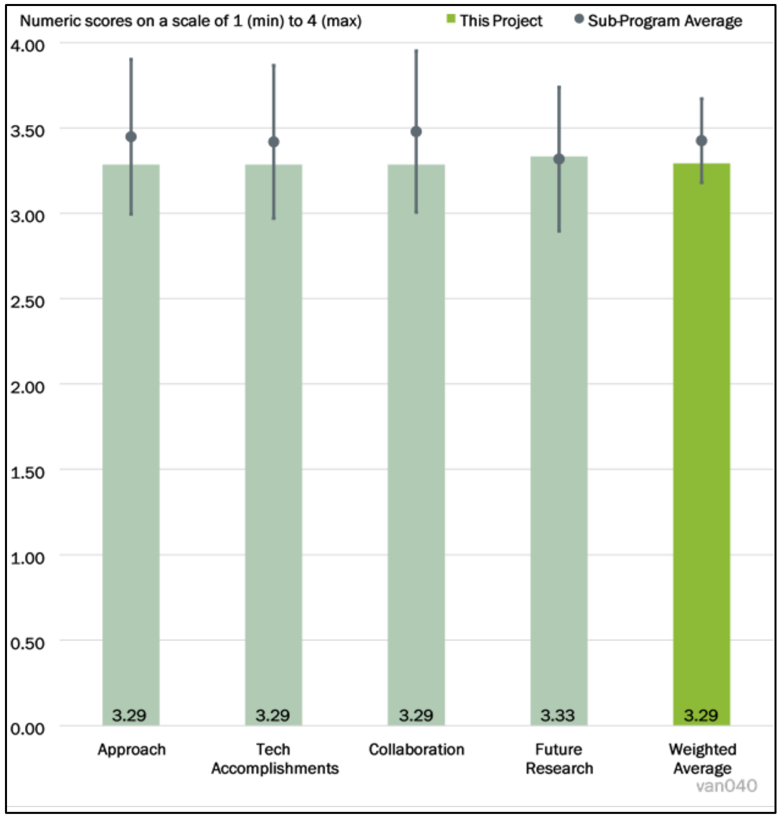


Figure 8-8 - Presentation Number: van040 Presentation Title: Energy Impacts of Electrified Passenger Air Transport Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted an excellent first cut at modeling electrified air transport. The reviewer remarked that the assumptions, attributes, and aircraft choices are well reasoned, as is the Urban Air Mobility (UAM) demand model.

Reviewer 2:

The reviewer indicated that this is a well-thought-out study and framework for developing a new model. The reviewer added that it has clear objectives and goals, even if a bit ambitious, and that the assumptions seem appropriate.

Reviewer 3:

The reviewer stated that the study addresses an important and emerging issue. The reviewer noted that the team explores both energy intensity of intercity and intracity air travel, as well as potential demand for UAM service through a travel choice model. The reviewer mentioned that the study has developed and refined a disaggregate energy model for fixed-wing and vertical takeoff and landing (VOTL) aircraft that can be refined as additional data are made available. The reviewer concluded that the study appears well designed and implemented.

Reviewer 4:

Research appeared to be somewhat preliminary in nature to this reviewer, who also acknowledged a well-designed project.

Reviewer 5:

The reviewer expressed interest in seeing the approach consider the anticipated growth of battery technology to achieve the 1,500 Watt-hours per kilogram (Wh/kg) power density that is projected to be required. The reviewer remarked that it would be helpful to the overall study to have a frame of reference for what technologies exist or are being developed to achieve the desired power density, thereby helping to establish the feasibility of passenger air transport.

Reviewer 6:

The reviewer emphasized that no milestones were listed in the presentation. The reviewer indicated that the approach to determine intercity market size—estimating share of existing air travel demand that can be met by an electric fixed-wing aircraft given varying battery assumptions—could be better designed, and that the technology itself (i.e., battery-powered fixed-wing aircraft) may not be feasible without making very ambitious assumptions. The reviewer noted that National Academy of Sciences (NAS) published a study a few years back that placed electric aircraft in the “not thinking about it right now” (reviewer’s words) category, i.e., beyond the 2050 timeline, and that neither Boeing nor Airbus has a strong desire/ambition to jump into that field. The reviewer did note that the intracity approach, which used current battery and other technology assumptions along with a utility-based mode choice model within specific cities, is well designed and its implementation is feasible, given reasonable assumptions. The reviewer said that, while not “trendy,” the team could have considered including non-electric VTOL in the analysis as a baseline for fuel consumption.

Reviewer 7:

The reviewer observed that the researchers use a set of hypothetical battery performance futures to assess the feasibility of electrifying commercial fixed-wing air travel miles and VTOL aircraft. The reviewer noted that, as a first analysis, it is interesting, although future work on electrified or decarbonized air transportation would need to start to engage with aircraft designs that could substantially improve energy efficiency (possibly from a move away from current engine configurations) to help close the gap with battery energy density. The reviewer added that the UAM model is highly speculative.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer mentioned that the project is on track and has yielded a highly useful UAM energy model and demand model, as well as interesting results regarding the percentage of all passenger-miles replaced by all electric.

Reviewer 2:

The reviewer indicated that model development appears to be very useful at establishing the conditions that could allow battery-powered air transport.

Reviewer 3:

This reviewer stated that the project has been made to a satisfactory degree.

Reviewer 4:

The reviewer noted good progress on model development and very interesting results about potential electric share of passenger miles. However, the reviewer noted that the project appears to be somewhat behind schedule.

Reviewer 5:

The reviewer noted that the project team has developed a parameterized model of energy requirements for air travel that allows for comparisons of technologies along different route structures. The reviewer warned that one potential issue for the choice model is the extent to which the availability of a low-cost air transport option might induce additional travel. The reviewer added that post-COVID-19 travel patterns may be significantly altered, which could change the motivations for mode changes.

Reviewer 6:

The reviewer stated that some COVID-19-related hiring delays may have impacted publication. The reviewer expressed some concern regarding changes to the modeling inputs for the timelines considered and whether that might impact publication timelines.

Reviewer 7:

The reviewer commented that, overall, it would have been nice to have the energy consumption comparisons in this final presentation rather than waiting to publish them this summer because they are the real output of interest.

When it comes to the intercity part of the project, the reviewer emphasized that the battery assumptions are highly optimistic. The reviewer added that the team had to double current highly ambitious solid-state battery developer specific energy goals (700–800 Wh/kg) to meet just one third of the current U.S. domestic travel demand. The reviewer stated that seeing this result (Slide 6) suggests that UAM will not be a concern for jet-engine aircraft's market share of travel demand for the foreseeable future (solely looking at reasonable projections of battery technology and cost). The reviewer suggested that the team may have benefitted from a go/no-go of sorts, perhaps to switch gears and dig into mode-switching from on-road vehicles if significant mode-switching from jet aircraft appeared unachievable. The reviewer mentioned that this could have been a result from this project rather than presenting electrification as a potential pathway for air travel decarbonization. The reviewer observed that the case was not fully made for how the intercity piece of the project provided more than what a literature review might have offered. The reviewer asserted that the project also does not seem to explicitly account for the fact that jet-engine aircraft lose weight as they fly (burning fuel), while electric aircraft do not. The reviewer hoped the team will include an energy consumption comparison calculation for intercity travel. The reviewer added that the fuel consumption per mile, passenger-mile, and ton-mile are all available by aircraft type (make and model) in the Bureau of Transportation Statistics (BTS) Schedule T2 dataset.

Regarding the intracity part of the project, the reviewer stated that the team built out what appears to be a nice modeling framework for UAM travel demand, including mode switching for two cities. The reviewer reported that there was not sufficient detail regarding the assumptions (e.g., wait times, value of travel time, value of not traveling with 10 other people, and price to ride). The reviewer concluded that the UAM vehicle level modeling (CAD/energy consumption) looks thorough.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project appears to have meaningful collaboration with the Georgia Institute of Technology (Georgia Tech).

Reviewer 2:

The reviewer remarked that the team appears to have collaborated well.

Reviewer 3:

The reviewer mentioned that the partnership between Georgia Tech and ANL was clearly highly productive and coordinated well. The reviewer agreed with another commenter who mentioned that it would be great to see further dialogue with the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), and other relevant federal agencies.

Reviewer 4:

The reviewer stated that the project team and shared responsibilities are described. The reviewer added that a private sector partner or technology company would significantly strengthen the study by providing access to data or validation.

Reviewer 5:

Collaboration with the U.S. Department of Transportation Federal Transit Authority was described by the reviewer as lacking but otherwise satisfactory across the project team.

Reviewer 6:

The reviewer noted good collaboration with air mobility technology experts, especially on UAM, but observed limited interaction with FAA and other agencies that focus on aviation, especially commercial aviation.

Reviewer 7:

The reviewer suggested enhancing the usefulness of the model by having a battery technology company or researcher as one of the collaboration partners. The reviewer asked if ANL or Georgia Tech is providing this input, noting that it was unclear from the presentation and the questions and answers. This reviewer speculated that perhaps this is in the next steps and/or proposed future 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. Note: if the project has ended, please state project ended.

Reviewer 1:

Proposed future research has been effectively planned from the reviewer's perspective.

Reviewer 2:

The reviewer stated that the remaining tasks are on track to be completed and no significant barriers exist.

Reviewer 3:

The reviewer stated that the next steps are well articulated and follow a logical progression from the current status.

Reviewer 4:

The reviewer remarked that the project is near completion, but that there is still some work that needs to be finalized and some results to be written up.

Reviewer 5:

The reviewer noted that the project has ended.

Reviewer 6:

The reviewer expressed special interest in the future research related to "finalizing technical assumptions 2030-2050" to provide a reference point for the timeline for battery research and development and to achieve the goal of 1,500 Wh/kg power density.

Reviewer 7:

The reviewer mentioned that the team plans to publish a final report this summer with some additional analysis regarding energy consumption. The reviewer agreed that this is the logical next step, although indicated that there was not a clear project timeline anywhere in the presentation explaining where the project was supposed to end up.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that this study addresses an emerging field with significant implications for low carbon mobility and transportation access.

Reviewer 2:

The reviewer stated that this project supports VTO's efforts to stay abreast of advanced vehicle technologies. The reviewer added that VTO does not have much work on air travel energy consumption, and that this project provides a base level of modeling and analysis support for UAMs and some initial work on larger fixed-wing aircraft.

Reviewer 3:

The reviewer said that, yes, the project established the scenario and potential impact of electrified aviation and the ability to displace liquid fuels for a portion of air travel.

Reviewer 4:

The reviewer said that, yes, this is an understudied area of research that could have large implications for future transportation system and energy impacts. The reviewer indicated that sustainable aviation opportunities need to be fully explored by DOE due to the difficult nature of decarbonizing this sector.

Reviewer 5:

The reviewer reported that the assessment of electrified aviation on energy consumption is directly relevant to DOE's mission.

Reviewer 6:

This reviewer asserted that the project supports overall DOE objectives satisfactorily.

Reviewer 7:

The reviewer remarked that these are interesting ideas, although more robust analysis of commercial aviation energy consumption would require a more detailed analysis of improvements to fixed-wing aircraft design. The reviewer added that looking at other, more energy-efficient micromobility/public transit options and ways to improve those would be more relevant, especially with large goals of decarbonization and equitable access to low-carbon 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 remarked that the project budget appears sufficient and recommended that additional funding should be applied to this research area.

Reviewer 2:

The reviewer remarked that resources are sufficient for the project to achieve the stated milestones.

Reviewer 3:

The reviewer observed that no resource constraints were identified.

Reviewer 4:

The reviewer indicated that the resources are in line with the project.

Reviewer 5:

The reviewer reported that the resources are reasonable.

Reviewer 6:

The reviewer stated that the team struggled to hire staff at the beginning, but that it appears to have the workload covered.

Reviewer 7:

The reviewer noted that funding was sufficient for a pilot-level study, and that more private sector interest and development is necessary before building a larger portfolio of UAM-focused projects.

Presentation Number: van041
Presentation Title: Location History
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

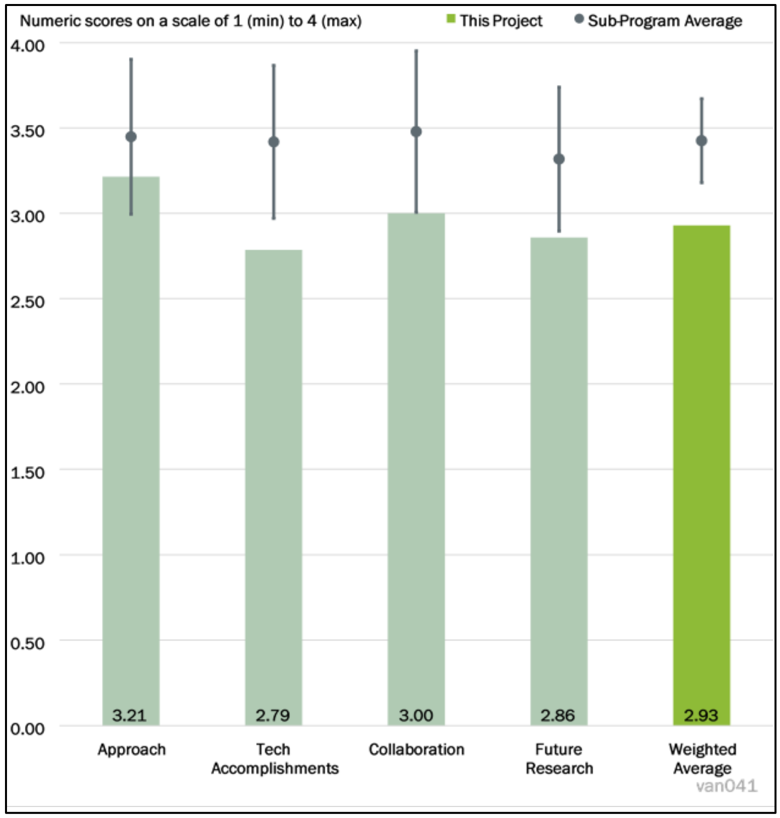


Figure 8-9 - Presentation Number: van041 Presentation Title: Location History Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter

Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

86% of reviewers felt that the project was relevant to current DOE objectives, 14% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 86% of reviewers felt that the resources were sufficient, 14% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the approach to performing the work addresses technical barriers. Furthermore, the project is well designed and feasible.

Reviewer 2:

The reviewer observed that it is unclear how this study addresses one of the primary barriers described, namely acquiring accurate and representative travel history data from a large sample of travel from which to estimate choice, travel, or activity models. The reviewer suggested that, in order to maximize the benefits of the modeling exercise, modelers from metropolitan planning organizations (MPOs) should perhaps be engaged earlier in the process. The reviewer noted that there are issues in mapping location-based service (LBS) data to the transportation network that the study could address. The reviewer questioned how to assure that samples are equitable and representative when pairing LBS data with survey responses.

Reviewer 3:

The reviewer stated that the ML implementation side and comparison to a traditional logit model seems to have gone relatively smoothly. The reviewer noted that most of the challenges were associated with the data collection process. The reviewer suggested that some delays are probably attributable to COVID-19, and that some additional care to schedule and clear privacy hurdles might have been helpful because it is important for future projects that are considering using native data collection to map travel patterns.

Reviewer 4:

The reviewer indicated that the approach to exploring location history data as an alternative to traditional travel surveys is well designed. The reviewer mentioned that the team is collecting a small sample of location history data and pushing it through ML and traditional choice models to see how accurately they each project travel behavior. The reviewer added that the app-based approach seems much simpler for respondents to use than traditional surveys, but that it is not clear how feasible this approach is, given privacy and security issues. The reviewer suggested that the team should explain how those barriers will be (or are being) overcome.

Reviewer 5:

The reviewer noted that the approach of using cell phone data to establish location history seems well suited to this methodology. The reviewer suggested applying this to other modes of transportation in addition to bikes, but said that this is a good place to start to establish the feasibility of this method of data collection.

Reviewer 6:

The reviewer acknowledged that this is an important area of research and that the approach makes sense. The reviewer suggested expanding the project to larger sample sizes and to include more data.

Reviewer 7:

The reviewer stated that the thinking behind this work was well reasoned, and that finding an alternative to traditional travel surveys is important and time/cost-saving work. The reviewer explained that the approach overall was well specified and logical; however, the approach to data collection has been less successful and has not contributed to overcoming barriers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that the presenter indicates solid progress toward overall project objectives.

Reviewer 2:

The reviewer commented that it looks like the team was slowed due to COVID-19 and was unable to accomplish as much as was anticipated. The reviewer believed the methodology is established with good potential to apply to a broader set of transportation modes.

Reviewer 3:

The reviewer observed that, unfortunately, the timing of the project in relation to COVID-19 impacted this work. The reviewer added that, given this constraint, the project was still able to move forward and yield some interesting results.

Reviewer 4:

The reviewer stated that, while the project is set to conclude on time, the technical progress has somewhat lagged. The reviewer observed that certainly COVID-19 has delayed/impacted both the ability of researchers to collect information and changed the nature of underlying data. However, the reviewer suggested that better data contingencies could have been potentially planned before the project began.

Reviewer 5:

The reviewer remarked that a small sample model was completed, but that the results are likely not generalizable, given the limited data. The reviewer added that some trip data were collected from the survey and smart app, but that the integration with the choice model is planned for future work.

Reviewer 6:

The reviewer stated that the results based on the pilot study are compelling, but that the number of respondents is very limited. The reviewer said that even if native data collection was not held up because of privacy concerns, the data collected during the peak of the pandemic would have not been representative of more normal transportation patterns. The reviewer noted that, according to the presenter, data collection permissions have now been cleared and the Colorado Energy Office (CEO) may be able to provide more data.

Reviewer 7:

The reviewer noted that the presentation did not include any milestones or project tracking information. The reviewer stated that the team was not able to complete the approach as initially stated, as COVID-19 delayed internal permissions. The reviewer added that the team pivoted to using an existing dataset to test drive the location history approach. The reviewer remarked that these data were, unfortunately, much less comprehensive and only included 13 participants and bikes (no other modes). The reviewer said that the results of both ML and traditional mode-choice were not great (39% and 50%, respectively), and suggested that the team might explore other mode choice equation specifications. The reviewer suggested trying the approaches on a larger aggregate dataset rather than overfitting to 13 people's choices.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted great collaboration with the CEO and the Colorado Department of Transportation (CDOT) and encouraged broader academic collaboration on this topic.

Reviewer 2:

The reviewer remarked that the partnerships, particularly with the CEO group, were the saving grace of this project in a COVID-19 year when native data collection was stalled. The reviewer added that including them in developing some future research questions to focus on if the model proves to be useful with non-COVID-19 data would be helpful for ensuring that the tools are most useful for mobility planners.

Reviewer 3:

Collaboration and coordination across the project team was described by this reviewer as sufficient for the scope of the project.

Reviewer 4:

The reviewer suggested that there was not much planned collaboration, but that the team ended up having to collaborate more with CEO to get data for an initial analysis due to data delays. The reviewer added that the two groups appear to have a good relationship and plan to work together on this in the future.

Reviewer 5:

The reviewer indicated that the researchers intend to review results with CDOT, but that not much collaboration appears to have been conducted thus far. The reviewer stated that further collaboration with CEO is anticipated.

Reviewer 6:

The reviewer said that it is good that the modeling work will be shared with CDOT and that the performers plan to work with CEO for access to data. However, the reviewer added that these seem like less coordinated and fully engaged partners.

Reviewer 7:

The reviewer stated that only one partner is identified, and suggested that the partner appears to not have been engaged with the research 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. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted a clear path forward to collect individual data via the app now that permissions have been worked out.

Reviewer 2:

The reviewer observed that the proposed future research aligns with finishing the project, and that the biggest barriers seem to finally be out of the way.

Reviewer 3:

Proposed future research has been effectively planned in a logical manner from this reviewer's perspective.

Reviewer 4:

The reviewer said that future work would focus on running the analysis on natively collected data or a larger dataset from CEO. The reviewer remarked that additional details about plans for results dissemination would be helpful.

Reviewer 5:

The reviewer mentioned that the proposed future research is logical, given the initial approach. The reviewer suggested that there could have been some additional risk mitigation regarding the future goal to "attempt native data collection for 50-100 individuals." The reviewer explained that the team had already struggled to complete this before, and suggested that it is likely there will be additional barriers (not least the end of the project and its funding).

Reviewer 6:

The reviewer encouraged the team to consider broader application of this methodology beyond bikes.

Reviewer 7:

The reviewer stated that this project is lacking a concrete plan for future data acquisition and research partnerships, with few to no alternatives for future work proposed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project is highly relevant to overall DOE objectives. The reviewer explained that, by exploring the potential for improving VTO's understanding of human decision-making (with respect to transportation), the project could improve the real-world representation of assumptions going into VTO's agent-based models. The reviewer added that, specifically, this project aims to improve VTO modeling and simulation tools using applied analysis of a unique dataset.

Reviewer 2:

The reviewer stated that this project supports overall DOE objectives.

Reviewer 3:

The reviewer observed that this work is relevant to understanding the range of customer/user choice models.

Reviewer 4:

The reviewer said that, yes, given the enormous effort and money put into modeling the transportation system and to the rapidly changing technology and behavior in the sector, it makes a lot of sense to focus on getting better data. The reviewer encouraged more exploration of novel methods and data collection efforts.

Reviewer 5:

The reviewer indicated that this work is highly relevant to DOE's modeling activities, and that opportunities for new datasets and better prediction enhance quality decision-making and save time and taxpayer dollars.

Reviewer 6:

The reviewer stated that this work is an important benchmarking activity to show how well ML methods perform when compared to other models, especially with large datasets, and that it is important given research trends and the goals of modeling how transportation contributes to energy consumption in the United States.

Reviewer 7:

The reviewer noted that there is a wide range of academic and private companies building ML models based on location-based services data and sociodemographic information, and suggested that this project could do a better job at addressing methodological or data gaps. The reviewer added that the project could be improved by focusing on partnerships with the local MPO agency and focusing data collection on ensuring an equitable and representative sample.

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 the project would benefit from short-term and relatively inexpensive COVID-19 time extensions to allow for additional data collection.

Reviewer 2:

Sufficient project resources to achieve stated milestones in a timely fashion were observed by this reviewer.

Reviewer 3:

The reviewer remarked that the project funding appears appropriate for the milestones described.

Reviewer 4:

The reviewer noted that project staff resources are sufficient to complete the work.

Reviewer 5:

The reviewer indicated that the resources are in line with the scale of the project.

Reviewer 6:

The reviewer noted adequate resources to complete the project.

Reviewer 7:

The reviewer observed that the barrier was noted, although it was not clear if this is resource constrained (related to data sources and modeling techniques).

Acronyms and Abbreviations

ADOPT	Automotive Deployment Options Projection Tool
AEO	Annual Energy Outlook
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
ANL	Argonne National Laboratory
BETO	Bioenergy Technologies Office
BEV	Battery electric vehicle
BTS	Bureau of Transportation Statistics
CAD	Computer-aided design
CDOT	Colorado Department of Transportation
CEC	California Energy Commission
CEO	Colorado Energy Office
COVID-19	Coronavirus disease 2019
CV	Commercial vehicle
DMV	Department of Motor Vehicles
DOE	U.S. Department of Energy
EV	Electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection tool
FAA	Federal Aviation Administration
FASTSim	Future Automotive Systems Technology Simulator
FCEV	Fuel-cell electric vehicle
FY	Fiscal Year
GEM	Greenhouse gas Emissions Model
Georgia Tech	Georgia Institute of Technology
GHG	Greenhouse gas
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
H	Hydrogen
HD	Heavy-duty
HDV	Heavy-duty vehicle
HFTO	Hydrogen and Fuel Cell Technologies Office
ICEV	Internal combustion engine vehicle
LBNL	Lawrence Berkeley National Laboratory

LBS	Location-based service
LCA	Life-cycle analysis
LCOD	Levelized cost of driving
LD	Light-duty
LDV	Light-duty vehicle
MA3T	Market Acceptance of Advanced Automotive Technologies model
MD	Medium-duty
ML	Machine learning
MPO	Metropolitan planning organization
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NDA	Non-disclosure agreement
NG	Natural gas
NHTS	National Highway Travel Survey
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PHEV	Plug-in hybrid vehicle
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
PUD	Public utility district
Q	Quarter
RDD&D	Research, development, demonstration, and deployment
SCE	Southern California Edison
SOC	State of charge
SNL	Sandia National Laboratories
TCO	Total cost of ownership
TEEM	Transportation Energy Evolution Modeling
TRB	Transportation Research Board
UAM	Urban Air Mobility model
UC Davis	University of California at Davis
VAN	Vehicle Analysis Program

VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle-miles traveled
VTO	Vehicle Technologies Office
VTOL	Vertical takeoff and landing
Wh/kg	Watt-hour per kilogram
ZEV	Zero-emission vehicle
ZIP	Zone Improvement Plan

9. Acronyms and Abbreviations

°C	Degrees Celsius
μm	Micron
0-D	Zero-dimensional
1-D	One-dimensional
2-D	Two-dimensional
3-D	Three-dimensional
3G	Third generation
3PL	Third-party logistics
4G	Fourth generation
A/F	Air/fuel
AC	Alternating current
ACE	Advanced Combustion Engines
ACEC	Advanced Combustion and Emissions Control
ACEEE	America Council for an Energy-Efficient Economy
ACM	American Center for Mobility
ACMZ	Aluminum-copper-manganese-zirconium
ACT	Applications and Collaboration Tool
ACT	Appalachian Clean Transportation
AD	Additive manufacturing
ADAS	Advanced driver-assisted system
ADOPT	Automotive Deployment Options Projection Tool
AEC	Advanced Engine Combustion
AEO	Annual Energy Outlook
AFA	Alumina-forming austentitic
AFC	Alternative Fuel Corridor
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
AFRL	Air Force Research Laboratory
AFV	Alternative fueled vehicle
Ag	Silver
AI	Artificial intelligence

AIMD	ab initio molecular dynamics
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
ALD	Atomic layer deposition
AM	Active material
AM	Additive manufacturing
AMAT	Applied Materials
AMBER	Advanced Model Based Engineering Resource
AMIPC	Advanced Materials Intelligent Processing Center
AMO	Advanced Manufacturing Office
AMOX	Ammonia oxidation
AMP	Assured Micropatching Program
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	Application performance interface
APS	Advanced Photon Source
APT	Atomic probe tomography
APTA	American Public Transportation Association
ARL	U.S. Army Research Laboratory
ARPA-E	Advanced Research Projects Agency-Energy
ASC	Ammonia slip catalyst
ASR	Area-specific resistance
ASSB	All-solid-state-battery
ASTM	American Society for Testing and Materials
ATCS	Adaptive traffic control system
ATRI	American Transportation Research Institute
AV	Autonomous vehicle
B	Boron
$BaTiO_3$	Barium titanate
BCC	Body-centered cubic
BEA	Zeolite beta

BEAM	Behavior, Energy, Autonomy, and Mobility
BEAM CORE	Behavior, Energy, Autonomy, and Mobility Comprehensive Regional Evaluator
BES	Basic Energy Sciences
BETO	Bioenergy Technologies Office
BEV	Battery electric vehicle
BG&E	Baltimore Gas & Electric
BMS	Battery management system
BN	Butyronitrile
BNL	Brookhaven National Laboratory
BOTTLE™	Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment
BP	Budget Period
BR	Battery Resourcers
BTE	Brake thermal efficiency
BTMS	Behind-the-meter storage
BTO	Building Technologies Office
BTS	Bureau of Transportation Statistics
BY	Budget year
BYU	Brigham Young University
C	Charge rate
C	Carbon
CA10	Crank angle at 10% mass fraction burned
CAD	Computer-aided design
CAFE	Corporate Average Fuel Economy
CALPHAD	CALculation of PHAase Diagram
CAMP	Cell Analysis, Modeling, and Prototyping
CARLA	Computer-Assisted Related Language Adaptation
CARTS	Capital Area Rural Transportation System
CAV	Connected and automated vehicle
CAVE	Connected and Automated Vehicle Environment
CB	Carbon black
cc	Close coupled

CCD	Critical current density
CCS1	Combined Charging System
CCT	Continuous cooling transformation
CCV	Cycle-to-cycle variation
CDOT	Chicago Department of Transportation
CDOT	Colorado Department of Transportation
Ce	Cerium
CE	Coulombic efficiency
Ce	Cerium
CEC	California Energy Commission
CEI	Cathode-electrolyte interface
CEM	Composite epoxy material
CEO	Colorado Energy Office
CF	Carbon fiber
CFD	Computational fluid dynamics
CFM	Complex framework materials
CFR	Cooperative fuel research engine
CFRC	Carbon fiber reinforced composite
CFRP	Carbon fiber reinforced polymer
CFTF	Carbon Fiber Technology Facility
CGS	Compressed gas storage
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression-ignition
CIERA	Cavitation-induced erosion risk assessment
CLEERS	Crosscut Lean Exhaust Emissions Reduction Simulations
cm	Centimeter
CMU	Carnegie Mellon University
CNC	Computer numerical control
CNF	Carbon nanofiber
CNG	Compressed natural gas

CNMS	Center for Nanophase Materials Sciences
CNT	Carbon nanontube
CO	Carbon monoxide
Co	Cobalt
CO_2	Carbon dioxide
CORE	Comprehensive Regional Evaluator
COTS	Commercial-off-the-shelf
COVID-19	Coronavirus disease 2019
CPUC	California Public Utilities Commission
CR	Compression ratio
Cr	Chromium
CRADA	Cooperative research and development agreement
CS	Cold start
CS	Cooled spray
CSRL	Cybersecurity Research Laboratory
CT	Computerized tomography
CTA	Chicago Transit Authority
Cu	Copper
CUC	Clean up catalyst
CV	Cyclic voltammetry
CV	Connected vehicle
CV	Commercial vehicle
C-V2X	Cellular vehicle-to-anything
CVVD	Continuously variable valve duration
CVVT	Continuous variable valve technology
CYC	Columbus Yellow Cab
DARPA	Defense Advanced Projects Research Agency
DC	Direct current
DCFC	Direct-current fast charger
DCIR	Direct current internal resistance
DCRNN	Diffusion Convolutional Recurrent Neural Network
DER	Distributed energy resources

DFI	Ducted fuel injection
DFP	Diesel particulate filter
DFT	Density function theory
DHS	U.S. Department of Homeland Security
DI	Direct injection
DIC	Digital image correlation
DICTRA	DIffusion-Controlled TRAnsformations in multi-component systems, a software diffusion module within Thermo-Calc for accurate simulation of diffusion-controlled reactions in multi-component alloy systems
DIW	Direct ink writing
DMBQ	Dimethoxy benzoquinone
DMTV	Discharge molecular tagging velocimetry
DMV	Department of Motor Vehicles
DNN	Deep neural network
DNS	Direct numerical simulation
DOC	Diesel oxidation catalyst
DOC-F	Combined diesel oxidation catalyst and diesel particulate filter
DOE	U.S. Department of Energy
DOL	Dioxolane
DOT	[state or city] Department of Transportation
DOT	U.S. Department of Transportation
DPF	Diesel particulate filter
DRX	Cation-disordered rock salt
DSRC	Dedicated short-range communication
DTNA	Daimler Trucks North America
Dy	Dysprosium
e	Electric
E10	10% ethanol, 90% gasoline blend
E_a	Activation energy
EAM	Electrochemically active mono-layers
EAT	Exhaust aftertreatment
EBSD	Electron backscatter diffraction

EC	Ethylene carbonate
ECFM	Extended coherent flame model
ECN	Engine Combustion Network
EcoCAR	EcoCAR Mobility Challenge Advanced Vehicle Technology Competition
EDT	Electric Drive Technology(ies)
EEMS	Energy Efficient Mobility Systems program
EERE	Office of Energy Efficiency and Renewable Energy
EERE	Office of Energy Efficiency and Renewable Energy
EETT	Electrical and Electronics Technical Team
EGR	Exhaust gas recirculation
EHC	Electrically heated catalyst
EHN	Ethylhexyl nitrate
ELSA	Euler-Lagrange spray atomization
EM	Electromagnetic
EMC	Ethyl methyl carbonate
EMI	Electromagnetic interference
EMSL	Environmental Molecular Sciences Laboratory
EOL	End of life
EPA	U.S. Environmental Protection Agency
EPR	Electron paramagnetic resonance spectroscopy
EPRI	Electric Power Research Institute
ES	Energy storage
ESB	Electric school bus
EV	Electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection tool
EVSE	Electric vehicle supply equipment
FAA	Federal Aviation Administration
FASTSim	Future Automotive Systems Technology Simulator
FCA	Fiat Chrysler Automobiles
FCC	Federal Communications Commission
FCE	First-cycle efficiency
FCEV	Fuel-cell electric vehicle

FCTO	Fuel Cell Technologies Office
FD	Fundamental diagram
Fe	Iron
Fe_4N	Iron nitride
FEA	Finite element analysis
FEC	Fluoroethylene carbonate
FEM	Finite element method
FFRDC	Federally Funded Research and Development Center
FIF	Fundamental Influencing Factor
FLM	First/last mile
FMLM	First-mile and last-mile
FSLW	Friction-stir linear welding
FSP	Flame Spray Pyrolysis
FSP	Friction-stir processing
F-SPR	Friction self-piercing rivet
FSW	Friction-stir weld(ing)
FT	Fuel and Lubrication Technologies
FTE	Freight-ton efficiency
FTIR	Fourier-transform infrared spectroscopy
FTP	Federal Test Procedure
FY	Fiscal Year
g	Gram
g/hp-hr	Gram per horsepower-hour
GaN	Gallium nitride
GBL	gamma butyrolactone
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GED	Gravimetric energy density
GEM	Greenhouse gas Emissions Model
Gen	Generation
Georgia Tech	Georgia Institute of Technology
GF	Glass fiber

GHG	Greenhouse gas
GHSV	Gas hourly space velocity
GM	General Motors
GPCF	Gallon per cubic foot
GPF	Gasoline particulate filter
GPR	Gaussian process regression
GPS	Global positioning system
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation model
GSE	Glassy solid electrolyte
GTI	Gas Technology Institute
GVSC	Ground Vehicles Systems Center
GVWR	Gross vehicle weight rating
H	Hydrogen
H_2	Hydrogen
H_2O	Water
HAPCAP	Hocking-Athens-Perry Community Action
HC	Hydrocarbon
HCE	High-consequence events
HCT	Hydrocarbon trap
HD	Heavy-duty
HDV	Heavy-duty vehicle
HE	High energy
HFET	Highway Fuel Economy Test
HFR	High-rate friction rivet
HFS	High fuel stratification
HFTO	Hydrogen and Fuel Cell Technologies Office
HIL	Hardware-in-the-loop
HIP	Hot isostatic pressing
HOPG	Highly oriented pyrolytic graphite
HPC	High-performance computing
HPDC	High-pressure die casting
HPPC	Hybrid pulse power characterization

HPSC	High-performance scientific computing
HQ	Headquarters
HRE	Heavy rare earth
HT	High temperature
HTA	Hydrothermally aged
HTC	High-temperature carbonization
HVAC	Heating, ventilation, and air conditioning
HVM	High volume manufacturing
HVR	High-velocity rivet
IACMI	Institute for Advanced Composites Manufacturing Innovation
IC	Internal combustion
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle
ICME	Integrated computational materials engineering
ID	Identification
IDS	Intrusion detection system
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IIT	Illinois Institute of Technology
IL	Ionic liquid
ILSS	Interlaminar shear strength
In	Indium
INEXUS	Individual Experienced Utility-based Synthesis
INL	Idaho National Laboratory
IP	Intellectual property
IRB	Institutional Review Board
ISO	International Organization for Standardization
ITE	Indicated thermal efficiency
ITS	Intelligent Transportation Systems
IUPUI	Indiana University – Purdue University Indianapolis
IZ	Isoxazol
JCP	Joining Core Program

JRC	Joint Research Center
kg	Kilogram
KIT	Karlsruhe Institute of Technology
k_p	Parabolic rate constant
kPa	Kilopascal
KPI	Key performance indicator
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
kWh/lb	Kilowatt-hour/pound
L	Liter
L	Level
lb	Pound
LBNL	Lawrence Berkeley National Laboratory
LBS	Location-based service
LCA	Life-cycle analysis
LCC	Inductor-capacitor-capacitor
LCO	Lithium cobalt oxide
LCOD	Levelized cost of driving
LD	Light-duty
LDV	Light-duty vehicle
LES	Large eddy simulation
LFP	Lithium iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
$Li_7La_3Zr_2O_{12}$	Lithium lanthanum zirconium oxide
LIB	Lithium-ion battery
LIBRA	Lithium Ion Battery Resource Assessment
LIC	Lithium-ion conducing
LIDAR	Light detection and ranging
LiF	Lithium fluoride
LiFSI	Lithium bis(fluorosulfonyl)imide

LIG	Laser-induced graphene
LightMAT	Lightweight Materials Consortium
LiNO3	Lithium nitrate
Li-SIA	Lithium structurally isomorphic alloys
LLNL	Lawrence Livermore National Laboratory
LLZO	Lithium lanthanum zirconium oxide
LMNO	Lithium manganese nickel oxide
LMO	Lithium manganese oxide
LNMC	Lithium nickel manganese cobalt oxide
LNMO	Lithium nickel manganese oxide
LNO	Lithium-nickel dioxide (LiNiO2)
LOE	Level of effort
LoOP	Local outlier probability
LPBF	Laser powder bed fusion
LPF	Lithium plating free
LPG	Liquified petroleum gas
LPS	Sulfide-based solid state electrolyte, Li_3PS_4
LPSCl	Halogenated sulfide-based solid state electrolyte
LSEV	Low-speed electric vehicle
LSPI	Low-speed pre-ignition
LT	Low-temperature
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTO	Lithium titanate (Li4Ti5O12)
LVF	Liquid volume fraction
M	Molar
m	Meter
M/O	Metal and oxide
MA3T	Market Acceptance of Advanced Automotive Technologies model
mAh	Milliamp-hour
MAS	Micro-alloyed steel
MAT	Materials Technology Program

MCCI	Mixing-controlled compression ignition
MCE	Multi-cylinder engine
MD	Medium-duty
MD	Molecular dynamics
MDF	Manufacturing Demonstration Facility
MDV	Medium-duty vehicle
MEP	Mobility Energy Productivity
MER	Molar expansion ratio
MERF	Materials Engineering Research Facility
MFA	Multi-factor authentication
MFI	Materials Flow through Industry
mg	Milligram
Mg	Magnesium
MIB	Management Information Base
MIC	Molecular ionic composite
Michigan Tech	Michigan Technological University
min	Minute(s)
Missouri S&T	Missouri University of Science and Technology
MIT	Massachusetts Institute of Technology
ML	Machine learning
MLPC	Multi-level porous carbon/multi-layer pouch cell
mm	Millimeter
Mn	Manganese
Mn	Manganese
MnCe	Manganese cerium
MOOSE	Multiphysics object oriented simulation environment
MOSFET	Metal-oxide semiconductor field-effect transistor
MOU	Memorandum of Understanding
MPa	Megapascal
MPC	Model predictive control
mph	Miles per hour
MPO	Metropolitan planning organization

MPR	Multi-pressure rail
MS	Mass spectroscopy
MSU	Michigan State University
MT	MegaTon
MTT	Materials Technical Team
MV	Medium-voltage
MVA	Megavolt-ampere
MW	Microwave
MW	Megawatt
MY	Model Year
N/P	Negative-positive ratio
N_2O	Nitrous oxide
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASEO	National Association of State Energy Officials
NCA	Nickel cobalt aluminum oxide
NCE	No-cost extension
NCEMC	North Carolina Electric Membership Corporation
NCM	Nickel cobalt manganese oxide
NCSU	North Carolina State University
Nd	Neodymium
NDA	Non-disclosure agreement
NDE	Non-destructive evaluation
NECST	Nanomaterials for Energy Conversion Storage Technology
NETL	National Energy Technology Laboratory
NF	Non-flammable
NG	Natural gas
NGO	Non-governmental organization
NGV	Natural gas vehicle
NHTS	National Highway Travel Survey
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel

NIST	National Institute of Standards and Technology
nm	Nanometer
NM	Non-methane
Nm	Newton-meter
NMC	Nickel manganese cobalt oxide
NMFTA	National Motor Freight Traffic Association
NMHC	Non-methane hydrocarbon
NMP	N-methyl-2-pyrrolidone
NO	Nitric oxide (nitrogen monoxide)
NO_2	Nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_x	Oxides of nitrogen
NPS	National Park Service
NRECA	National Rural Electrification Association
NREL	National Renewable Energy Laboratory
NTC	Negative temperature coefficient
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
NVBL	National Virtual Biotechnology Laboratory
NVH	Noise, vibration, and harshness
NYCC	New York City Cycle
NYPA	New York Port Authority
O	Oxygen
OCPP	Open charge point protocol
ODOT	Ohio Department of Transportation
OE	Office of Electricity
OEM	Original equipment manufacturer
OHC	Oxidation half cycles
OIM	Organic insertion materials
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity/component
P	Pressure

PACE	Partnership for Advanced Combustion Engines
PAH	Polycyclic aromatic hydrocarbon
PAN	Polyacrylonitrile
PAPSC	Pressure-assisted precision sand casting
PATH	Partners for Advanced Transportation Technology
PBI	Polybenzimidazole
PC	Pre-chamber
PCB	Printed circuit board
PCI	Precision Combustion Inc.
PCP	Peak cylinder pressure
Pd	Palladium
PDF	Pair-distribution function
PDPA	Phase Doppler particle analyzer
PE	Power engineering
PE	Polyethylene
PEEK	Polyetheretherketone
PEG	Polyethylene glycol
PEKK	Polyetherketoneketone
Penn State	Pennsylvania State University
PEO	Polyethylene oxide
PET	Polyethylene terephthalate
PEV	Plug-in electric vehicle
PF	Proportionally fair
PFI	Port fuel injection
PFS	Partial fuel stratification
PGM	Platinum group metals
pH	Power of hydrogen
Ph.D.	Doctor of Philosophy
PHEV	Plug-in hybrid vehicle
PI	Principal Investigator
PII	Personally identifiable information
PIV	Particle image velocimetry

PKI	Public key infrastructure
PM	Particulate matter
PMCP	Powertrain Materials Core Program
PNA	Polynuclear aromatics
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
PP	Polypropylene
ppm	Parts per million
PPS	Passenger protection system
PS	Polysufide
Pt	Platinum
PTO	Power take-off
PUD	Public utility district
PV	Photovoltaic
PVDF	Polyvinylidene difluoride
PVDF	Polyvinylidene fluoride
PZLT	Piezoelectric
Q	Quarter
Q&A	Question and answer
QDTA	Quasi-dynamic traffic assignment
R&D	Research and development
R2R	Roll to roll
RANS	Reynolds-averaged Navier-Stokes
RASIC	Responsible, Approving, Supporting, Informed, and Consulted
Rb	Rubidium
RCM	Rapid compression machine
RCT	Charge transfer resistance
RD5-87	Research-grade regular E10 gasoline
RDD&D	Research, development, deployment, and demonstration
RDE	Real Driving Emissions test
RE	Rare earth
ReaxFF	Reactive force field

ReaxFFMD	Reactive force field molecular dynamics
REE	Rare earth element
ReFUEL	Renewable Fuels and Lubricants Laboratory
RE-PM	Rare-earth permanent magnet
RESS	Rechargeable energy storage system
RF	Radiofrequency
RFP	Request for proposal
Rh	Rhodium
RHC	Reduction half cycle
RL	Reinforcement learning
RMP	Rocky Mountain Power
RNN	Recurrent neural networks
ROI	Return on investment
rpm	Revolutions per minute
rpm	Revolutions per minute
RSW	Resistance spot weld
RTM	Resin transfer molding
RTO	Recovery time objective
Ru	Ruthenium
RyThMiCCS	Real-Time Mobility Communications and Control System
S	Flame speed
S	Sulfur
s	Second(s)
S@PAN	Sulfurized polyacrylonitrile
S@PC	Sulfurized porous carbon
SAC	Single-atom catalyst (catalysis)
SAE	Society of Automotive Engineers
SA-LTC	Spark-assisted low-temperature combustion
SBIR	Small Business Innovation Research
SCE	Single-cylinder engine
SCE	Southern California Edison
SCM	Smart charge management

SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SEI	Solid-electrolyte interface
SEM	Scanning electron microscopy
SETO	Solar Energy Technologies Office
ShAPE™	Shear Assisted Processing and Extrusion
SHM	Simple harmonic motion
SI	Spark ignition
Si	Silicon
SiC	Silicon carbide
SIL	Software-in-the-loop
SIMS	Secondary Ion Mass Spectrometry
SiO_x	Oxides of silicon
SIS	Safety instrumented system
SLAC	Stanford Linear Accelerator Center
SMART	Systems and Modeling for Accelerated Research in Transportation
SMC	Soft-magnet composite
SN	Succinonitrile
SNAP	Rideshare software interface
S-NIC	Secure network interface card
SNL	Sandia National Laboratories
SNS	Spallation Neutron Source
SOA	State of the art
SOC	State of charge
SOF	System optimal fuel use
SOPO	Statement of project objectives
SOT	System optimal travel time
Spaci-MS	Spatially resolved capillary inlet - mass spectroscopy
SPAN	Sulfurized polyacrylonitrile
SpEC	Smartgrid EV Communication
SPI	Stochastic pre-ignition
SPIN	Smart Power Integrated Node

SPR	Self-piercing rivet
Sr	Strontium
SSB	Solid-state battery
SSE	Solid-state electrolyte
SSL	Self-supervised learning
SST	Solid-state transformer
SStAC	Stainless steel alloy corrosion
STA	Static traffic assignment
STEM	Scanning transmission electron microscopy
SULEV	Super Ultra-Low Emissions Vehicle
SUMO	Simulation of Urban Mobility
SUNY	State University of New York
SURF	Scale-Up Research Facility
SVTRIP	Stochastic vehicle trip prediction
SW	Spray wall
SWI	Spray-wall interaction
SwRI	Southwest Research Institute
t	Time
T	Temperature
TCC-III	Transparent combustion chamber
TCF	Technology Commercialization Fund
TCO	Total cost of ownership
TDOT	Tennessee Department of Transportation
TEA	Techno-economic analysis
TEEM	Transportation Energy Evolution Modeling
TEM	Transmission electron microscopy
TFP	Tailored fiber placement
Tg	Glass transition temperature
Ti	Titanium
TI	Technology Integration
TiAl	Titanium aluminide (gamma titanium)
TMF	Thermochemical fatigue

TMP	Thermo-mechanical processing
TNC	Transportation network company
ToF	Time-of-Flight
TOU	Time of use
TPD	Temperature programmed desorption
TPR	Temperature programmed reduction
TPRF	Toluene primary reference fuel
TRB	Transportation Research Board
TRL	Technology Readiness Level
TTSI	Total Transportation Services Inc.
TuFF	Tailorable universal feedstock for forming
TVR	Taylor Vortex Reactor
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 sustainability
UAM	Urban Air Mobility model
UC Davis	University of California at Davis
UCLA	University of California at Los Angeles
UDF	Undefined user files
UET	User equilibrium travel time
UFPV	Unsteady flamelet progress variable
UH	University of Houston
UIC	University of Illinois at Chicago
UPS	United Parcel Service
URI	University of Rhode Island
USABC	United States Advanced Battery Consortium
USAMP	U.S. Automotive Materials Partnership
USC	University of Southern California
USCAR	United States Council for Automotive Research
USD	Unified School District

USU	Utah State University
USW	Ultrasonic spot welding
UTK	University of Tennessee-Knoxville
UTS	Ultimate tensile strength
UVA	University of Virginia
UW-Madison	University of Wisconsin at Madison
V	Volt
V2G	Vehicle-to-grid
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-anything
VAN	Vehicle Analysis
VGI	Vehicle-grid integration
VIL	Vehicle-in-the-loop
Virginia Tech	Virginia Polytechnic Institute and State University
VIUS	Vehicle Inventory and Use Survey
VMT	Vehicle-miles traveled
VOF	Volume of fluid
VPPG	Virtual physical proving ground
VTO	Vehicle Technologies Office
VTOL	Vertical takeoff and landing
WBG	Wide bandgap
WERC	Wisconsin Engine Research Consultants
Wh	Watt-hour
Wh/kg	Watt-hour per kilogram
WHR	Waste heat recovery
WPI	Worcester Polytechnic Institute
WSR-MZ	Well-stirred reactor multi-zone
wt.%	Weight percent
WU	Waynesburg University
XANES	X-ray absorption near edge structure spectroscopy
XCEL	eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries

XCT	X-ray Computed Technology
xEV	An electric vehicle, including battery electric vehicle (BEV), hybrid xEV electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), etc.
XFC	Extreme fast charging
XIL	Anything-in-the-loop
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
XSS	Cross-site scripting
Y	Yttrium
YS	Yield strength
Zero-RK	Zero-Order Reaction Kinetics
ZEV	Zero-emission vehicle
ZIP	Zone Improvement Plan
Zn	Zinc
ZnO	Zinc oxide
ZNP	Zion National Park
Zr	Zirconium
ZSM-5	Zeolite Sacony Mobil5

(This Page Intentionally Left Blank)

U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/vehicles

DOE/EE-2504 ▪ November 2021