5. Fuel and Lubricant Technologies

More than 90% of transportation relies on petroleum-based fuels: gasoline and diesel. While alternative fuels and plug-in electric vehicles offer great promise to reduce America's petroleum consumption, petroleum-based fuels are likely to play a substantial role for years to come. However, the sources of these petroleum-based fuels are changing, with more fuels than ever from unconventional sources. Canada, which is the United States' largest foreign supplier of crude oil, is currently getting more than half of its petroleum from oil sands. In addition, new advanced combustion engines are particularly sensitive to variations in fuel composition.

The Vehicle Technologies Office (V O) supports research into fuels to enable more efficient engine and more effective emissions control systems that improve fuel economy and reduce emissions. Much of this research can also provide insight into how biofuels' unique properties can affect these engines and systems.

Currently, VTO is supporting the Co-Optimization of Fuels and Engines Initiative (Co-Optima). Over the course of this multi-year initiative, VTO and the Bioenergy Technologies Office are supporting research and development (R&D) to concurrently accelerate the introduction of affordable, scalable, and sustainable biofuels along with high-efficienc , low-emission vehicle engines. This coordinated R&D effort brings together nine U.S. Department of Energy (DOE) national laboratories and numerous industry and academic partners to integrate the research areas of biofuels, combustion, and analysis. The Co-Optimization Initiative has three concurrent phases of R&D:

- Optimizing spark ignition (SI) fuels and engines for near-term effect;
- Developing fuels and engines to enable advanced compression ignition (CI) technologies needed for revolutionary long-term solutions; and
- Developing and applying analysis tools to assess the economic and environmental impact of the proposed technologies.

Investigating technologies such as lubricants that will improve the efficiency of today s vehicles is essential, as most vehicles are on the road for more than 15 years before they are retired. VTO supports R&D on lubricants that can improve the efficiency of vehicles w th internal combustion engines. Because 11.5% of fuel energy is consumed by engine friction, improving lubricants enough to result in a 1% fuel savings in the existing vehicle fleet could save more t an 90 thousand barrels of oil a day.

Research that the VTO supports includes:

- Developing better base oils and oil additives that have the potential to improve the mechanical efficiency of internal combustion engines by 10% without causin increased wear, emissions, or damage to emission aftertreatment systems. In particular, using ionic liquids (IL), which are salts in a liquid state, as lubricants or lubricant additives may result in 30% less friction than comparable lubricants.
- Working to improve the understanding of the relationship between benchtop and engine tests when studying friction and wear performance data. This work will help improve standards and the accuracy of future research.
- Developing and optimizing tribochemical films (the protective l yer that forms on metal surfaces when using oil additives) to reduce friction, reduce wear, and improve fuel economy.
- Developing additives to lubricants that are compatible with the use of higher levels of biofuels that will enable the adoption of low-carbon fuels.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2016 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

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

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

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

Question 3: Were important issues and challenges identified?

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

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

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

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

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

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

Question 10: Has the program area engaged appropriate partners?

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

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

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

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

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

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

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

Overview of the VTO Fuel and Lubricant Technologies R&D: Kevin Stork (U.S. Department of Energy) - ft000

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

Reviewer 1:
The reviewer stated that the overall strategy of the Fuel and Lubricant Technologies program was very well described: directly displace petroleum and enhance combustion using lubricants to retrofit existing technology to provide a 4% fuel economy improvement.

Reviewer 2:
The reviewer replied yes, the program was covered in adequate detail.

Reviewer 3:
The reviewer said the presentation gave a nice, broad overview of this large program, which has two very separate activities (fuels and lubricants). However, the reviewer remarked that the presentation lacked details about selection of the fuels and status and criteria of that selection. The reviewer stated that it was not possible to get a real idea of the programs until after attending individual merit review talks.

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

Reviewer 1:
The reviewer stated that there appears to be an appropriate balance between practical goals and long term research goals. The reviewer further stated that there also appears to be an appropriate balance between technology development and development of new methods for assessing technologies.

Reviewer 2:
The reviewer asserted that the program area adequately discussed near-, mid-, and long-term R&D. The work in this area has strategies to help address the 2017 to 2025 U.S. Environmental Protection Agency (EPA) Tier 3 emissions regulations, the fuel economy standard, and the Renewable Fuels Standard in 2022 and 2025. This reviewer also noted that the co-optimization of fuels and engines looks at long-term fuel economy gains in the 2040 timeframe.

Reviewer 3:
The reviewer replied yes, the Co-Optima program is an excellent example of looking at 5-year and 20-year programs.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer asserted that the three automotive challenges of meeting fuel economy standards, renewable fuels standards, and EPA emissions standards were discussed.

Reviewer 2:
The reviewer said yes, the presentation gave an overview about octane and advanced combustion fuels.

Reviewer 3:
The reviewer indicated that the presentation was mainly focused on SI engines and octane effects. This person observed very little detail about diesel/CI engines and fuels, apparently because they are mainly being covered in Phase 2. The reviewer was not sure why diesel was assigned to second place, unless this was due to budget considerations and pressure from advisor groups. Although there was no mention of fuel effects on low-speed pre-ignition, the reviewer later learned that this criterion is part of the Co-Optima screening criteria.

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

Reviewer 1:
The reviewer agreed yes, there were clear plans and projects identified to meet the challenges, especially through the Co-Optimization of Fuel and Engines projects.

Reviewer 2:
The reviewer asserted that the program discussed the lubricants challenges with good detail.

Reviewer 3:
This reviewer replied yes, but really got the sense of identified plans for addressing issues and challenges from following the review talks, as this presentation was a broad overview. The reviewer elaborated that the development of a new fuel and corresponding engine types are enormous challenges and this project could be important for laying the groundwork for further work. The reviewer concluded that, to a large extent, the issues and challenges will be identified as the project progresses, rather than at the front end

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

Reviewer 1:
The reviewer agreed that yes, the benchmarks and progress were clearly shown.

Reviewer 2:
The reviewer stated that some detail was provided about accomplishments including the novel lubricant formulation scheme for 2% fuel efficiency improvement and power cylinder friction reduction through coating and surface finish

Reviewer 3:
The reviewer indicated that, on Slide 3, the goals and accomplishments for fuels research were not aligned for direct comparison. In addition, the reviewer remarked that for the funnel slide describing fuel selection and screening, it would be useful to know real numbers. This reviewer inquired about how many fuels and components are going to be screened, and how many have already advanced to more rigorous evaluation.

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

Reviewer 1:
The reviewer replied yes and characterized this program as supporting the broad program goals of improved fuel efficienc , lower greenhouse gas (GHG) emissions, and increased use of low-carbon fuels. The reviewer also stated that the program is well aligned with the biofuels program and with the Advanced Combustion Engine program, as it should be.

Reviewer 2:
The reviewer observed that fuels and lubricants are one area that directly affect DOE's goals for reducing GHGs and petroleum dependence.

Reviewer 3:
The reviewer indicated that there was not much information provided regarding many of the projects in the Fuel and Lubricant Technologies program. Therefore, it is difficult to address whether it is addressing the VTO barriers. However, the reviewer added that through the discussion of the plans of the program, it appears the barriers would be adequately addressed.

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

Reviewer 1:
The reviewer declared that the Technology Manager is doing an excellent job of managing the program and the recent addition of program staff is likely to make the program stronger.

Reviewer 2:
The reviewer stated yes, the program is well-managed and should be effective in addressing VTO's needs.

Reviewer 3:
The reviewer commented that the presentation did not give sufficient detail to assess e fectiveness of management and focus, elaborating that while the program certainly has all the right elements and work is progressing, the reviewer could not decide if things were adequately managed or if the program could benefit from stronger management.

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

Reviewer 1:
The reviewer remarked that the new effort of Co-Optima should develop into a strength of the program. This person also observed that it is essential to work on fuel and engines as a pair to make sure the goals can be attained.

Reviewer 2:
The reviewer commented that the lubricants portion of the program has obvious advantages for legacy vehicles that the rest of the VTO program cannot help and that the only weakness is the lack of funding for lubricants. Fuels appears to be on a good track now with the Co-Optima program, and the reviewer added that it would be nice if the Advanced Combustion Engine program would try to integrate more fuels research into its program.

Reviewer 3:
The reviewer said that Co-Optima is a very important thrust and could be considered a key strength, while recognizing that the program has limited resources to achieve rapid and real benefits and that such a la ge, diverse group will be hard to manage and coordinate. Regarding the lubricants area, the reviewer acknowledged not really being qualified to assess the detailed technologies being studied, and thinks it is important to maintain industry involvement to ensure that DOE is working on relevant topics.

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

Reviewer 1:
The reviewer said that the program has a good balance of practical, traditional approaches focusing on octane, ignition delay, and low-carbon fuels combined with engine performance research. The program also addresses the need for new methods or metrics for screening new technologies as they are developed.

Reviewer 2:
This reviewer indicated that the Co-Optima project represents a very good approach to creating mechanisms to reach the goals and eliminate program barriers.

Reviewer 3:
The reviewer replied yes to this question.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer said the collaboration with the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) Fuels Working Group (FWG), and the Coordinating Research Council (CRC) on the fuels side, is excellent and a very good way to engage fuel and engine manufacturing in a manner that could lead to real change in future fuels and engines design. The reviewer characterized collaboration with lubricant and additive manufacturers and engine and vehicle designers as critical to ensuring that lubricants work is properly focused to yield both short- and long-term results.

Reviewer 2:
The reviewer observed that the program works with all of the appropriate partners including many national laboratories and members of the FWG in U.S. DRIVE.

Reviewer 3:
The reviewer replied yes, the lubricants partners are all excellent. The reviewer suggested that the fuels program could use more energy companies, but speculated that most of these companies do not want to be involved in government work.

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

Reviewer 1:
The reviewer stated that the program seems to have a very good relationship with the program partners and there is great collaboration and coordination with them.

Reviewer 2:
The reviewer remarked that the current partners are working together well.

Reviewer 3:
The reviewer stated that the collaborations appear to be effective, but suggested collaborations might be a little slow moving because of collaborators that are mainly consensus-driven groups and organizations. As more practical results are achieved, the reviewer opined that maybe things can be accelerated.

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

Reviewer 1:
The reviewer stated that with the addition of the Co-Optima projects, there do not appear to be any gaps in this program area.

Reviewer 2:
The reviewer commented that more work needs to be done on how to introduce new fuels to the market.

Reviewer 3:
The reviewer pointed out that there was not any discussion of fuel properties beyond octane, ignition delay, and bio equivalence. Based upon follow-on talks, the reviewer learned that secondary fuel properties such as flame velocity, detailed chemistry, and molecular weight range, among others, are being studied. The reviewer stated that long term, there has to be a step taken beyond research octane number (RON) and cetane number (CN).

The reviewer offered that more details about fuel chemistry are probably best studied using a combination of detailed kinetic modeling, surrogate fuels, and refinery-based blended fuels. The reviewer also suggested that new lubricants and additives can enable new lighter weight or lower friction engine designs through a long term iterative process. It was not clear to this reviewer whether there is much focus on engine design.

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

Reviewer 1:
The reviewer commented that projects in the program area adequately cover the necessary topics to have the program meets its goals.

Reviewer 2:
The reviewer stated that it was not clear from the presentation if the following important areas had been addressed by the program: fuel properties beyond octane and cetane; kinetic modeling of fuel chemistry effects; and co-evolution of lubricants and engine design. The review acknowledged being more comfortable about the program's progress after hearing the follow-on talks.

Reviewer 3:
The reviewer stated that more work needs to be done on how to introduce new fuels to the market.

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

Reviewer 1:
The reviewer commented that the program should continue funding the project areas in its portfolio.

Reviewer 2:
The reviewer replied no, but added that increased or accelerated funding might be appropriate.

Reviewer 3:
The reviewer offered that some work looking at stoichiometric compression ignition (SCI) with lower octane fuels would be a welcome addition.

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

Reviewer 1:
The reviewer replied that the program seems to be adequately addressing the barriers.

Reviewer 2:
The reviewer stated that the start of the Co-Optima project is a very good way to approach the barriers and was glad to see it was implemented.

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

Reviewer 1:
The reviewer replied no, adding that the program appears to be pursuing appropriate projects and is funded adequately.

Reviewer 2:
The reviewer suggested the program continue to communicate results in a timely manner so that feedback from interested groups can be obtained.

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 Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Engine Friction Reduction Technologies	Fenske, George (ANL)	5-12	3.50	3.50	3.63	3.25	3.48
Ionic Liquids as Engine Lubricant Additives, Impact on Emission Control Catalysts, and Compatibility with Coatings	Qu, Jun (ORNL)	5-15	3.67	3.50	3.83	3.50	3.58
Integrated Friction Reduction Technology to Improve Fuel Economy without Sacrificing Durability	Hsu, Stephen (George Washington University)	5-18	2.67	3.00	3.50	3.00	2.98
Hybrid Ionic-Nano-Additives for Engine Lubrication to Improve Fuel Efficiency	Zhao, Bin (University of Tennessee)	5-21	2.67	2.83	2.83	2.83	2.79
Hyperbranched Alkanes for Lubes	Cosimbescu, Lelia (PNNL)	5-24	3.33	3.17	3.00	3.33	3.21

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Lubricant Effects on Combustion, Emissions, and Efficiency	Wagner, Robert (ORNL)	5-27	3.50	3.67	3.83	3.33	3.60
Co-Optimization of Fuels and Engines Overview	Farrell, John (NREL)	5-30	2.88	2.88	3.13	2.88	2.91
Co-Optimization of Fuels and Engines (Co-Optima) -- Fuel Properties and Thrust I Engine Research	Szybist, Jim (SNL)	5-35	3.13	3.13	3.50	3.13	3.17
Co-Optimization of Fuels and Engines (Co-Optima) -- Thrust II Engine Research, Sprays Research, and Emissions Control Research	Miles, Paul (ORNL)	5-41	2.63	2.88	2.75	2.63	2.77
Co-Optimization of Fuels and Engines (Co-Optima) -- Simulation Toolkit Team	McNenly, Matt (LLNL)	5-45	2.88	3.00	3.25	2.75	2.97
Utilizing Alternative Fuel Ignition Properties to Improve Spark-Ignited and Compression-Ignited Engine Efficiency	Wooldridge, Margaret (University of Michigan)	5-51	2.40	2.50	3.20	2.60	2.58

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
E85/Diesel Premixed Compression Ignition	Kocher, Lyle (Cummins)	5-56	3.64	3.64	3.07	3.43	3.54
GEFORCE: Gasoline Engine and Fuels Offering Reduced Fuel Consumption and Emissions	Sluder, Scott (ORNL)	5-60	3.50	3.50	3.20	3.30	3.44
GDI Metrics	Goldsborough, Scott (ANL)	5-64	3.17	3.17	3.17	3.17	3.17
Efficiency-Optimized Dual Fuel Engine with In-Cylinder Gasoline/CNG Blending	Wallner, Thomas (ANL)	5-68	3.00	3.30	3.10	3.20	3.19
Overall Average			3.10	3.18	3.27	3.09	3.16

Engine Friction Reduction Technologies: George Fenske (Argonne National Laboratory) - ft012

Presenter
George Fenske, Argonne National Laboratory

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

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

Reviewer 1:
The reviewer praised the approaches identified to address the barriers in this project and stated that they are very good. The reviewer remarked that the use of multiple approaches of using base fluids, additives, and coatings to reduce engine friction will lead to a high likelihood of success of the project. The reviewer further commented that the approach to develop and assess lab protocols to replicate tribological environments in engines and drivetrains will provide for innovative lab-engine correlation.

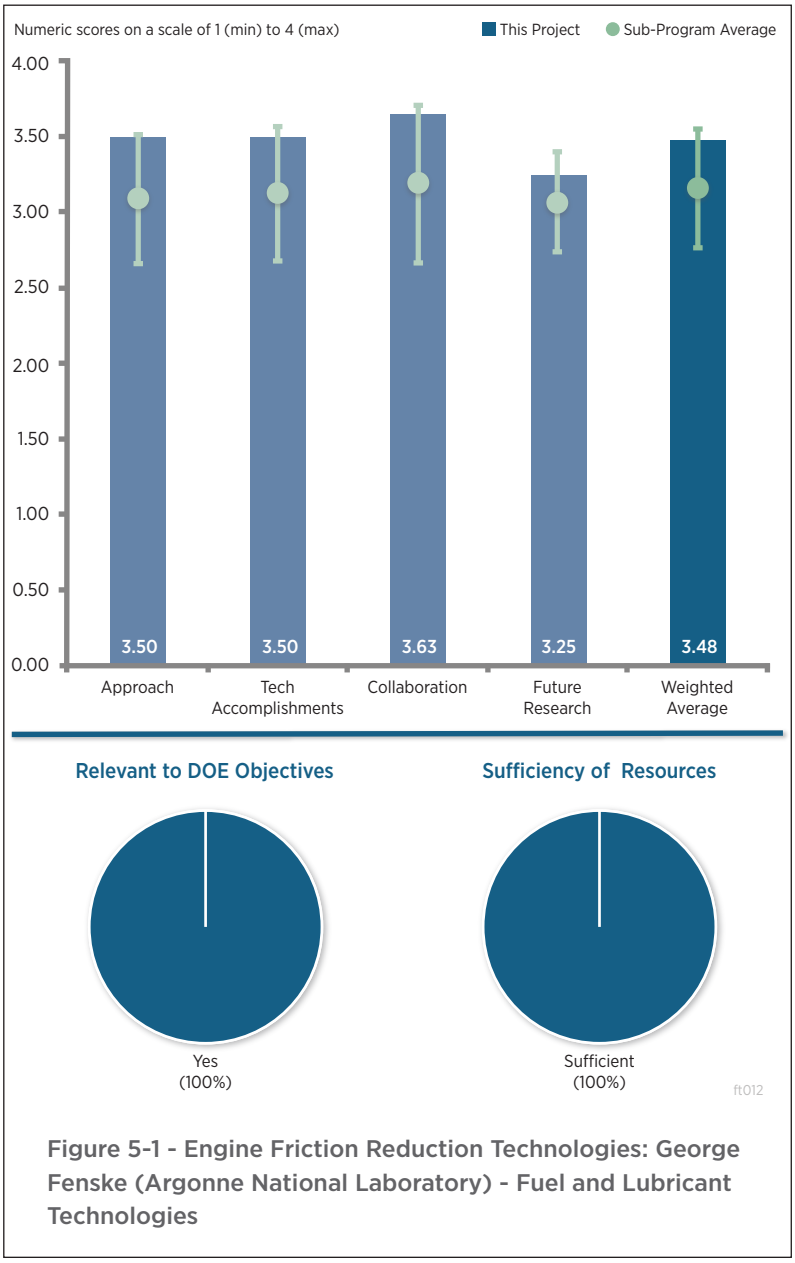

Figure 5-1 - Engine Friction Reduction Technologies: George Fenske (Argonne National Laboratory) - Fuel and Lubricant Technologies

Reviewer 2:
The reviewer remarked that the modification to the reciprocating rig that includes the tilt angle impact on scuffing is a good improvement. The reviewer questioned what the fundamental mechanism is that could be looked at to understand why this has an impact instead of just testing it on the rig.

Reviewer 3:
The reviewer commented that the project takes a very broad approach to developing new lubricant related technologies, including base fluids, additives, and coatings. The reviewer noted that the project includes boundary, mixed, and hydrodynamic regimes, screening methods, and surface science related measurements.

Reviewer 4:
The reviewer remarked that the project is producing vital information regarding major issues. The reviewer would have liked to hear more in-depth information on the project. However, due to presentation time constraints and the wide breadth of the program, it is hard to tell in-depth information on any given project. This is not the fault of the presenter, but this reviewer would like to see a deeper dive in one or two projects, instead of a general overview of several. Any given project within the program could easily be the topic of a presentation.

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

Reviewer 1:
The reviewer said the technical accomplishments this year have been excellent. The reviewer said that the project accomplishments including development and validation of scuffing protocols and the identification of factor that affect scuffing including temperature, speed, and load have provided information to successfully address the barriers of the project.

Reviewer 2:
The reviewer praised the good progress in developing standardized scuffing test. The reviewer further remarked on the good progress with catalytic coatings, i.e., narrowed down focus to a single representative coating so that performance and underlying science can be studied in greater detail.

Reviewer 3:
The reviewer remarked that the focus on base fluids and additives appears syne gistic towards the goals, and the coating work is also progressing well.

Reviewer 4:
The reviewer commented that the project spans several huge issues in the tribology world. In particular, scuffing predictability, tribofilm generation mechanisms, and creating a benchtop test that has the ability to predict engine performance are all longstanding endeavors that have not been well understood even though they have been researched for decades.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the coordination and collaboration in this project is excellent. The reviewer commented that the project works with industry consortia, vehicle and engine original equipment manufacturers (OEMs), additive and lubricant OEMs, engineering companies, and suppliers. Through the interaction with all of these entities, the project is able to address barriers that are important to industry so that the results of this effort will be useful.

Reviewer 2:
The reviewer remarked on the good mix of collaborative partners and opportunities for disseminating information and gaining feedback. The reviewer further noted the good involvement with interested groups.

Reviewer 3:
The reviewer remarked that the Massachusetts Institute of Technology consortium is necessary to stay close to the industry and keep the program focused. The reviewer asked if there are any programs that Argonne National Laboratory (ANL) is working on that have plans for production from the collaborations.

Reviewer 4:
The reviewer commented that this is an immense project involving several major collaborators.

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

Reviewer 1:
The reviewer commented that the program will continue to support DOE goals through developing new technologies and methods.

Reviewer 2:
The reviewer said future direction of lab-engine correlation, basefluid development, and catalytic coatings will continue to provide advancements in this project's work to develop engine friction reduction technologies.

Reviewer 3:
The reviewer said that it seems all of the components within the project are continuing adequately and that the future directions were addressed for each and seem appropriate, but due to presentation time constraints, the reviewer would have liked a higher level of project detail.

Reviewer 4:
The reviewer noted that there should be more work on non-ferrous materials and compatibility with advanced lubricants because the trend is towards more lightweight, non-ferrous materials. The reviewer said many conventional lubricant additives have trouble with non-ferrous materials.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer noted that by developing lubricants to reduce frictional losses and improve fuel economy, this project helps to address the DOE objective of petroleum displacement.

Reviewer 2:
The reviewer said lubricants were one of the few spots in the VTO program that can affect both future and legacy vehicles.

Reviewer 3:
The reviewer remarked that the project is aimed at both the development of new lubricant science and new lubricant methods to support industry in the advancement of fuel economy and downsizing goals.

Reviewer 4:
The reviewer said this project addressed many of the major questions of the tribology research realm. However, achieving the level of understanding necessary to elucidate these questions is no easy task.

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 addition of an experienced formulator was a welcome addition a few years ago. The current team is excellent but could benefit from another experienced industry hire

Reviewer 2:
The reviewer said the resources appear to be adequate to keep progress and goals on track.

Reviewer 3:
The reviewer commented that funding appears to be adequate for this project to meet its goals and objectives.

Reviewer 4:
The reviewer said due to the wide scope of the program, the funding level seems adequate.

Ionic Liquids as Engine Lubricant Additives, Impact on Emission Control Catalysts, and Compatibility with Coatings: Jun Qu (Oak Ridge National Laboratory) - ft014

Presenter
Jun Qu, Oak Ridge National Laboratory.

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

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

Reviewer 1:
The reviewer praised the approach taken by the project team and said it has been well thought out and provides excellent insight into how ILs, as well as zinc dialkyldithiophosphates (ZDDP), function. The investigator's efforts to understand the antagonistic behavior between ILs and ZDDPs, as well as diamond-like carbon (DLC) coatings was fruitful.

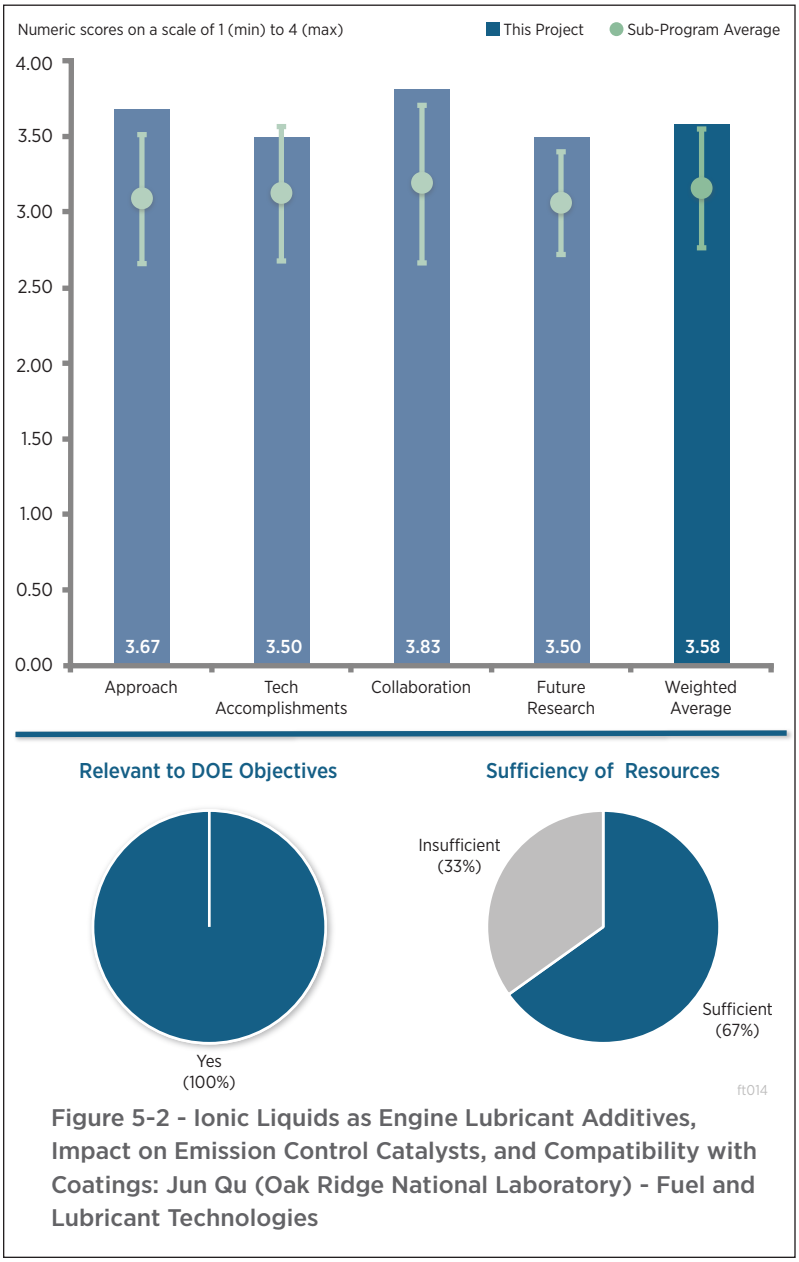

Figure 5-2 - Ionic Liquids as Engine Lubricant Additives, Impact on Emission Control Catalysts, and Compatibility with Coatings: Jun Qu (Oak Ridge National Laboratory) - Fuel and Lubricant Technologies

Reviewer 2:
The reviewer said the approach of this project was well designed and described for this project and that each of the tasks including using ILs as a lubricant to enhance engine efficienc , lubricant effects on emission control technologies, and compatibility of lubricant additives with hard coatings were described fully. The reviewer remarked that it was clear the project team would provide a path to addressing the barriers of this project.

Reviewer 3:
The reviewer said the approach to look at the tribofilm is exce lent and said the project team is doing a great job to fundamentally explain why the ZDDP and ILs have a synergistic effect. The reviewer noted that the project needs to conduct more full-engine tests to look at the compatibility with some of the non-ferrous materials under real operating conditions.

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

Reviewer 1:
The reviewer remarked that the technical accomplishments in this project throughout this three-year program have been excellent and that all of the required milestones in this project have been met. The reviewer further noted that the accomplishments to complete the project in fiscal years (FY) 2015 and 2016 (i.e., completing dynamometer tests to demonstrate fuel economy improvement when using a prototype oil and also the studies of the impact of additives on three-way catalysts which showed less impact of the IL additive) specifically addressed the barriers of this project

Reviewer 2:
The reviewer praised the technical progress to date as excellent and very promising. The reviewer also noted that additional work on materials compatibility with non-ferrous materials, such as copper, is required to prove the potential corrosion issues are manageable.

Reviewer 3:
The reviewer commented that the investigators were able to make significant headway against the barriers. The reviewer noted that the effects of ILs on three-way catalyst (TWC) seems to be clearly understood and that the investigation into ILs compatibility with non-metallic coatings is well underway with significant findings related to the ch ge of the phosphate ion and its impact on wear of DLCs.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer praised the project team as one of the best examples of a superstar team with members from DOE, the world's largest lubricant supplier, one of the largest automotive OEMs, a large additive company, and a national laboratory.

Reviewer 2:
The reviewer commented that the team assembled for this project, which included energy companies, additive manufacturers, laboratories, and academia, brought together all of the entities that are needed to be involved in developing new lubricant additives to ensure acceptance of the results for potential future use in vehicles.

Reviewer 3:
The reviewer remarked that the project seems to have had good cooperation between the collaborators.

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

Reviewer 1:
The reviewer commented that the project team has identified and understands the important barriers that remain. The reviewer remarked that the barriers that have been investigated during this project to date are relevant and important for the successful transition of this technology to the commercial sector.

Reviewer 2:
The reviewer said this current project is 100% complete. The reviewer also noted that there is, however, a new joint funding opportunity announcement (FOA) project with General Motors that has tasks identified that will continue to address fuel economy improveme t through the development of lubricant technology for engine lubrication. The reviewer remarked that the project will also investigate the impact of these lubricants on TWCs, which will help eliminate the identified barriers

Reviewer 3:
The reviewer said that the future research should include identifying how low viscosity can go with advanced additives that decrease boundary friction and wear. The reviewer said some testing to push the limits on viscosity would be interesting if funding allows.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said the project supports the DOE goal of oil displacement because the development of engine oil additives will improve the efficiency of internal co bustion engines.

Reviewer 2:
The reviewer said lubricants are one of the few research areas in VTO that can affect both future and legacy vehicles.

Reviewer 3:
The reviewer said this project will result in a better understanding of the chemical mechanisms underpinning the development of tribofilms that will enable the use of lower viscosity, energy efficient lubricants, and a reduction in overall petroleum use.

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

Reviewer 1:
The reviewer remarked that additional funds are needed to complete additional materials compatibility work. The reviewer said materials compatibility is a major hurdle hindering production.

Reviewer 2:
The reviewer said the resources appear to be sufficient to meet the goals of the project, with the assumption that the technology being developed will be licensed or otherwise taken up by a commercial champion at some point and then further developed into a commercial product.

Reviewer 3:
The reviewer commented that the funding is adequate to complete the project.

Integrated Friction Reduction Technology to Improve Fuel Economy without Sacrificing Durability: Stephen Hsu (George Washington University) - ft033

Presenter
Stephen Hsu, George Washington University.

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

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

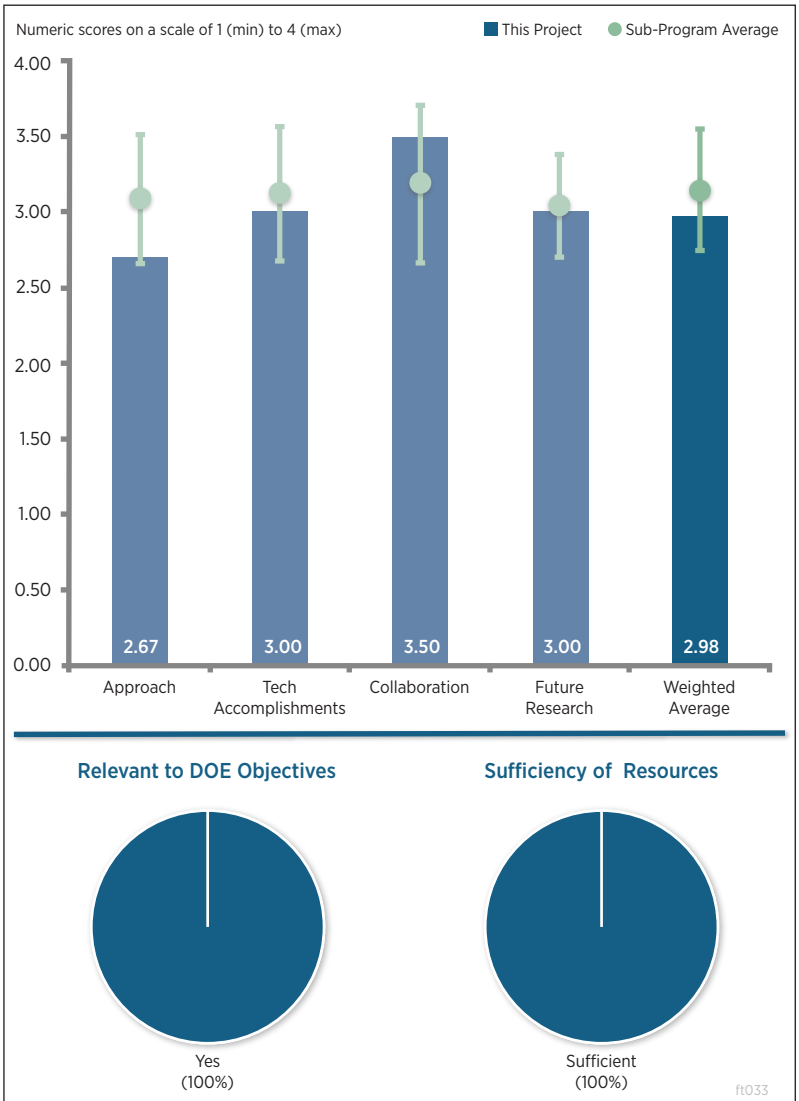

Figure 5-3 - Integrated Friction Reduction Technology to Improve Fuel Economy without Sacrificing Durability: Stephen Hsu (George Washington University) - Fuel and Lubricant Technologies

Reviewer 1:
The reviewer remarked that the project's approach is sound. The reviewer said the project looked at the base oil composition, additive components, and conducted some friction and wear bench testing leading up to fuel economy testing in an industry standardized engine test. The reviewer noted that the project team did not supply any statistical information concerning the variability of the bench test results, which made it difficult assess the results. The reviewer further remarked that no detail was provided about the composition of the test oils other than a lube code and said that this lack of detail resulted in difficulty in understanding the significance of some testin

Reviewer 2:
The reviewer said attempts were made to formulate futuristic American Petroleum Institute (API) automotive specifications for passenger car motor oils (GF-6 and GF-6B) with low viscosity passenger car crankcase oils using available base oils and additives. The reviewer noted that the project considered novel microencapsulation techniques to protect ZDDP and the reviewer noted that friction modifier was carried out. The reviewer said the project involved Edisonian screening of numerous additive and base oil technologies and the reviewer noted that this may not be the most effective way to address existing challenges. The reviewer commented that more direct focus on additives microencapsulation techniques should be pursued and suggested this focus may provide potential for technical breakthroughs.

Reviewer 3:
The reviewer said the VTO program appears to rely heavily on a formulation similar to current production

formulations. The reviewer suggested that it would be advantageous to be more aggressive and look at more aggressive changes to viscosity.

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

Reviewer 1:

The reviewer noted that the project addressed numerous base oils and additives that were examined in screen tests focusing on friction and wear measurements of fresh oils including Plint tester, high frequency reciprocating rig (HFRR) with temperatures up to 130° Celsius (°C), four ball at room temperature only, and tribological experiments using a mini traction machine (MTM). The reviewer further noted the team introduced a novel thermal gravimetric analysis (TGA) test run on neat base oils using argon rather than nitrogen. The reviewer said the project addressed "Sequence variable interest entity (VIE)" tests run before final test conditions are officiall approved and further commented that the Sequence VIE tests showed potential for fuel consumption benefit The reviewer said no information was offered on the type of base oil or novel additive chemistry in generic terms that was used to formulate candidate GF-6A oil. The reviewer said that because no statistical assessments with bars representing confidence level of reported bench tests data were provided, it was difficult to judge th actual level of improvements in frictional and wear performance observed in reported screen tests. The reviewer further commented that no hypothesis was put forward to address why microencapsulated ZDDP or friction modifier should o fer improved wear or frictional performance. The reviewer remarked that no used oil analysis was reported from oxidation or low-temperature and high-temperature deposits screen bench tests. The reviewer questioned if encapsulated additives impact upper piston deposits formation. The reviewer indicated that no storage stability, corrosion, or seals results were reported.

Reviewer 2:

The reviewer said the project was able to formulate an oil which when tested in an industry standard engine fuel economy test showed significant improvement over a relevant baseline engine oil. The reviewer stated these baselines were 0.89% for new oil and 1.51% for aged oil. The reviewer claimed the method of summing the new and aged fuel economy improvement is only relevant for the American Society for Testing and Materials (ASTM) and International Lubricants Standardization and Approval Committee ILSAC test limits. The reviewer further stated that a driver will not experience a summing of these two improvements. The reviewer said that a driver can expect to get some combination or average of the new or aged fuel economy benefit but not the sum. The reviewer remarked that it will be interesting to see if the encapsulation of additives will provide benefits for these formulations.

Reviewer 3:

The reviewer noted that the VTO program is on track for the objectives.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said the team is excellent and has all of the necessary components for success.

Reviewer 2:

The reviewer noted that the project includes representatives of key OEM and oil additive suppliers.

Reviewer 3:

The reviewer commented that the project worked closely with collaborators in the oil industry to develop its current 0W-20 lubricant.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points,

considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the proposed future work includes durability testing of the lower viscosity 0W-16. The reviewer noted that the project also plans to continue its work on surface textures and investigate the use of microencapsulated friction modifiers to prolong friction reduction. The reviewer concluded that these are logical extensions of the current work.

Reviewer 2:
The reviewer noted that the project made a list of several relevant challenges that were described in a relatively general fashion. The reviewer remarked that no timeline or listing of specific tasks assigned to key project collaborators, specifically their labs, was given. The reviewer stated that no analysis of metal contact areas to explain mechanisms of lubricating film formation or chemistry was planned or proposed

Reviewer 3:
The reviewer stated that work looking at coating every surface in an engine is of limited value and said that not all moving surfaces may benefit from coatings or surface texturing. The reviewer offered that it would be more interesting to look at coating or texturing select components and then testing them one by one instead of as a whole system.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said lubricants are one of the few research areas in VTO that can affect both future and legacy vehicles.

Reviewer 2:
The reviewer pointed out that the project goal is to improve the fuel economy of vehicles which will reduce the use of fuel.

Reviewer 3:
The reviewer stated that forthcoming API GF-6A and GF-6B oils will offer significant fuel economy improvements. The reviewer remarked that no specific focus to provide vital fundamental knowledge regarding utilization and potential barriers of novel microencapsulated additives technologies is described. The reviewer said there was no description of how the future technology discovery steps and intellectual property (IP) will be handled.

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

Reviewer 1:
The reviewer remarked that the project has not commented on current or future funds available. The reviewer cautioned that the project may run short of funds specifically when multiple sets of API GF-6A and GF-6B engine tests need to be carried out.

Reviewer 2:
The reviewer said according to the overview the funding received for FY 2016 is $751,000. The reviewer stated that this funding amount appears to be sufficient for the project to complete new formulations, bench testing, and engine testing.

Hybrid Ionic-Nano-Additives for Engine Lubrication to Improve Fuel Efficiency: Bin Zhao (University of Tennessee) - ft034

Presenter
Bin Zhao, University of Tennessee

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

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

Reviewer 1:
The reviewer remarked that the project seems like a well thought out nanoparticle (NP) study. The reviewer expressed some concern on the stability and dispersion side. The reviewer stated that there was little mention of how stable and dispersed these formulations are over time. The reviewer assumed particle size data over time by way of a technique such as dynamic light scattering was conducted by the project, but not shown due to presentation time constraints. The reviewer specified that zeta potential of the particles over time would also be a very good metric to quantify stability. The reviewer further noted that stability and dispersion state can vary greatly over many parameters, such as concentration, agitation state, temperature, interface materials, and others.

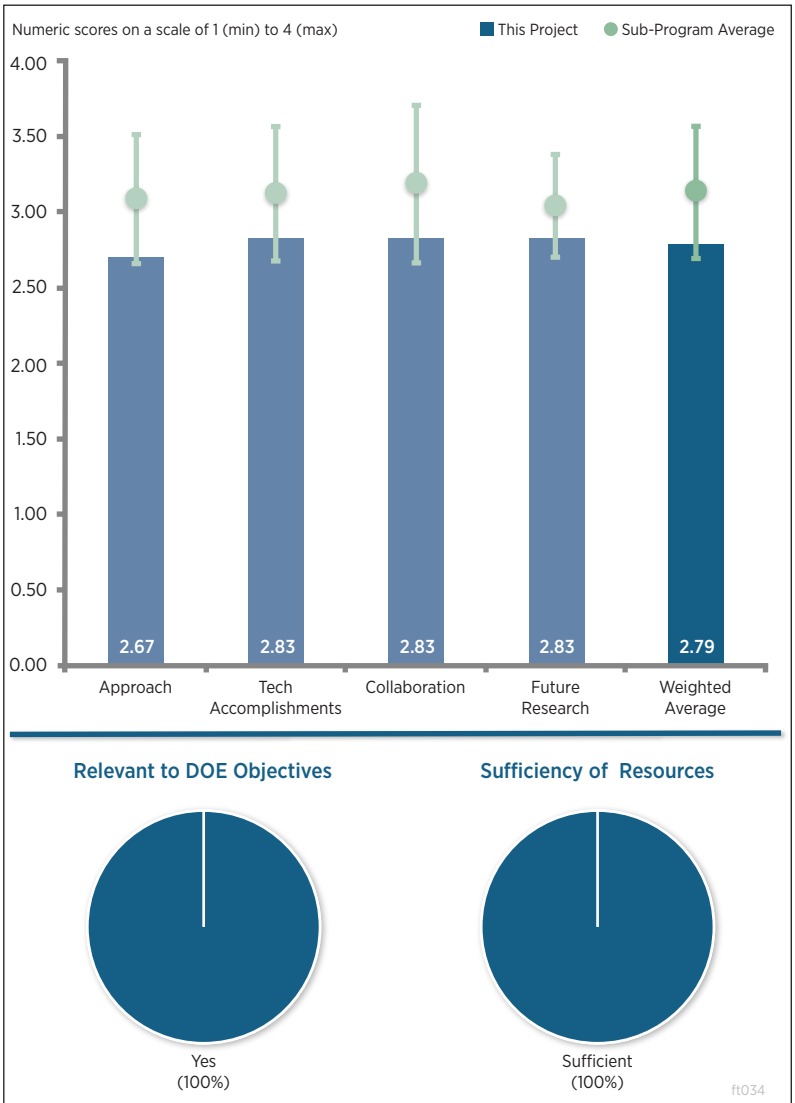

Figure 5-4 - Hybrid Ionic-Nano-Additives for Engine Lubrication to Improve Fuel Efficiency: Bin Zhao (University of Tennessee) - Fuel and Lubricant Technologies

The reviewer cautioned that it is imperative to be certain the nanofluid subjected to tribological testing is the true intended monodispersed nanofluid, not a system of agglomerates. The reviewer further remarked that if this cannot be proven, the performance could vary greatly and thus the validity of the data could be brought into question.

Reviewer 2:
The reviewer said the approach was satisfactory but it would be useful to have a more detailed explanation of how the project is going to be implemented.

Reviewer 3:
The reviewer said that there does not appear to be any baselining against current technology, that is to say, current motor oil or against current dispersants. The reviewer warned that the use of plain Polyalphaolefin (AO) 4 as a baseline is not really realistic and said that probably almost anything added to it will improve friction and wear.

The reviewer remarked that the project needs a better way to assess suspension stability beyond taking photographs to show transparency. The reviewer said that there was no detail or discussion about engine dyno testing.

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

Reviewer 1:

The reviewer remarked that several technical accomplishments have shown friction reduction of as much as 50%. The reviewer said that milestones have been met or are on track, which will contribute to overcoming the barriers of this effort.

Reviewer 2:

The reviewer noted that the project conveyed the good potential in the novel nanofluid formulations. The reviewer specified that the room temperature performance of the ionic liquid nanoparticles (IL-NPs), albeit beneficial, is no very important and indicated that this is because it lacks practicality to the real world application. The reviewer said scuffing issues at higher temperature are a major concern that must be immediately addressed. The reviewer claimed that at higher temperatures, the oil will thin out, and the smaller fluid film thickness could lead to build up on the leading edge and oil starvation in the contact. The reviewer stated that this problem could be exacerbated if the solution has agglomerates and suggested that a more detailed dispersion study may provide information regarding the scuffing issue

Reviewer 3:

Program appears to be a little behind schedule based on 30% completion number, but it does appear that milestones are being met.

The reviewer said the selection of NPs is not described and therefore it is hard to assess how novel they are. The reviewer warned that failure of IL-NP lubrication at 100°C is troubling and warrants much more study. The reviewer suggested that maybe the NPs desorb from the metal surface or the polymers desorb from the NPs.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said the national laboratory and university support seems adequate. The reviewer noted that there is a strong influence from the national laboratory regarding the IL-N dispersion science and said that this is vital for program success. The reviewer remarked that there is no influence from industry and said that this is not a major concern at this stage of the project, but also suggested that the project team may want to seek this in the future. The reviewer would like to see more influence from additive companies. The reviewer commented that the performance may be vastly different once added to a fully formulated oil and that an additive company could provide important guidance on how to overcome these barriers.

Reviewer 2:

The reviewers remarked on the useful partnerships with Oak Ridge National Laboratory (ORNL) for ILs and testing. The reviewer said there was a useful partnership with the University of California-Merced for modeling. The reviewer pointed out that there does not appear to be a relationship with a lubricant manufacturer to deal with formulation issues and that this was a project weakness. The reviewer said there also does not appear to be a collaboration with engine, vehicle, or component manufacturers to indicate industrial interest in new technology.

Reviewer 3:

The reviewer said collaboration between ORNL and the University of California-Merced is good. The reviewer commented that it may be useful to also have interactions with industry partners such as OEMs or engine lubrication companies.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points,

considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the proposed future work is very good and that it will address the challenges and barriers that remain in the project.

Reviewer 2:
The reviewer would like to see more stability-over-time data addressing the previously stated concerns.

Reviewer 3:
The reviewer remarked that there was no discussion about addressing 100°C performance issues, other than developing new formulations. The reviewer asked if there was a systematic plan for developing new formulations, along with selection criteria, or if the project was conducting more Edisonian type research. The reviewer said that it sounds like there could be a lot of combinations for NPs, ILs, polymers, and polymer molecular weights (MWs). The reviewer indicated that the matrix was not defined in the talk, relative to the total number of combinations and screening tests being used. The reviewer said there was no discussion about engine dyno testing plans or about baselining against current oil and additive technologies.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said the main objective of the project is to improve engine efficiency by developing additives to be used in engine lubrication and that this definitely supports the DOE objective of petroleum displacement

Reviewer 2:
The reviewer said that this project illustrated the potential to reduce both friction and wear, which could ultimately lead to fuel efficiency gains

Reviewer 3:
The reviewer affirmed by saying yes, the development of new or novel additives can result in friction and wear reduction to enable more efficient engines. The reviewer noted that it is also possible that some of these additives could be used in the existing vehicle fleet with lower viscosity base 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 said that the level of control over the NP surface chemistry demands an appropriate budget and strong partners, which this project has.

Reviewer 2:
The reviewer said that there appears to be sufficient funds to accomplish the project objectives and milestones

Reviewer 3:
The reviewer commented that the resources appear to be adequate to complete the project and said the current progress does not warrant an increase in effort.

Hyperbranched Alkanes for Lubes: Lelia Cosimbescu (Pacific Northwest National Laboratory) - ft035

Presenter
Lelia Cosimbescu, Pacific Northwest National Laboratory.

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

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

Reviewer 1:
The reviewer remarked that the project approach was divided into two components: design, synthesis, and screening of molecular structures with unique hyperbranched architectures for proof of concept experiments; and engine testing on the developed additives that pass the screening criteria, which has proven to be an excellent method.

Reviewer 2:
The reviewer said the project's approach was thorough and included synthesis of new viscosity modifiers (VMs), simulation and bench testing, and also engine testing.

Reviewer 3:
The reviewer said the approach for the go/no go points was well designed. The reviewer stated that the project team had a nice design to focus on the synthesis and testing of the additives before spending much effort in full engine tests.

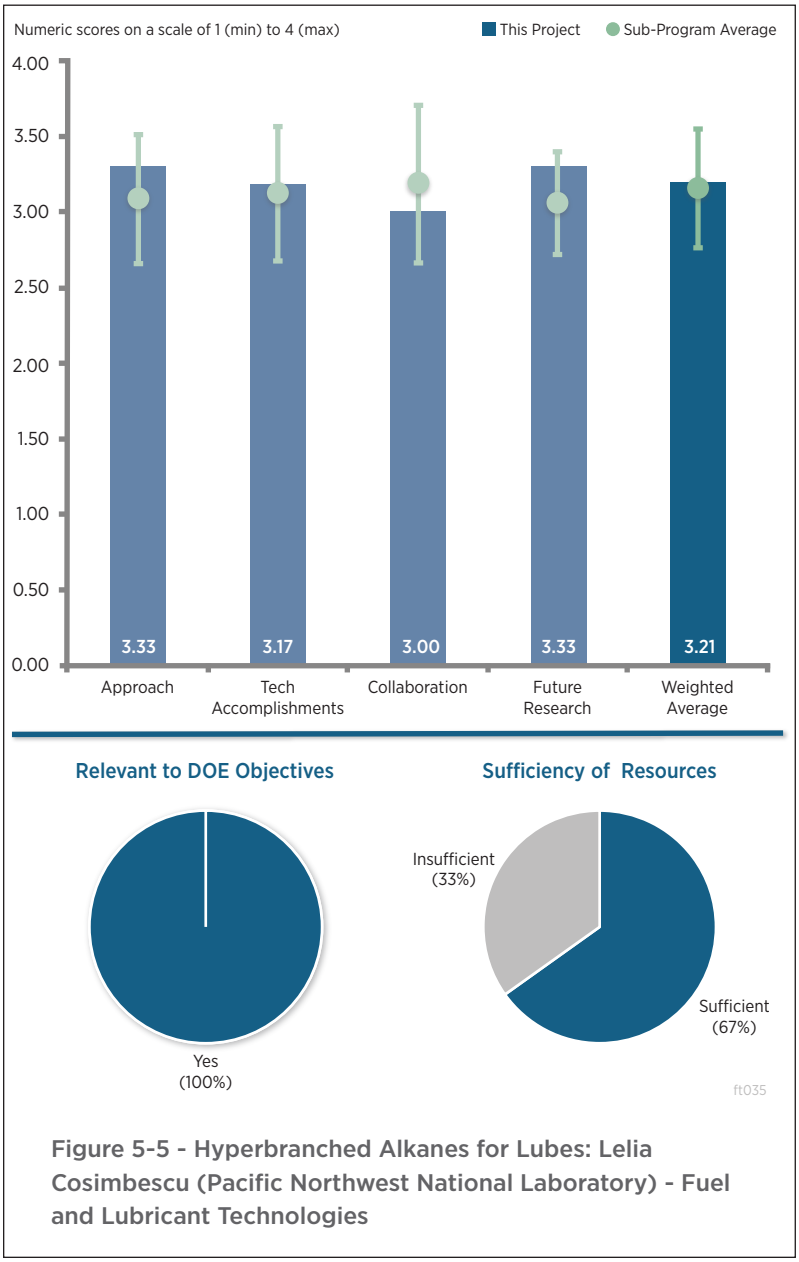

Figure 5-5 - Hyperbranched Alkanes for Lubes: Lelia Cosimbescu (Pacific Northwest National Laboratory) - Fuel and Lubricant Technologies

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

Reviewer 1:
The reviewer said that the technical accomplishments in this project provided data and information to meet the milestones that were identified. The reviewer noted that engine testing demonstrated the feasibility of the Pacific Northwest National Lab (PNNL) polymer with commercial packages and also showed fuel economy increases that met the objective of 2% fuel economy increase.

Reviewer 2:
The reviewer stated that the project is essentially finished so the progress is good. The reviewer said that the demonstration of 2% fuel economy could have been improved with different baseline fluids but that this is a moot point now.

Reviewer 3:
The reviewer remarked that although the project did achieve a fuel economy benefit over the reference oil, the reference oil is not a modern fuel efficient formulation. The reviewer pointed out that additional optimization of the formulation could lead to improvements. The reviewer said that other significant concerns include shear stability of the new VMs and the potential for increased wear.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
There reviewer remarked that there is very good collaboration and coordination in this project with other national laboratories, academia, and industry partners, which have provided guidance and advice on the project to make it a success.

Reviewer 2:
The reviewer said the project team brings excellent experience, but a partner familiar with full engine formulation would have been useful.

Reviewer 3:
The reviewer said the project included adequate collaboration between the project team and an industry additive marketer. The reviewer noted that the bench and engine testing were also completed by collaborators.

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

Reviewer 1:
The reviewer said the project team identified important barriers and issues that still need to be addressed prior to this product becoming commercialized.

Reviewer 2:
The reviewer remarked that the proposed future work to continue the development of hyperbranched structures and to develop and strengthen industrial relationships will help to address the remaining challenges and barriers identified for this project

Reviewer 3:
The reviewer mentioned that the pressure and viscosity effect and shear stability were not evaluated and should be considered if the project continues. The reviewer indicated that the project needs another reference oil for a baseline if the project continues.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that the project is relevant to the overall DOE objective of petroleum displacement through the development of novel lubricant formulations that are expected to improve fuel efficiency of vehicles

Reviewer 2:
The reviewer said lubricants are one of the few research areas in VTO that can affect both future and legacy vehicles.

Reviewer 3:
The reviewer said the project goals were to reduce fuel consumption through the development of novel friction and viscosity modifiers combined on the same molecule. The reviewer indicated that a successful project would lead to reduced use of petroleum.

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

Reviewer 1:
The reviewer said the project could use some additional funding to continue some necessary work.

Reviewer 2:
The reviewer said that the resources were sufficient for the envisioned project, but further work will be needed and noted that it is unclear if resources are available.

Reviewer 3:
The reviewer said that the resources are sufficient to complete the project

Lubricant Effects on Combustion, Emissions, and Efficiency: Robert Wagner (Oak Ridge National Laboratory) - ft036

Presenter
Brian West, Oak Ridge National Laboratory.

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

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

Reviewer 1:
The reviewer said the investigative techniques used to test the various hypothesis are excellent and unique.

Reviewer 2:
The reviewer said that the approach of targeted engine, vehicle, and flow reactor studies with in-depth characterization of combustion, emission control devices, and fuel economy to better understand fuel and lubricant effects is very good and provides for a plan to adequately address the barriers

Reviewer 3:
The reviewer said that the fuel and lubricant interface is a critical area, but is also immensely complex and dynamic. The reviewer remarked that the mixture of fuel, lube, soot, and others may not be adequately investigated with gas chromatography-mass spectrometry (GC-MS) analysis alone. The reviewer suggested that the project consider testing the rheology and lubricity of the mixture.

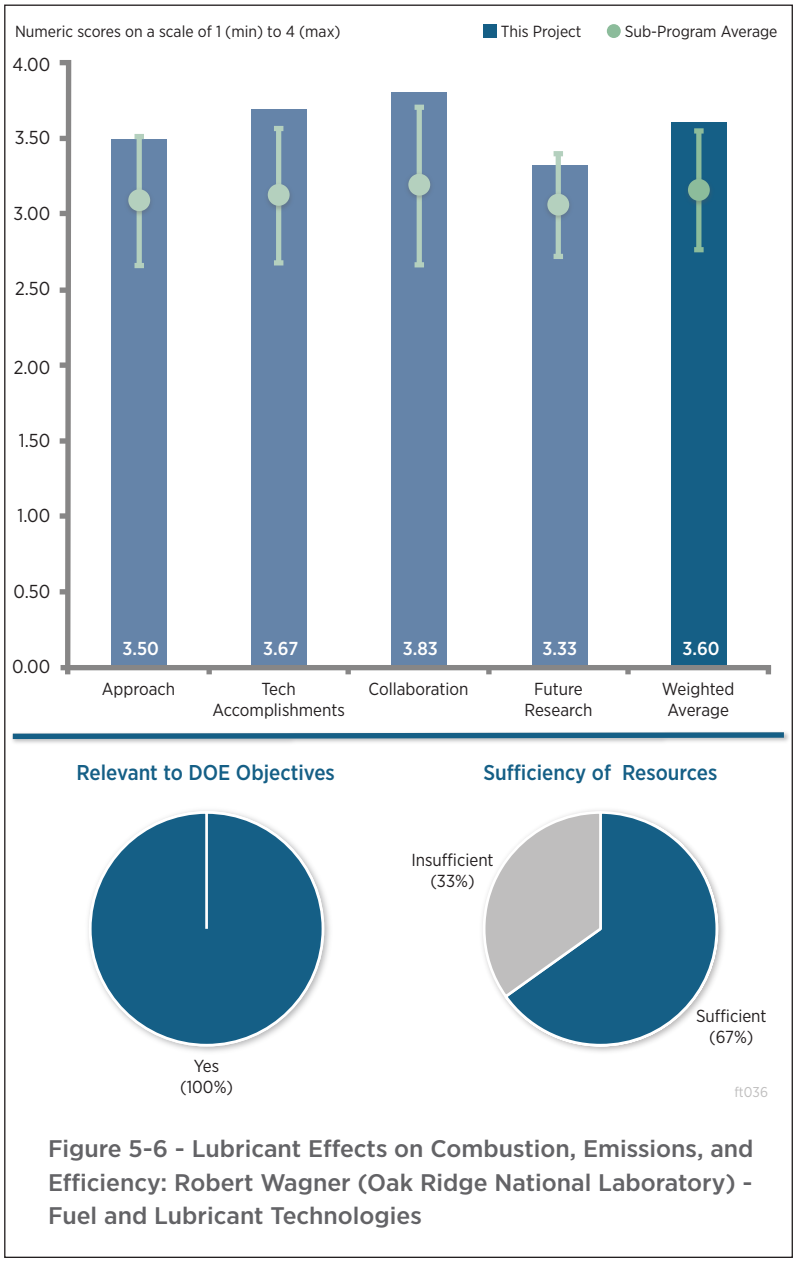

Figure 5-6 - Lubricant Effects on Combustion, Emissions, and Efficiency: Robert Wagner (Oak Ridge National Laboratory) - Fuel and Lubricant Technologies

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

Reviewer 1:
The reviewer said the accomplishments have been adequate thus far. The reviewer stated that the proof of concept apparatus seems viable and that it will be interesting to see further research with this approach.

Reviewer 2:
The reviewer said the technical accomplishments for this project—including quantification of fuel and lubricant impacts on gasoline direct injection (GDI) particulate matter (PM) and the work to establish vehicle-based methods

to measure fuel economy improvement from lubricants—have provided excellent results to address the barriers of this project.

Reviewer 3:
The reviewer remarked that the progress to date was excellent.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that collaboration and coordination with other organizations was excellent. The reviewer said that working with industry, academia, and other national laboratories provides for an excellent set of partners, which will lead to the success of the project.

Reviewer 2:
The reviewer said, as usual, Oak Ridge is collaborating with excellent, world-class partners.

Reviewer 3:
The reviewer said due to the applied nature of this project that it was appropriate to have a solid influence from industry collaborators, which this project has.

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

Reviewer 1:
The reviewer stated that the future direction of the project has identified very good plans that will help to address the remaining barriers.

Reviewer 2:
The reviewer said that it seems like the direction of the project is well thought out and clearly defined. The reviewer suggested that if the project team can determine what the fuel, lubricant, or soot mixture is composed of then that could lead to many interesting tribological studies. The reviewer said an interesting starting point would be to test the mixture lubricity in a Plint TE 77 with segmented ring and liner.

Reviewer 3:
The reviewer indicated that low- and high-temperature fuel economy would be very high impact tests for future research. The reviewer said that demonstrating how a high viscosity index gives more real world benefit would help the scientific communit .

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that determining the effects of lubricants on combustion, emissions, and efficiency is very relevant to the DOE objective of petroleum displacement.

Reviewer 2:
The reviewer said the area where the lubricant and fuel meet is not well understood. The reviewer remarked that this project addresses some of those concerns and associated phenomena. The reviewer said, if successful, the project could elucidate some observed technical issues.

Reviewer 3:
The reviewer said lubricants are one of the few research areas in VTO that can affect both future and legacy 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 said the resources appear to be sufficient to achieve the work identified in this projec

Reviewer 2:
The reviewer said that the program needs to expand and do fuel economy tests at more temperatures and with more vehicles on multiple drive cycles.

Reviewer 3:
The reviewer said the amount of funding seems adequate. The reviewer remarked that it was not clear to what level the collaborators are contributing, and noted in-kind contributions, hardware/component, testing, consultation, etc.

Co-Optimization of Fuels and Engines Overview: John Farrell (National Renewable Energy Laboratory) - ft037

Presenter
John Farrell, National Renewable Energy Laboratory.

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

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

Reviewer 1:
The reviewer remarked that overall the project team appears to be doing an excellent job approaching a very difficult task. The reviewer provided praise by saying that this is one of the highest impact programs to come from VTO or the DOE Bioenergy Technologies Office (BE O) since the E15 program in 2008-2011. The reviewer said there is a buzz in the industry that resonates outside of the typical fuels and engines community and that the VTO program is influencing industry research programs in the energy industry as far away as China and Saudi Arabia.

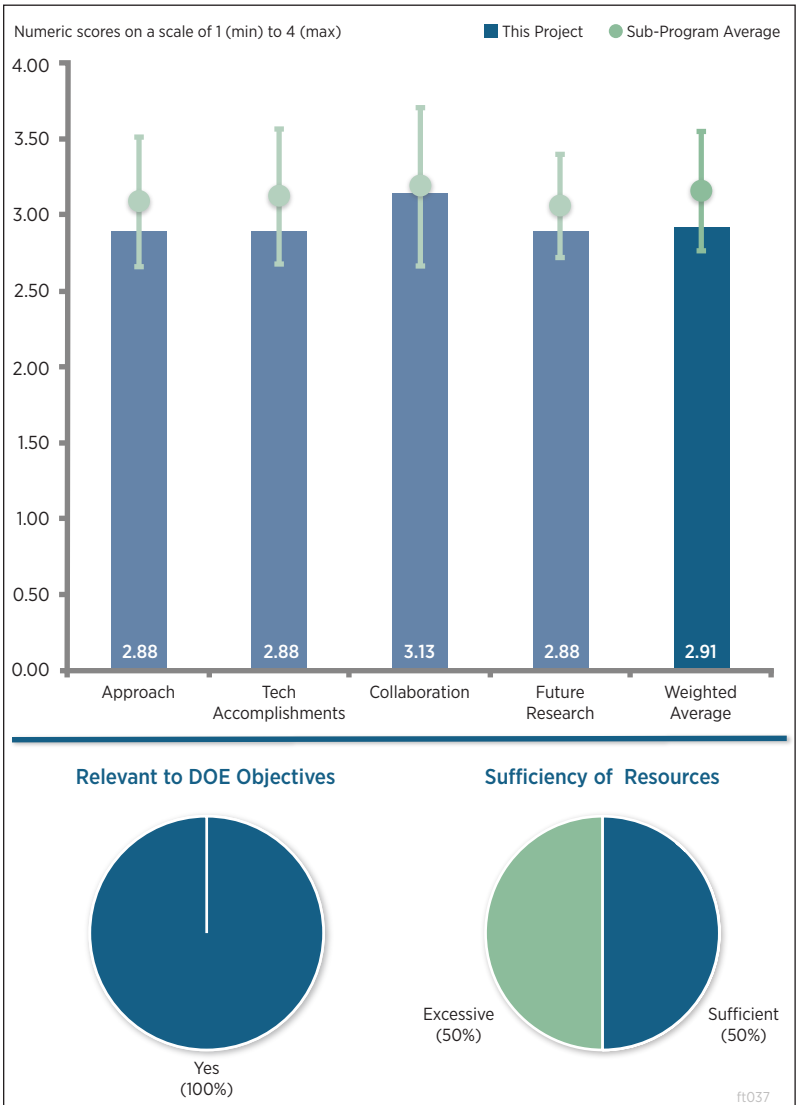

Figure 5-7 - Co-Optimization of Fuels and Engines Overview: John Farrell (National Renewable Energy Laboratory) - Fuel and Lubricant Technologies

The reviewer said the split between Thrust I and Thrust II is critical to maintain focus in the near-term and to not enter down a path of bias towards kinetically-controlled and compression ignition, including low-temperature combustion (LTC), too quickly. The reviewer also remarked that adding a decision point to extend the Thrust I program beyond 2019 would be beneficial. The reviewer cautioned that switching the project's full R&D effort to Thrust II too quickly would put any gains from Thrust I at risk. For example, if a high-octane and increased ethanol content fuel is chosen, it will likely have trouble with market introduction. The reviewer pointed out that some extension of Thrust I to make a more market friendly fuel with the majority of the chosen fuel benefits might be the better path forward. The reviewer suggested that, perhaps, a higher-octane refinery fuel without the ideal properties would be the better path

The reviewer said the distillate fuel volumes are projected to dominate the U.S. fuel pool in the coming decades. The reviewer remarked that optimizing light-duty vehicles (LDVs) is a noble goal but heavy-duty vehicles (HDVs) might be the more critical need. The reviewer said change of fuels would also be simpler for on-highway heavy-duty (HD) engines than light-duty (LD) simply because the vehicle parc is smaller and the refueling system is not as large as gasoline. The reviewer also noted that Thrust II should consider splitting the HD and LD activities.

The reviewer further remarked that engine size does make a difference; that is to say, the large bore engines have different chemical requirements due to operating range and torque requirements.

Reviewer 2:

The reviewer remarked that the work involved with the Thrust I projects is very interesting to OEMs and will support the industry's progress towards further improvements in fuel economy. The focus on improvement in a fuel for these near-term needs is imperative. However, as shown with a timeline decision point in 18 months on the Thrust I fuel and given the overall length of the project, it seemed to this reviewer that very little focus is being given to these near-term needs. The reviewer said that seems extremely ambitious given some of the existing challenges with current market fuels and current technologies that would be addressed with a new fuel going forward for the Thrust I technologies. The reviewer said it seems that more focus should be spent on the Thrust I portion of the project to really understand the fuel aspects of technologies, which would then apply to understanding the challenges of other technologies.

In reference to The Approach Strategy slides, the reviewer commented that it is not clear what the metrics are to know that the project team has success in these areas. The reviewer wanted to know if there is a set of metrics being developed (e.g., goal/outcome; ASTM specification/proposal, etc.). The reviewer questioned if Thrust I and Thrust II should really just be combined.

Reviewer 3:

The reviewer said that from a technical perspective, this project seems well thought out. The reviewer expressed concern that there is an undue focus on using biomass for a fuel source. The reviewer noted that with the abundance of natural gas (NG) and the problems associated with diverting crops from food to fuel that it seems to make better sense converting NG into fuels. The reviewer also mentioned that the other problem with this is that there seems to be little to no cooperation with universities, fuel manufacturers, and vehicle manufacturers. The reviewer was uncomfortable because the entire program seems to be run using only the national laboratories.

Reviewer 4:

Considering that introducing a new fuel into the market is a monumental task, this reviewer suggested that it would behoove the Co-Optima panel to perform a thorough investigation to assess the use of the same fuel for both Thrust I and Thrust II engine concepts. The reviewer warned that if the Thrust II fuel is dramatically different than the Thrust I fuel, then the challenges posed by introduction of a second new fuel and new powertrains that require use of the new fuel may pose insurmountable challenges.

The reviewer indicated that development of the modeling toolkit is extremely valuable work and should be given as much support as possible. The reviewer suggested that care should be taken to ensure that appropriate experimental hardware is used for validating the models being developed. For instance, the optical single cylinder engine at Sandia National Laboratories (SNL) is an excellent tool for helping with the development and validation of computational models but that engine is not representative of the Thrust I production engine technologies. The reviewer said that the use of the optical engine to validate computational models may lead to validation of combustion regimes, which would not be encountered in Thrust I production technology.

The reviewer remarked that as part of the proposed research, extensive data will be generated on the physical and chemical properties of fuels and their impact on engine combustion. The reviewer suggested that this may be a good opportunity to develop and define a new knock resistance metric that is more representative of combustion in modern engines compared to the research octane number (RON) and motor octane number (MON) tests.

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

Reviewer 1:

The reviewer said the project only recently began but that it has made excellent progress. The reviewer noted that the screening criteria led by the project team are excellent and a needed tool for the industry. The reviewer remarked that, while some individuals will disagree with the criteria, the development of a tool fills a critical need.

The reviewer also said the market transformation reports are needed and appear to be on-track for completion by the end of 2016.

Reviewer 2:
The reviewer said that it looks like the project is just getting started and therefore there is not much progress yet on the project. The reviewer noted that the project team make some important notes on the critical assumptions and issues of the project. The reviewer asked how those issues are being addressed so that the project will be successful. The reviewer said those are very insightful and show the great leadership on the project.

Reviewer 3:
The reviewer said that while the targets and milestones for the Co-Optima program are clearly spelled out, the metrics for assessing the success and completion of the program are not well defined. The reviewer stated that it would be helpful if the deliverables and targets for the overall program are well defined and quantifiable alon with the metrics to be used for assessing the completion and success of the project. The reviewer also noted that good progress has been made on the down-selection of biomass-based fuel components with the ultimate goal of identifying components for engine testing (Tier 3 candidate evaluation). The reviewer specified that as part of the Analysis of Sustainability, Scale, Economics, Risk, and Trade (ASSERT) tasks on Slide 13, it was not clear how the economy wide benefits have been quantified when the fuels and engine technologies have not been finaliz

Reviewer 4:
The reviewer said it seems like ethanol fuels are a pre-determined winner here. The reviewer acknowledged that other fuels definitely will be tested, but opined that ethanol seems to be the winner alread . As was stated, the project purpose is to see what can compete with ethanol. The reviewer expressed uncertainty about how to make sufficient ethanol to supply the need without significantly impacting the food supp .

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said the span of partners is very impressive and the collaboration effort is the largest since the E15 effort. The reviewer also remarked that the team has made a great effort to engage external stakeholders and organize an advisory board. The reviewer noted that the current board is well covered by government, engine OEMs, energy companies, and the biofuel industry. In relation to the stakeholder groups, the reviewer asked about off-road manufacturers (e.g., marine, lawn equipment, and recreational equipment). The reviewer noted that these entities do not use much fuel but will be impacted and should be considered for a place on the external advisory board. The reviewer remarked that the emissions equipment manufacturer should also be considered for a position on the external advisory board simply because emissions will be critical for future success and transformation. The reviewer stated that the United States Council for Automotive Research (USCAR) should not be relied upon to represent them. The reviewer noted that the nine national laboratories appear to have well defined splits in the work to take full advantage of their individual specialties.

Reviewer 2:
The reviewer said that it seems that there is good collaboration on the project. The reviewer also pointed out that the project seems low on the stakeholders that would be involved in implementation of any new market fuels, whether there is one or more new fuels for various engine technologies. The reviewer noted that the project team indicated such stakeholders were suggested as a barrier and challenge to the project and suggested it would be helpful to open the lines of communication and add these kinds of stakeholders to the discussion. The reviewer said a project on new and improved fuels and engine technologies would be a terrible waste of money if it could not be implemented in the market for the reduction of petroleum consumption and benefit of all stakeholders

Reviewer 3:
The reviewer stated that it is encouraging to see the close collaboration between the various national laboratories and the concerted effort to maximize the synergies between the participating teams. The reviewer emphasized that considering the scale of the Co-Optima program and the significance of the scope of work, stakeholder feedback and engagement are critical for the ultimate success of the project. The reviewer said stakeholder conference calls

and listening days are steps in the right direction for soliciting feedback from stakeholders. The reviewer pointed out that it is not clear how the stakeholder feedback is being incorporated into planning Co-Optima activities.

Reviewer 4:

The reviewer asked why universities or fuel manufacturers are not a part of this work. The reviewer said that universities have already done a lot of this work, so it could be that researchers are recreating the wheel. The reviewer also said that fuel manufacturers need to be involved to make sure that whatever fuel is chosen can be manufactured, stored, and distributed. The reviewer further asked if researchers know that the fuel can be run in the vehicle without first developing a new fuel system

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

Reviewer 1:

The reviewer remarked that the Co-Optima program has aggressive timelines and the desired targets for the 18 month decision point are well specified. The reviewer said developing a good understanding of the various market transformation scenarios is essential for the successful adoption of the new fuels and engine technologies that are expected to be developed as part of the program. The reviewer expressed that it would behoove the project team to ensure that the aggressive timeline does not compromise the research and analysis required for market adoption and growth of Thrust I technologies.

Reviewer 2:

The reviewer commented that the team seems to be making good progress towards their 18 month decision point. The reviewer remarked that the ASSERT team should include the impact on petroleum refinery efficien , GHGs, and economics if they are not planning for it. The reviewer said impacts of biorefineries and biofuel production is critical but the petroleum refineries should not be trivialized. The small changes in the fuel octane rating or distillation changes from the refinery can impact the refinery efficiency by several percen The reviewer said that, while several percent on the well-to-tank is often trivialized by people considering the entire lifecycle, the economic impact is more severe. The reviewer remarked that the margins from refineries are typically miniscule and small changes can make or break the refiner .

Reviewer 3:

The reviewer remarked that this is a very interesting and challenging project that appears to have just gotten started and therefore, much of the work ahead is in the future. The reviewer commented that reviewers were shown a set of very high level tasks for the different integrated teams, but not all tasks, and that it was unclear on the timeline when the project would to accomplish these tasks. The reviewer said that due to this it was not really clear how aggressive the project is in completing the Thrust I goals for the 18 month decision point. The reviewer said that the Thrust I projects are very important to the OEMs for introduction of the new downsized boosted engines and therefore the timeline should be worked out and communicated to stakeholders immediately. The reviewer stated that the hardest part of the project will be the implementation of the fuel in the market and that the project needs to show greater focus and emphasis in this area. The reviewer concluded that most of the work is needed in demonstrating a clear plan in the near-term for Thrust I.

Reviewer 4:

The reviewer did not like the fact that the first milestone is time driven and not event driven. The reviewer said that this time constraint could leave new developments out of the picture.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer applauded this effort as one of the most critical VTO programs for the DOE goals of reducing

petroleum dependence and GHGs. The reviewer said the project actually has a chance to drastically change the fuels landscape and have a larger impact than most of the electric vehicle and materials programs.

Reviewer 2:

The reviewer remarked that improvement of existing engine combustion technologies, identification of desirable fuel properties, and development of new biofuels are all expected to contribute to DOE's goal of petroleum displacement.

Reviewer 3:

The reviewer said that there are certainly aspects of the Thrust I portion of the project that will enable displacement of petroleum through improvement in fuel efficienc . The reviewer explained that it has been shown in the literature and it is well known that higher octane and higher sensitivity fuels with downsized boosted engines will provide fuel economy improvements. The reviewer remarked that the Thrust I project is interesting and will benefit the auto industry goal of furthering the downsized boosted engines. The reviewer also said that the Thrust II projects are not clear if they will provide petroleum displacement through improved efficienc .

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

Reviewer 1:

The reviewer said that it is not clear how the money will be divided between the projects but highly encouraged the project team to move more of the funds to the near-term Thrust I projects rather than the Thrust II projects. The reviewer remarked that the timeline appears as if most of the research will focus on Thrust II projects. The reviewer pointed out that the Thrush II projects are not the prime time technologies that OEMs are working on because these are technologies that are more than 15 years away from market introductions. The reviewer further commented that the timeline shows very little focus on the Thrust I projects and said that is surprising given that the technologies are the main line technologies for current OEMs.

Reviewer 2:

The reviewer remarked that, while the individual subprojects have budgets associated with them, it would also be helpful if the overview presentation included a slide showing the breakdown of the overall budget and how the resources are allocated to the different activities.

Reviewer 3:

The reviewer said the level of funding appears sufficient for the current goals. The reviewer mentioned that expansion of funding may increase in the coming years depending on the initial results. The reviewer said additional funds at the current time would not significantly contribute to the scope or success of the project and might detract from other critical activities in the VTO Fuel and Lubricant Technologies program. The reviewer said if additional funding from the Fuel and Lubricant Technologies program is required, it should be taken from any gaseous fuel activities. Direct-injection propane is a waste of money. NG should be used in power plants to displace coal first; further e fort in engine development is not very useful.

Co-Optimization of Fuels and Engines (Co-Optima) - Fuel Properties and Thrust I Engine Research: Jim Szybist (Oak Ridge National Laboratory) - ft038

Presenter
Jim Szybist, Oak Ridge National Laboratory.

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

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

Reviewer 1:
The reviewer remarked that the general approaches identified for the overall Co-Optima program and for the 13 individual projects discussed during the presentations were excellent and should be effective in addressing the barriers identified

Reviewer 2:
The reviewer said that the approach follows a logical progression for defining key fuel properties and parameters, screening candidate fuels according to those properties as well as some other key characteristics, and testing performance of the identified fuels in laboratory combustion experiments, along with kinetic modeling followed by engine testing. The reviewer noted that in order to do this, new test methods such as heat of vaporization and auto-ignition quality from small samples are to be developed. The reviewer said promising approaches to those have been described.

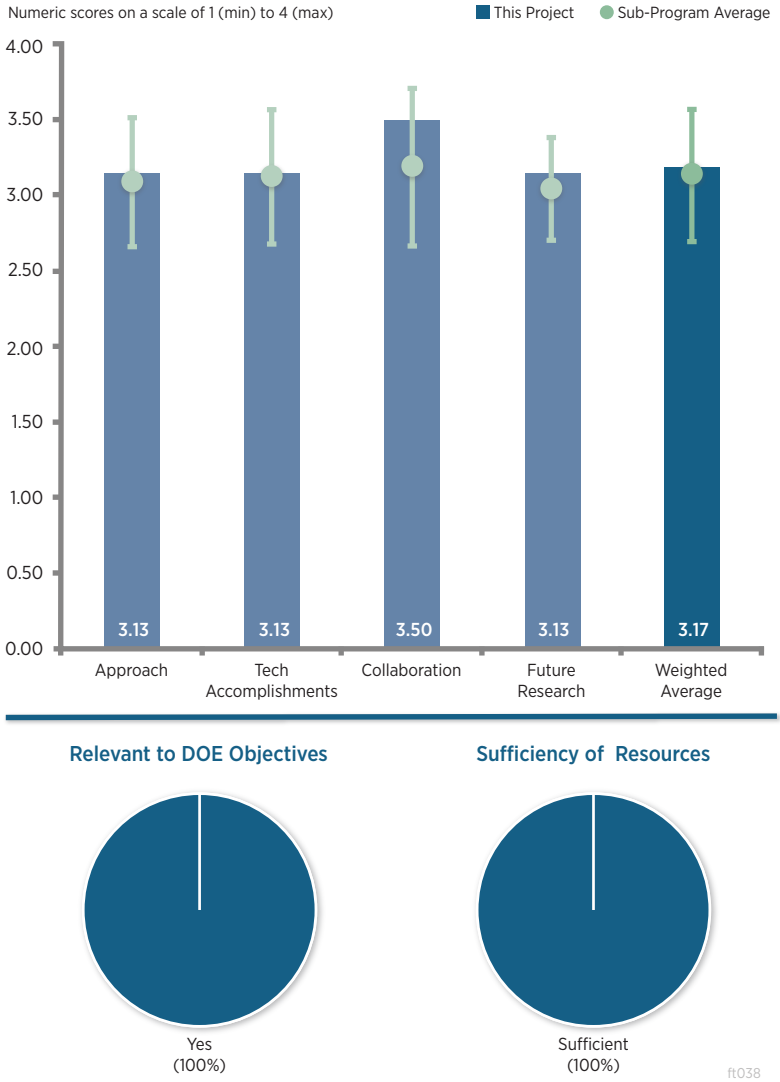

Figure 5-8 - Co-Optimization of Fuels and Engines (Co-Optima) -- Fuel Properties and Thrust I Engine Research: Jim Szybist (Oak Ridge National Laboratory) - Fuel and Lubricant Technologies

Reviewer 3:
The reviewer remarked this project had a good approach to a very complex set of problems. The reviewer did not see oil company involvement. The reviewer acknowledged not being aware of efforts to involve industry or universities from the outset. The reviewer expressed skepticism about the ultimate importance of LTC-based engines. The data on cold starting and full load range capability remain missing. The reviewer noted that with this absence, it was unclear if there was a real benefit. The reviewer said some work suggests aftertreatment requirements have largely eliminated the originally expected fuel economy benefits. The reviewer cautioned that given this, the major emphasis on fuels for such engines may be misdirected.

Reviewer 4:

The reviewer said that the following Co-Optima projects have been reviewed as one and provided one set of comments for all four presentations: FT037, Co-Optima Overview (John Farrell, et al); FT038, Co-Optima Fuel Property and Advanced Engine Development Team, Part 1—Fuel Properties and Chemical Kinetics (Robert McCormick and Jim Szybist, et. al.) and Part 2—Thrust I engine projects (Jim Szybist, et. al.); ft039, Co-Optima of Fuels and Engines and Advanced Engine Development Team, Part 1—Thrust II engine projects (Paul Miles and Matt Ratcliff, et. al.); and ft040, Co-Optima Simulation Toolkit Team (Matt McNenly and Sibendu Som, et. al.). The reviewer provided 11 Thrust I comments that follow below.

Beginning the first Thrust I group of comments, the reviewer remarked that Co-Optima and Thrust I should be sharply focused on the overall Co-Optima goal vision of "Better fuels and better vehicles sooner." The reviewer noted that a lot of effort has gone into collaborating and coordinating between the various national laboratories and that these efforts and results are commended. The reviewer pointed out that collaboration and coordination is obviously needed and beneficial. For example, bringing to bear all the simulation work going on at the national laboratories on fuel property and engine response work, this work is bound to have high impact even if later than sooner. The reviewer cautioned that, with all the emphasis on collaboration between the various national laboratories and the coordination of the various teams with their diverse skills and tasks, it is easy for the program to become narrowly focused and lose sight of the forest for the trees. The reviewer also noted that the Co-Optima program has quickly become bureaucratic, with sub-teams providing reports to other teams within itself and to DOE. The reviewer said that while the project is admittedly a non-trivial challenge, in order to gain the trust of its stakeholders as being a legitimate effort to bring about significant GHG reduction, Co-Optima should continuously strive to be seamless across DOE, VTO, BETO, and the individual national laboratories and to keep the focus on the customer, vision, and the stakeholders.

For the second Thrust I group of comments, the reviewer remarked that Co-Optima has correctly concluded that the major barrier and challenge to realizing better fuels and better vehicles sooner in the marketplace is related to the large number of stakeholders with competing value propositions. The reviewer also said that because this is the major barrier, the full strength and weight of the Co-Optima program should be brought to bear squarely on removing this major barrier and not simply end up majoring on the minors.

Initiating the third Thrust I group of comments, this reviewer asked what was driving the 18-month decision point for Thrust I and noted that it gives the perception of Co-Optima being eager to hastily disengage from Thrust I issues and challenges and desiring to move on to Thrust II. The reviewer said that the one thing this implies, perhaps inadvertently, is that Thrust II engines, which are yet to be identified, and Thrust II fuels, which are also yet to be identified, will be more impactful in reaching Co-Optima goals than Thrust I engines and fuels. The reviewer questioned, if given the well-acknowledged risks associated with Thrust II engine concepts, whether there is overwhelming evidence that the only barrier remaining for Thrust II engines is the lack of a co-optimized Thrust II fuel. On the other hand, Thrust I engines and fuels are largely already identified by overwhelming industry and OEM practice and literature evidence, both recent and historical. Therefore, it seems prudent and a more reasonable strategy for Co-Optima to first tackle co-optimizing Thrust I engines and fuels, focusing sharply on the major barrier for Thrust I, which this reviewer referenced in the second Thrust I group of comments.

Starting the fourth Thrust I group of comments, the reviewer recommended that Co-Optima should refrain from proposing timelines for commercialization targets because Co-Optima can only provide research information, motivation, and incentive for commercialization, and perhaps play the very valuable role of bringing all stakeholders to the table. Those timelines can probably only be set by the stakeholders themselves because stakeholders typically have to follow free enterprise principles for commercial success.

For the fifth Thrust I group of comments, this reviewer remarked that Co-Optima should include a R&D milestone titled "Can Thrust II fuel be the same as Thrust I fuel?" Having the same fuel for both Thrust I downsized boosted SI engines as well as Thrust II advanced compression ignition (ACI) engines has obvious benefits. The reviewer referenced the second Thrust I group of comments, and then remarked that the major barrier for any new fuel, Thrust I or Thrust II, has already been acknowledged to be the large number of stakeholders with competing value propositions. The reviewer asked if there is an opportunity to bust this major roadblock once, why choose a path that would need this roadblock busted twice. Having Thrust I and Thrust II fuels be the same is an incredible opportunity to further the main goal of Co-Optima vision of "Better fuels and better vehicles sooner." The reviewer also noted a related sub-milestone comment under Thrust II.

Opening the sixth Thrust I group of comments, the reviewer remarked that the Co-Optima program should verify that high RON and high sensitivity fuels do indeed substantially increase engine and vehicle fuel efficienc . The reviewer commented that this should be done quickly and with minimal research, as this ground has been plowed numerous times by many studies, and the answer is generally well-known and accepted.

Beginning the seventh Thrust I group of comments, this person stated that the Co-Optima program should focus major resources and effort on identifying promising low-GHG fuel compositions and blendstocks that are sustainable, affordable, scalable, and with attractive infrastructure and retail attributes. The reviewer said that the understanding is that Co-Optima has already started the life-cycle and techno-economic analysis on the 20 Thrust I fuel blendstocks.

Introducing the eighth Thrust I group of comments, the reviewer said that it is anticipated, that of the six teams that Co-Optima has put in place, the following hold the key to overcoming the main barrier already discussed: the Low Greenhouse Gas Fuels (LGGF) team, which is focused on low-GHG blendstock properties and pathway attributes; the ASSERT team, which is focused on environmental impacts, cost, scalability, and feed logistics; and the Market Transformation (MT) team, which is focused on infrastructure and legacy fleet compatibilit . The reviewer is of the opinion that these three teams will need to be primarily engaged in assisting stakeholders going forward. The reviewer also warned that, if Co-Optima declares Thrust I complete and disengages at FY 2019, it may fall short of its goal and will have at most a flash-in-the-pan e fect.

Starting the ninth Thrust I group of comments, this reviewer said that the Thrust I engine projects currently being carried out on the 1.6-L Ford Ecoboost engine at ORNL and the 2.0-LTG General Motors (GM) engine at the National Renewable Energy Laboratory (NREL) are scoped reasonably well. The reviewer remarked that several appropriate changes have been made to the base engines to make it more relevant for evaluating high octane fuel performance. The reviewer also noted that appropriate changes in the engine compression ratio (CR) are planned, along with an appropriate selection of relevant fuels. The reviewer also remarked that appropriate issues like low-speed pre-ignition (LSPI) are being studied. The reviewer also commented that the project has the potential of informing the community about the tradeoffs that need to be dealt with when designing downsized boosted engines with high octane fuel to realize high fuel efficienc .

For the 10th Thrust I group of comments, the reviewer opined that the single cylinder head engine choice at SNL may not be representative of the state-of-the-art Thrust I engine that industry currently has and continues to evolve. The referenced engine at SNL has good optical access and also has port and other information needed for computational fluid dynamics (CFD) simulation provided by an OEM. Howeve , the typical downsized, boosted SI engine today utilizes high-tumble ports, special combustion chamber and piston topologies, and Miller cycle valve strategies, of which none are present in that cylinder head. The reviewer explained that work on knock-limited performance on this cylinder head will fall way short of understanding real low- and high-speed wide open throttle (WOT) knock-limited behavior.

Presenting the 11th Thrust I group of comments, this person stated that engine downsizing causes the load-factor of an engine to increase. Therefore, the current work on the effect of laminar flame speed increasing dilution tolerance at light loads should be extended to mid-loads also where knock typically compromises the optimum location of CA50.

The reviewer provided five Thrust II comments that follow below.

Commencing the first Thrust II group of comments, this person remarked that verifying whether Thrust I fuel and Thrust II fuel can be the same should be the first, and foremost, Thrust II goal. The reviewer noted that in this regard, the use of an Octane Index (OI) as a means to evaluate fuel properties simultaneously suitable for both Thrust I and Thrust II engines is encouraged.

For the second Thrust II comment, the reviewer asserted that Co-Optima should pursue the path of discovering a new Thrust II fuel and by implication, a new Thrust II engine, only after it has been convincingly proved that these two fuels cannot be the same.

Presenting the third Thrust II group of comments, this reviewer commented that the literature on Thrust II engine concepts suggests more than a handful of recipes for ACI combustion. The reviewer inquired about what would be the anticipated Co-Optima fuel requirements for each recipe. The reviewer provided that choices could be as follows: exactly the same; slightly different; or significantly di ferent. The reviewer noted if the answer turns out to

be “exactly the same,” then the path forward is simplified. If it also stands that Thrust II fuel equals Thrust I fuel, then the path forward is incredibly faster and beneficial for all stakeholders, as previously noted

Starting the fourth Thrust II group of comments while also referencing the third Thrust II group of comments, the reviewer questioned whether the path forward would be fraught with huge challenges if the answer turns out to be “significantly di ferent,” or even “slightly different.” The reviewer expressed interest in knowing who decides the winning Thrust II engine-plus-fuel combination. This person further inquired whether Co-Optima could really be the one who picks the winner, or if each stakeholder would have a differing opinion on the winning combination. The reviewer also asked about the role of free market enterprise for selecting the winning combination.

Concluding with the fifth Thrust II group of comments and referencing the fifth Thrust I group of comments, this reviewer remarked that Co-Optima could include a sub-milestone under another milestone. Recognizing that in the context of the current discussion, perhaps the suggestion that Thrust II fuel and Thrust I fuel can be the same may hold true only for LD applications because Thrust I engines largely imply SI, gasoline, LD engines. The reviewer offered that, on the other hand, Thrust II fuel can be targeted to any or all applications including LD, medium-duty (MD), or HD. For example, if it turns out that new Thrust II fuels can be profitably optimized with Thrust II engine recipes for MD or HD applications, perhaps then a case could be made that Thrust II fuel should be different than Thrust I fuel for these applications.

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

Reviewer 1:
The reviewer commented that there was a great deal of progress in both the fuel property team and the Thrust I engine projects, especially because the projects were only started recently. The reviewer said progress and accomplishments identified in the presentations from both teams appear to be addressing the barriers adequately and milestones in the project have been met or are on track. The reviewer noted that there were seven individual projects discussed in the Fuels and Engines Fuel Properties Team and six individual projects discussed in the Advanced Engine Development team. The reviewer suggested that in the future, it may be necessary to devote more time for these individual projects to allow a more in-depth review of each project.

Reviewer 2:
The reviewer commented that there is a mix, with some new projects and some older projects. The reviewer remarked that, overall, there was good progress and useful data. The reviewer assumed that there will be work to collate the various results and understand results on the many different engines and test rigs. The reviewer wanted to know if there would be any work to correlate different labs and pointed out that very small details of test methods can have large effects on results. The reviewer said that cold start conditions are critical for the ability to run lean, for hydrocarbon (HC) speciation for catalyst light off, and for the ability to operate heavily retarded to generate heat for catalyst light off. The reviewer said experimental plans and models should consider this because 90% of emissions occur in the first 60 seconds of engine operation

Reviewer 3:
The reviewer remarked that the project was in the early stages and therefore most of the technical accomplishments are yet to come. The reviewer said that the presentation was necessarily abbreviated considering the wide scope of project activities. The reviewer pointed out that while a fair amount of relevant data were presented within the presentations, it was not clear how much of this was actually from project results and how much was pre-existing data. The reviewer remarked that notwithstanding this, the data presented, along with the well planned and explained work plan, indicate a more than satisfactory level of progress.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said the project includes six national laboratories and that the collaboration between them shows every indication of being ample and productive.

Reviewer 2:
The reviewer said that the Co-Optima project has a very extensive set of researchers collaborating and coordinating the research. The reviewer commented that the nine national laboratories bring together some of the best talent in the country to help solve the fuel and lube barriers identified. The reviewer expressed a concern that, with so many entities participating, there is a possibility that so much time could be spent on coordination meetings and it will take away from the time available to do the research.

Reviewer 3:
The reviewer suggested that more collaboration with industry and universities would be helpful in the long run. The reviewer expressed some concern that the large number of players means a lot of time will be spent on meeting, coordination, and reporting. The reviewer asked what the overhead cost of project management was versus actual research. The reviewer noted that DOE had a policy 20 years ago of putting certain kinds of research in specific labs. The reviewer said that SNL's combustion lab did optical engines, ORNL did full scale engines, and Lawrence Livermore National Laboratory (LLNL) did kinetics, etc. The reviewer remarked that this is now diffused so that there is a large overhead of engines at multiple labs, with large mission overlap. The reviewer said that this requires a lot of coordination, and the reviewer suspected there will also be a big management cost [DOE Program Clarification: DOE plans to increase industry engagement over the life of this project, and still strives to not duplicate efforts at 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.

Reviewer 1:
The reviewer said that the proposed work of both the fuels properties project team and the Thrust I engine project team to include the incorporation of biofuels, with a wide range of chemical compositions, into the experiments will provide information to continue to address the goals and objectives of the project.

Reviewer 2:
The reviewer observed a good plan towards important goals.

Reviewer 3:
The reviewer remarked that the directions of future research described are logical and potentially very useful, particularly in getting better understanding of fuel property impacts including octane sensitivity, heat of vaporization (HOV), exhaust gas recirculation (EGR) dilution tolerance, and others on combustion flame, auto ignition, and ultimately efficiency of high CR engines. The reviewer commented that the 18 month make-or-break decision point, apparently dictated to the program office and project team exogenousl , is very unfortunate and probably unrealistic [DOE Program Clarification: The decision point is only to decide what compounds can reasonably be made at scale by the year 2025. It will not be the end of investigations of fuels for spark-ignition engines, and therefore, should not be viewed as a “make-or-break” decision.].

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said that both the fuel properties and chemical kinetics, as well as the Thrust I engine projects, are very relevant to helping to meet the DOE objectives of petroleum displacement because a major goal is to develop a robust and quantitative understanding on how efficiency is impacted by fuel properties

Reviewer 2:
The reviewer noted a core of work on future engine systems.

Reviewer 3:
The reviewer said the project is potentially very relevant in that it would enable future development of much more efficient SI engines, as well as use with mid-level biofuels blends. The reviewer noted an issue with the relevance was, however, that fuel candidates are being selected without substantial grading by production cost or difficult . The reviewer said while this is very difficult to assess at this point or even conterminously with the project progress, it is the ultimate determinant of the relevance of the project. The reviewer commented that while it is known that many different compounds can be produced from various biofuels processes, the reality is that attempts to commercially produce biofuels other than corn ethanol and heavily subsidized biodiesel have been unsuccessful to date despite seemingly viable pathways for cellulosic ethanol having been identified for decades

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 funding appears to be sufficient for the tasks to be completed in this project

Reviewer 2:
The reviewer acknowledged not having a basis for evaluating the sufficiency of the resources provided other than that the work plans appear to be well-tailored based on those resources.

Reviewer 3:
The reviewer said the project is a well-funded large effort. The reviewer said that it seems misleading to call this a $21 million program because most of the work is a continuation of earlier efforts and rebranded as Co-Optima. The reviewer remarked that, still, the overall funding seems about right [DOE Program Clarification: Although much of the work is building on earlier efforts, the novel aspect of Co-Optima is the explicit coordination of the programs.].

Co-Optimization of Fuels and Engines (Co-Optima) - Thrust II Engine Research, Sprays Research, and Emissions Control Research: Paul Miles (Sandia National Laboratories) - ft039

Presenter
Paul Miles, Sandia National Laboratories

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

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

Reviewer 1:
The reviewer remarked that the advanced combustion regimes appear to be focused on making the combustion actually possible, which is critical. The reviewer said that it would be beneficial to also consider emissions early in the program and noted that it appears to not even be a part of the combustion program. The reviewer commented that the only emissions work seems to be with current engines. The reviewer expressed that emissions problems will prevent certain combustion regimes from ever entering the market, barring miraculous efforts on the aftertreatment. The reviewer offered that getting an early look at the engine-out emissions would help downselect candidate fuels and regimes. The reviewer commented that the spray work feeding into the modeling team is a critical effort that should be continued and noted that the modeling efforts are of very limited value without the empirical data to support them. The reviewer remarked that the emissions work looking at fuel impurities (i.e., Toops/Pihl at ANL) is critical to get an early look at unintended consequences with biofuels. The reviewer stated that the unexpected impact of molecules such as potassium should be considered early and not after a fuel is picked. The reviewer said that this work should continue.

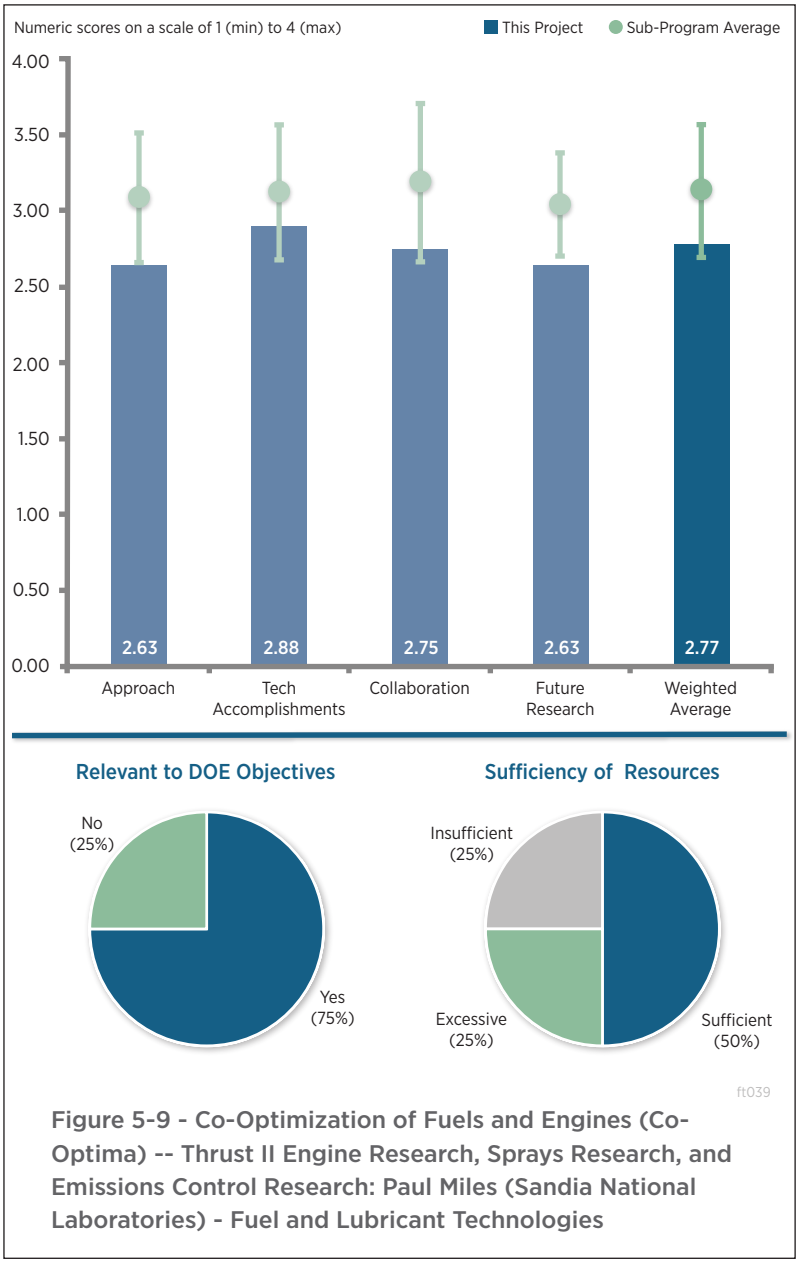

Figure 5-9 - Co-Optimization of Fuels and Engines (Co-Optima) -- Thrust II Engine Research, Sprays Research, and Emissions Control Research: Paul Miles (Sandia National Laboratories) - Fuel and Lubricant Technologies

Reviewer 2:
The reviewer wanted to know what efforts will be included in Thrust II that can address all of the barriers to implementation of these new advanced combustion modes. The reviewer said that these barriers include, but are not limited to, transient response, tailpipe emissions over a drive cycle, cold start performance, variations in market fuel, robustness to ambient conditions, and robustness to production-build tolerances and engine aging affects. The reviewer referenced Slide 3 of the presentation and pointed out that the Thrust I milestone is March 2017 and that the testing of Thrust I fuels in gasoline compression ignition (GCI) has a target date of September 30, 2016.

The reviewer wanted to clarify if this implied that all five Tier 3 fuels are to be tested by September 30, 2016, even though the fuels have not been down-selected as of June 2016. The reviewer commented that understanding the impact of new fuel components on the engine emissions is critical for evaluating the feasibility of the fuels and engine concepts being evaluated. The reviewer remarked that it is encouraging to see that emissions assessment is being considered from the start of the project.

Reviewer 3:

The reviewer said that although this is a very admirable project, the Thrust II objectives are too aggressive for market implementation even after the technology might be well developed. The reviewer remarked that the timeline development for the project seems rather novice, as many of the issues that OEMs will have with the technology on controls and meeting emissions regulations seem to be an oversight. The reviewer said that as the presenter was going over the projects, it was difficult to determine if the team was talking about something that was for a diesel engine or a gasoline engine or both. The reviewer also said that it seems like there are many combustion modes and processes and on-going work, but no clear identification process for techniques or technologies so a down-selection can be made based on metrics. The reviewer stated that it seemed like a laundry list of projects without a clear method to identify the winners and losers. The reviewer suggested that it would be best to combine both the Thrust I and Thrust II aspects to better help in the development and definition of fuels and the technology winners and losers. With regard to Thrust I and Thrust II fuels, the reviewer noted that much of the framework and metrics will be the same, so it seems like a duplication of effort to separate them.

Reviewer 4:

The reviewer expressed concern that there is no apparent input from industry or academia on this work. The reviewer further questioned if researchers are re-inventing the wheel on certain subtasks. The reviewer's final point of concern was that no thought seems to have been made regarding the final fuel cost and said that this will directly affect market acceptance.

The reviewer noted that, later in the presentation, the project team stated that a cooperative research and development agreement (CRADA) is currently being drafted with Ford Motors and Caterpillar. The reviewer questioned why this was not done up front. The reviewer also commented that there were too many undefined acronyms in the presentation.

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

Reviewer 1:

The reviewer remarked that the technical accomplishments to date are impressive.

Reviewer 2:

The reviewer remarked that there are a lot of projects and on-going work being accomplished, but it is unclear how this is moving towards meeting the goals of the Thrust II projects. The reviewer said that those goals were not clearly explained here, just a very brief list of objectives and milestones. The reviewer asked what the goal of Thrust II was. The reviewer also wanted to know how the project team will know that they made it or not. The reviewer further questioned how the technologies are being sorted for good or bad progress towards the goals. The reviewer commented that it all seems very disjointed, by the look of the slides and the summary of the progress. The reviewer remarked that the projects on the spray and emission control research were much better. The reviewer said it seems like these pertain to the Thrust I and Thrust II areas, so will support both projects.

Reviewer 3:

The reviewer remarked that it is critical to test the compatibility of Thrust I fuels with Thrust II engine concepts. The reviewer said that thus, it is encouraging to see that this activity is a priority for the Thrust II engine program. The reviewer said that most of the emissions research outlined in the presentation is focused on Thrust I engine technology. The reviewer noted that while this research is very pertinent and needs to continue, it is not clear how the planned emissions activities will address aftertreatment for LTC or ACI engine concepts. The reviewer offered that similar to the testing of Thrust I fuels on Thrust II engines, the aftertreatment efforts should also include some

work on Thrust II technologies with the goal of early identification of challenges that may influence the feasibilit of the advanced combustion concepts. The reviewer questioned if particulate matter index (PMI) translated from Thrust I to Thrust II.

Reviewer 4:
The reviewer got the sense that E30 is the presumptive winner. The reviewer asserted that both FEV and AVL have done substantial work on E30 and wanted to know why these groups were not part of this effort. The reviewer also questioned why fuel bulk modulus was not taken into account. The reviewer stated that depending on the fuel system, this property can have a great effect on ignition.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that it is encouraging to see the close collaboration between the various national laboratories and the concerted effort to maximize the synergies between the participating teams.

Reviewer 2:
The reviewer said that the collaborative work between the labs is impressive. The reviewer remarked that they appear to actually be leveraging their individual strengths instead of competing against each other. The reviewer noted that collaborations with external stakeholders and companies is either not presented or at a low level. The reviewer suggested that some additional interaction with non-government stakeholders would ensure the programs are working towards relevant problems.

Reviewer 3:
The reviewer said that this looked like it was mostly collaborations between the national laboratories, but not so much on other collaborations. The reviewer noted that it would be helpful to include OEMs and industry in this process.

Reviewer 4:
The reviewer said that again, the partner list is very good but it only includes national laboratories. The reviewer asked where the industrial partners and academics were.

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

Reviewer 1:
The reviewer remarked that the focus on the evaluation of Thrust I fuels in Thrust II advanced combustion concepts is encouraging. The reviewer said that the spray and emissions research outlined for future work is very relevant. The reviewer noted that, however, additional work should be included to identify and address aftertreatment challenges for advanced combustion concepts.

Reviewer 2:
The reviewer commented that it would be beneficial to expand the work to look at unintended consequences

Reviewer 3:
The reviewer said, again, it seems that the proposed projects and work is scattered with no clear plan to determine winners and losers. The reviewer commented that it was not clear how the technologies will be completely evaluated and down-selected to focus on more promising areas. The reviewer remarked, as is stated on the Thrust II slide, the project focus is to focus on projects across the labs rather than an approach to develop the technologies into usable solutions for industry. The reviewer said it is not clear how one would know that the Thrust II is completed and successful without metrics. The reviewer noted that, also, it is not clear that the future work is helping to move the project forward to achieve the challenges and barriers. The reviewer stated that more work needs to be done at a high level to determine what the goal to be achieved really is.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said that, while long-term, the advanced combustion concepts are expected to help achieve DOE's goal of petroleum displacement. In addition, the emissions research is expected to contribute to achieving improved engine efficiency along with lower emissions

Reviewer 2:
The reviewer said that fuels and lubricants are one of the few research areas in VTO that can affect both future and legacy vehicles.

Reviewer 3:
The reviewer asked if petroleum displacement is being looked at too hard. The reviewer wanted to know where ethanol will come from if it wins this and further inquired if it will come from food production.

Reviewer 4:
The reviewer remarked that it is not clear that the Thrust II technologies will prove to be more fuel efficient and displace petroleum. The reviewer questioned if those data are available and in the literature. The reviewer was unsure what this technology will help support because the project team did not cover that. With regard to the question about data in the literature, the reviewer commented that it would be good to establish that first and to determine if this technology will afford a winning solution for the future as compared to current OEMs technology paths.

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 needs resources to look at toxics and other unintended consequences.

Reviewer 2:
The reviewer remarked that it seems like the Thrust II projects should be evaluated on an engine that is relevant for what current OEMs are working on for the market. The reviewer also said that it seems that the project could be evaluated in just one engine for the different combustion modes. The reviewer noted that the Thrust II does not have a clear focus and seems a bit excessive, especially given that this technology is more than 15 years away and not the current focus of OEMs.

Co-Optimization of Fuels and Engines (Co-Optima) - Simulation Toolkit Team: Matt McNenly (Lawrence Livermore National Laboratory) - ft040

Presenter
Matthew McNenly, Lawrence Livermore National Laboratory

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

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

Reviewer 1:
The reviewer remarked that the overall approach of the Simulation Toolkit Team to leverage existing VTO software and expertise and to build a shared community around computing and data to accelerate research is very good. In addition, for each of the subtasks in this project, a detailed goal, approach, and Co-Optima impact were identified that will contribute towards meeting the milestones and barriers of the effort.

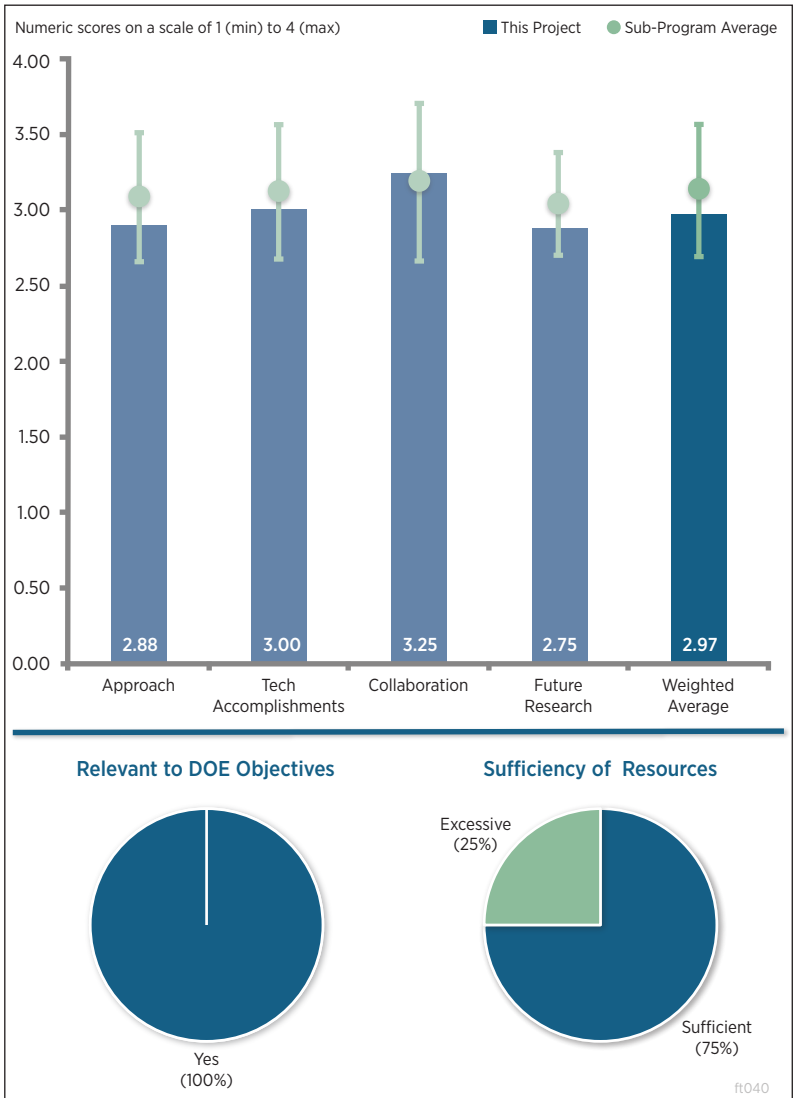

Figure 5-10 - Co-Optimization of Fuels and Engines (Co-Optima) -- Simulation Toolkit Team: Matt McNenly (Lawrence Livermore National Laboratory) - Fuel and Lubricant Technologies

Reviewer 2:
The reviewer praised that this is a very good approach to develop a highly skilled team and certainly world leading technology. The reviewer said that it would be more effective if all of the team were co-located, but that is probably impossible. The reviewer commented that the wide geographical spread necessarily means some overhead cost in organization and management. The reviewer remarked that the best collaboration is over a water cooler, not a telephone.

Reviewer 3:
The reviewer said that the approach as laid out in the overview and on Slide 33 appears reasonable and potentially beneficial. The reviewer commented that specific task descriptions, howeve , are very difficult to understand, both individually, and in terms of the relationships between them, particularly the relationships between different kinds of data being input in the simulations. The reviewer remarked that it is not even clear if this project includes generation of much of the data identified and depicted in the photos of testing equipment, etc., or if this project team is simply processing data received from other Co-Optima teams. The reviewer pointed out that no indication is given of a logical progression being followed but rather of certain types of data being generated, or otherwise obtained, on certain surrogate fuels without clear direction based on analysis of what is needed and what steps should lead to what others.

Reviewer 4:

The reviewer said that the following Co-Optima projects have been reviewed as one and provided one set of comments for all four presentations: FT037, Co-Optima Overview (John Farrell, et al); FT038, Co-Optima Fuel Property and Advanced Engine Development Team, Part 1—Fuel Properties and Chemical Kinetics (Robert McCormick and Jim Szybist, et. al.) and Part 2—Thrust I engine projects (Jim Szybist, et. al.); ft039, Co-Optima of Fuels and Engines and Advanced Engine Development Team, Part 1—Thrust II engine projects (Paul Miles and Matt Ratcliff, et. al.); and ft040, Co-Optima Simulation Toolkit Team (Matt McNenly and Sibendu Som, et. al.). The reviewer provided 11 Thrust I comments that follow below.

Beginning the first Thrust I group of comments, the reviewer remarked that Co-Optima and Thrust I should be sharply focused on the overall Co-Optima goal vision of "Better fuels and better vehicles sooner." The reviewer noted that a lot of effort has gone into collaborating and coordinating between the various national laboratories and that these efforts and results are commended. The reviewer pointed out that collaboration and coordination is obviously needed and beneficial. For example, bringing to bear all the simulation work going on at the national laboratories on fuel property and engine response work, this work is bound to have high impact even if later than sooner. The reviewer cautioned that, with all the emphasis on collaboration between the various national laboratories and the coordination of the various teams with their diverse skills and tasks, it is easy for the program to become narrowly focused and lose sight of the forest for the trees. The reviewer also noted that the Co-Optima program has quickly become bureaucratic, with sub-teams providing reports to other teams within itself and to DOE. The reviewer said that while the project is admittedly a non-trivial challenge, in order to gain the trust of its stakeholders as being a legitimate effort to bring about significant GHG reduction, Co-Optima should continuously strive to be seamless across DOE, VTO, BETO, and the individual national laboratories and to keep the focus on the customer, vision, and the stakeholders.

For the second Thrust I group of comments, the reviewer remarked that Co-Optima has correctly concluded that the major barrier and challenge to realizing better fuels and better vehicles sooner in the marketplace is related to the large number of stakeholders with competing value propositions. The reviewer also said that because this is the major barrier, the full strength and weight of the Co-Optima program should be brought to bear squarely on removing this major barrier and not simply end up majoring on the minors.

Initiating the third Thrust I group of comments, this reviewer asked what was driving the 18-month decision point for Thrust I and noted that it gives the perception of Co-Optima being eager to hastily disengage from Thrust I issues and challenges and desiring to move on to Thrust II. The reviewer said that the one thing this implies, perhaps inadvertently, is that Thrust II engines, which are yet to be identified, and Thrust II fuels, which are also yet to be identified, will be more impactful in reaching Co-Optima goals than Thrust I engines and fuels. The reviewer questioned, if given the well-acknowledged risks associated with Thrust II engine concepts, whether there is overwhelming evidence that the only barrier remaining for Thrust II engines is the lack of a co-optimized Thrust II fuel. On the other hand, Thrust I engines and fuels are largely already identified by overwhelming industry and OEM practice and literature evidence, both recent and historical. Therefore, it seems prudent and a more reasonable strategy for Co-Optima to first tackle co-optimizing Thrust I engines and fuels, focusing sharply on the major barrier for Thrust I, which this reviewer referenced in the second Thrust I group of comments.

Starting the fourth Thrust I group of comments, the reviewer recommended that Co-Optima should refrain from proposing timelines for commercialization targets because Co-Optima can only provide research information, motivation, and incentive for commercialization, and perhaps play the very valuable role of bringing all stakeholders to the table. Those timelines can probably only be set by the stakeholders themselves because stakeholders typically have to follow free enterprise principles for commercial success.

For the fifth Thrust I group of comments, this reviewer remarked that Co-Optima should include a R&D milestone titled "Can Thrust II fuel be the same as Thrust I fuel?" Having the same fuel for both Thrust I downsized boosted SI engines as well as Thrust II ACI engines has obvious benefits. The reviewer referenced the second Thrust I group of comments, and then remarked that the major barrier for any new fuel, Thrust I or Thrust II, has already been acknowledged to be the large number of stakeholders with competing value propositions. The reviewer asked if there is an opportunity to bust this major roadblock once, why choose a path that would need this roadblock

busted twice. Having Thrust I and Thrust II fuels be the same is an incredible opportunity to further the main goal of Co-Optima vision of "Better fuels and better vehicles sooner." The reviewer also noted a related sub-milestone comment under Thrust II.

Opening the sixth Thrust I group of comments, the reviewer remarked that the Co-Optima program should verify that high RON and high sensitivity fuels do indeed substantially increase engine and vehicle fuel efficienc . The reviewer commented that this should be done quickly and with minimal research, as this ground has been plowed numerous times by many studies, and the answer is generally well-known and accepted.

Beginning the seventh Thrust I group of comments, this person stated that the Co-Optima program should focus major resources and effort on identifying promising low-GHG fuel compositions and blendstocks that are sustainable, affordable, scalable, and with attractive infrastructure and retail attributes. The reviewer said that the understanding is that Co-Optima has already started the life-cycle and techno-economic analysis on the 20 Thrust I fuel blendstocks.

Introducing the eighth Thrust I group of comments, the reviewer said that it is anticipated, that of the six teams that Co-Optima has put in place, the following hold the key to overcoming the main barrier already discussed: the LGGF team, which is focused on low-GHG blendstock properties and pathway attributes; the ASSERT team, which is focused on environmental impacts, cost, scalability, and feed logistics; and the MT team, which is focused on infrastructure and legacy fleet compatibility. The reviewer is of the opinion that these three teams will need to be primarily engaged in assisting stakeholders going forward. The reviewer also warned that, if Co-Optima declares Thrust I complete and disengages at FY 2019, it may fall short of its goal and will have at most a flash-in-the-pan effect.

Starting the ninth Thrust I group of comments, this reviewer said that the Thrust I engine projects currently being carried out on the 1.6-L Ford Ecoboost engine at ORNL and the 2.0-LTG GM engine at NREL are scoped reasonably well. The reviewer remarked that several appropriate changes have been made to the base engines to make it more relevant for evaluating high octane fuel performance. The reviewer also noted that appropriate changes in the engine CR are planned, along with an appropriate selection of relevant fuels. The reviewer also remarked that appropriate issues like LSPI are being studied. The reviewer also commented that the project has the potential of informing the community about the tradeoffs that need to be dealt with when designing downsized boosted engines with high octane fuel to realize high fuel efficienc .

For the 10th Thrust I group of comments, the reviewer opined that the single cylinder head engine choice at SNL may not be representative of the state-of-the-art Thrust I engine that industry currently has and continues to evolve. The referenced engine at SNL has good optical access and also has port and other information needed for CFD simulation provided by an OEM. However, the typical downsized, boosted SI engine today utilizes high-tumble ports, special combustion chamber and piston topologies, and Miller cycle valve strategies, of which none are present in that cylinder head. The reviewer explained that work on knock-limited performance on this cylinder head will fall way short of understanding real low- and high-speed WOT knock-limited behavior.

Presenting the 11th Thrust I group of comments, this person stated that engine downsizing causes the load-factor of an engine to increase. Therefore, the current work on the effect of laminar flame speed increasing dilution tolerance at light loads should be extended to mid-loads also where knock typically compromises the optimum location of CA50.

The reviewer provided five Thrust II comments that follow below.

Commencing the first Thrust II group of comments, this person remarked that verifying whether Thrust I fuel and Thrust II fuel can be the same should be the first, and foremost, Thrust II goal. The reviewer noted that in this regard, the use of an OI as a means to evaluate fuel properties simultaneously suitable for both Thrust I and Thrust II engines is encouraged.

For the second Thrust II comment, the reviewer asserted that Co-Optima should pursue the path of discovering a new Thrust II fuel and by implication, a new Thrust II engine, only after it has been convincingly proved that these

two fuels cannot be the same.

Presenting the third Thrust II group of comments, this reviewer commented that the literature on Thrust II engine concepts suggests more than a handful of recipes for ACI combustion. The reviewer inquired about what would be the anticipated Co-Optima fuel requirements for each recipe. The reviewer provided that choices could be as follows: exactly the same; slightly different; or significantly di ferent. The reviewer noted if the answer turns out to be "exactly the same," then the path forward is simplified. If it also stands that Thrust II fuel equals Thrust I fuel, then the path forward is incredibly faster and beneficial for all stakeholders, as previously noted

Starting the fourth Thrust II group of comments while also referencing the third Thrust II group of comments, the reviewer questioned whether the path forward would be fraught with huge challenges if the answer turns out to be "significantly di ferent," or even "slightly different." The reviewer expressed interest in knowing who decides the winning Thrust II engine-plus-fuel combination. This person further inquired whether Co-Optima could really be the one who picks the winner, or if each stakeholder would have a differing opinion on the winning combination. The reviewer also asked about the role of free market enterprise for selecting the winning combination.

Concluding with the fifth Thrust II group of comments and referencing the fifth Thrust I group of comments, this reviewer remarked that Co-Optima could include a sub-milestone under another milestone. Recognizing that in the context of the current discussion, perhaps the suggestion that Thrust II fuel and Thrust I fuel can be the same may hold true only for LD applications because Thrust I engines largely imply SI, gasoline, LD engines. The reviewer offered that, on the other hand, Thrust II fuel can be targeted to any or all applications including LD, MD, or HD. For example, if it turns out that new Thrust II fuels can be profitably optimized with Thrust II engine recipes for MD or HD applications, perhaps then a case could be made that Thrust II fuel should be different than Thrust I fuel for these applications.

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

Reviewer 1:
The reviewer said that project team has made a lot of progress for only starting the project a short while ago. The reviewer remarked that each of the tasks and subtasks have identified several accomplishments that will provide the necessary tools to help meet the projects milestone and overcome the barriers. The reviewer noted that the milestones identified in this project are on schedule to be completed, and said because there are so many projects in the simulation toolkit team, it may be necessary to have each subtask reviewed independently during the AMR.

Reviewer 2:
The reviewer noted lots of good progress. However, researchers need to ensure that the needs of boosted, high-output engines that will be the main part of the market are being addressed. The reviewer said that there are a lot of tools and it seems like there is some overlap that needs to be controlled.

Reviewer 3:
The reviewer stated that the accomplishments and progress in the presentation appeared to be largely a data dump, with only cursory references to the significance of the relationships shown and almost no explanation given of any relationships between them. The reviewer concluded that, therefore, it is unclear to what extent the enormous computing power utilized has been needed, effectively utilized, or what progress has actually been made.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that this was an amazing job of focusing research into one organized program.

Reviewer 2:
The reviewer remarked that the overall team assembled of national laboratories and an external advisory board have brought together a very high caliber of expertise that will be able to implement the program to meet the

required milestones and eliminate barriers. The reviewer's only concern was that the team is so large and so many tasks are being worked on, there may be too much time spent on coordination and outside meetings that may take away from the research.

Reviewer 3:

The reviewer said that the project apparently involves collaboration and cooperation between six national laboratories. The reviewer said some of the slides showed data that identify the source as one or more of the specific lab partners, but most do not. In reference to the data displayed in the presentation, the reviewer said that some show testing equipment identified as at institutions that are not project partners. The reviewer said that thus, overall, the presentation is unclear as to how much actual collaboration and coordination is occurring between the partners beyond what the project team stated in an answer to a question that there is a phone call between the principal investigators (PIs) every month.

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

Reviewer 1:

The reviewer remarked that the following future work planned are all appropriate and that these tasks should continue helping to overcome the barriers: Task G.1.2, Support Small Volume Fuel Testing; Task G.2.1, Extreme Mechanism Reduction for Direct Injection Spark Ignition (DISI) (which will include a focus on Thrust 1 ethanol gasoline blends and bio-diesel); and Task G-3, Blendstock-to-Efficiency Application (single and multi-cylinder engine modeling).

Reviewer 2:

The reviewer commented that the project team needs engine data for high brake mean effective pressure (BMEP), boosted, and Miller Cycle operation. The reviewer said that the bulk seems aimed at LTC, homogeneous charge compression ignition (HCCI), and reactivity controlled compression ignition (RCCI) and expressed doubt that those will ever be large volume products.

Reviewer 3:

The reviewer said that most of the future research slides are stated in general terms which appear to project very useful models linking efficiency to fuel properties and engine parameters for both gasoline spark ignition (GSI) and gasoline compression ignition (GCI) engines, based on fuel maps as well as external data on vehicle miles traveled (VMT), market penetration, etc. It was not clear how any (if at all), let alone all, of the prior work is to be integrated into this model. Moreover, a question was raised as to the appropriateness of using the optical engine at SNL for the initial part of this work, and the reviewer said that the PIs did not provide a particularly good answer to that question.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer said that the work of the Simulation Toolkit Team is very relevant to the DOE goal of petroleum displacement. The reviewer remarked that by developing models to show the impact of new fuels on engine performance, the project team will provide the necessary information to aid in developing optimum fuels to be used in advanced engines to reduce fuel consumption.

Reviewer 2:

The reviewer noted a large impact on future fuel efficienc .

Reviewer 3:

The reviewer remarked that the project would support the objectives of petroleum displacement if it achieves its objectives of better understanding the relationships between fuel properties, engine design, and efficienc . The

reviewer commented that the presentation, however, did not establish the likelihood of those objectives being realized.

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

Reviewer 1:
The reviewer said that the funding for this Co-Optima Simulation Toolkit Team is adequate to achieve the milestones in the project.

Reviewer 2:
The reviewer said that it seems to be a good use for skilled personnel and big computers.

Reviewer 3:
The reviewer said that the presentation did not provide any basis for this reviewer to make judgments as to the sufficiency in terms of achieving the objectives in a well-planned and o ganized progression. The reviewer remarked that the overall impression given is that lots of activities are being undertaken and data generated without a logical progression and decision tree.

Utilizing Alternative Fuel Ignition Properties to Improve Spark-Ignited and Compression-Ignited Engine Efficiency: Margaret Wooldridge (University of Michigan) - ft042

Presenter
Andre Boehman, University of Michigan

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

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

Reviewer 1:
The reviewer remarked that this project is very well planned and executed. The reviewer stated that aside from not meeting the CI target and requiring a no-cost time extension, that the project team were meeting all objectives of the project.

Reviewer 2:
The reviewer noted that overall, the various research tasks individually seem to be interesting and useful. However, together as a program things seem a bit unfocused. The reviewer said that it was not clear how exactly the project plans to move towards the goal of achieving 40% brake thermal efficiency (BTE). The reviewer stated that the project team has, as presenter put it, lots of knobs to turn to improve efficienc , but that there does not appear to be a systematic approach. The reviewer commented that the project team wants to use rapid compression machine (RCM), ignition quality tester (IQT), and CI demonstration studies to learn about autoignition and single-cylinder engines to learn about the various sensitivities to the knobs that the project team can turn. The reviewer stated that this was vague and does not map out a clear plan. Furthermore, by the project team's own admission it is not assured that the project team will be able to take advantage of what they learn in the simpler platforms including RCM, IQT, and single-cylinder engine when the project team goes to the multi-cylinder engine. The reviewer stated that the project team indicated that they very well might not be able to achieve the commanded conditions.

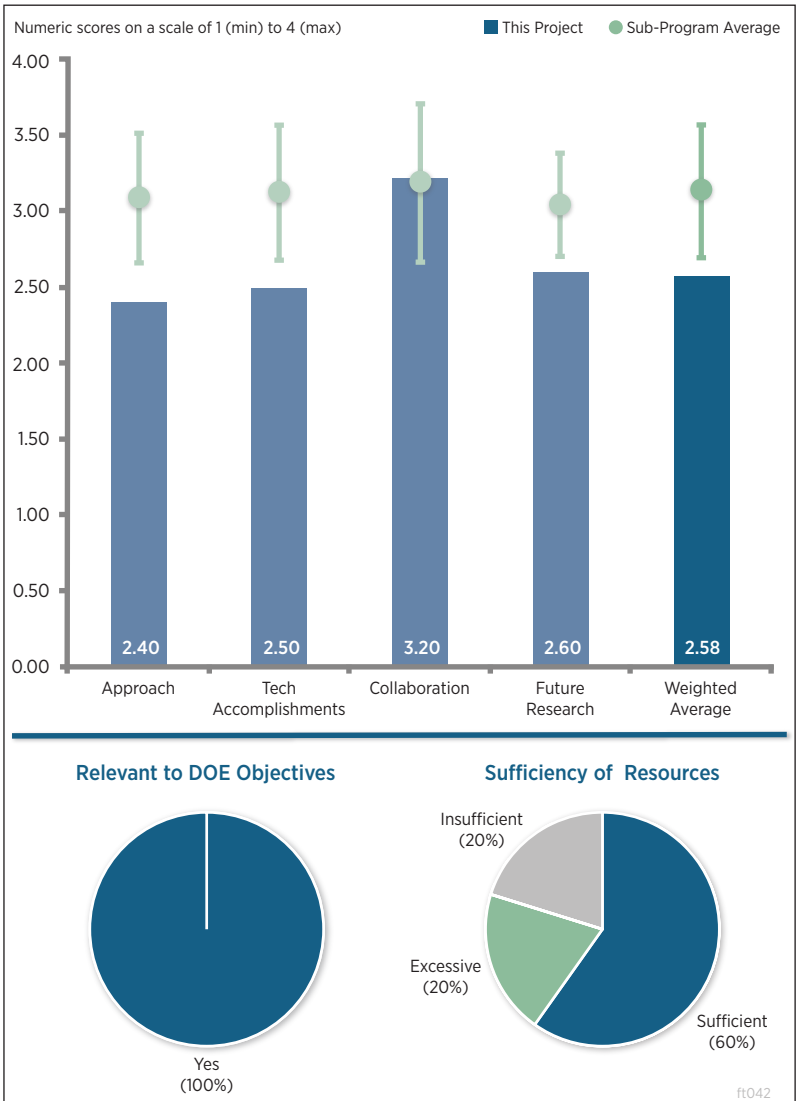

Figure 5-11 - Utilizing Alternative Fuel Ignition Properties to Improve Spark-Ignited and Compression-Ignited Engine Efficiency: Margaret Wooldridge (University of Michigan) - Fuel and Lubricant Technologies

Reviewer 3:
The reviewer remarked that the approach including progression from simulations, ignition quality tester, RCM, single cylinder engine, multicylinder engine, and others was a logical way of examining the potential for increased FE with high-level ethanol blends in SI engines by varying engine conditions such as intake pressure, EGR

dilution, spark timing, and others, and as well as benefitting from cha ge cooling. The reviewer said that the project appears on track to meet objectives. The reviewer commented that the investigation of CI dimethyl-ether (DME) and propane blends applicability was less clear and the objectives determined were not attainable. The reviewer remarked that this investigation appears to have been prompted largely by another study that the project team now has determined was flawed

Reviewer 4:

The reviewer stated that the deliverables and scope of the project are not well defined. The reviewer remarked that one of the key deliverables of the project has been defined as achieving 40% BTE on an SI engine. The reviewer said that the presentation, as well as the slide deck, made available for review did not elaborate on any qualifying criteria for the 40% BTE. The reviewer said that for instance, if the goal of the project is to demonstrate a peak BTE of 40% on an SI engine, then that has already been demonstrated. The reviewer indicated that prior DOE funded projects have demonstrated peak BTEs well in excess of 40%. The reviewer also pointed out that current Atkinson cycle production engines from Toyota and Hyundai have achieved a peak BTE of 40%. The reviewer noted that it was also not clear if the peak 40% BTE target is to be met while retaining the power and torque output of the engine. The reviewer said that if the efficiency needs to be increased while retaining the specific outpu of the engine, then the project may need to include development activities such as turbocharger matching, EGR system modifications, and ignition system upgrades

The reviewer said that the reference or baseline condition was not well defined. The reviewer claimed that the peak BTE of the stock Daimler M274 engine is in excess of 37% and that thus, achieving a peak BTE of 40% is not a very difficult task. For instance, increasing the CR from a stock value of one equal to 9.8 to one equal to 12 might be sufficient to achieve an increase of 3% in part load BTE. The reviewer concluded that thus, in the absence of the baseline or reference condition being well defined, achieving 40% BTE was not a very challenging ta get.

The reviewer said that extensive data already exists in the literature on the impact of ethanol and exhaust gas recirculation (EGR) on combustion separately. The reviewer claimed that data also exist on the combined impact of ethanol and EGR. The reviewer noted that one recent example of a study investigating ethanol and EGR effects is SAE 2016-01-0715. The reviewer suggested that the project leads may want to clearly define the new technical information that this study expects to contribute to the existing body of knowledge.

The reviewer remarked that Task 1.2 refers to the use of simulations for evaluating the impact on knock and flame limits of alternate fuels and combustion strategies on engine efficienc . The reviewer expressed that it was not clear if that task is referring to one-dimensional or three-dimensional simulations, or both. The reviewer cautioned that one-dimensional analysis alone was not sufficient to assess the impact on knock and flame limits of fue properties such as octane number and heat of vaporization. The reviewer said that also, as alluded by Task 1.2, one-dimensional analysis is probably not the most effective and accurate tool for assessing the impact of fuel spray on combustion.

Reviewer 5:

The reviewer remarked that it was disappointing to see DOE fund such poorly scoped and funded projects. The reviewer stated that the project seemed to be scoped poorly to begin with. The reviewer remarked that the goal of 40% BTE for SI and 50% for CI was a worthy goal, but that the resources and the pathway to achieve it seems to fall way short. The reviewer commented that the original time of one year as well as the funding are way below what would be needed for a project of this magnitude. The reviewer said no wonder a no-cost extension has been requested and no wonder the diesel portion of the goal has been abandoned. The reviewer said that fundamentally, operating an SI engine with ethanol and ethanol-gasoline blends, which are higher in RON, and increasing the CR to gain efficiency is a well-known and studied strateg . The reviewer said that if that was all this project was going to demonstrate for an SI engine, then it is a waste of money. The reviewer wanted to know what new efficiency improving proposals were going to be studied in this project.

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

Reviewer 1:
The reviewer remarked that one technical objective was not met, but the presenter promised a continued effort as part of another program.

Reviewer 2:
The reviewer said that the overall progress and accomplishments are generally on target but that the score is slightly downgraded due to lack of success on CI engine work.

Reviewer 3:
The reviewer referenced prior comments, and said that useful data were collected on SI combustion with gasoline and ethanol fuels at various pressures and EGR rates. The reviewer remarked that the test engine calibration and modelling was completed. The reviewer also stated that data on CI was useful mainly in dispelling interest in pursuing indicated strategies.

Reviewer 4:
The reviewer said that considering the ignition delay testing, development of a GT-Power model, and the testing on the Ford Motors single cylinder engine, that it appears that reasonable amount of work has been performed as part of the project. However, it is not clear how the work performed thus far has contributed to the existing body of knowledge on combustion of ethanol-gasoline blends. The reviewer remarked that with discontinuation of the dual-fuel CI work stream, this project is essentially an investigation on combustion of gasoline-ethanol blends, which is a topic that has been extensively investigated. The reviewer said that the project leads may want to identify and define deliverables that are expected to contribute new information and in the process help achieve DOE's goals

Reviewer 5:
The reviewer said that the project was made up of what seems like loosely connected sub-projects, with no clear indication of how each sub-project contributes to reaching the main goal of 40% BTE. The reviewer provided as an example that single-cylinder engine studies have been conducted and that these studies show an indicated thermal efficiency of about 38% with E100. The reviewer would like to know what the plan was to get to 40% thermal efficiency on a brake basis on the multi-cylinde . The reviewer said that GT-Power simulations can only offer analytical insight. Furthermore, the single cylinder engine is a Ford Fox engine, but that the multi-cylinder is a Daimler M274 2.0-L engine. The reviewer said that the single cylinder engine probably has a multi-hole fuel spray while the multi-cylinder engine has a piezo spray. The reviewer asked what the plan was to make sure that the single cylinder engine learnings translate to the multi-cylinder. The reviewer questioned what the hope was that E100 will be the fuel of the future.

The reviewer also questioned why a PM emission study was included in this project. The reviewer asked if it has that significant a bearing on demonstrating the BTE goals of the project. The reviewer said that more details would be appreciated, otherwise, it is left to the interpretation of the reviewer.

The reviewer asked how conducting Engine Combustion Network (ECN) Spray G experiments contributes to demonstrating the BTE goals of the project. The reviewer also wanted information on how these measurements were going to be related to the different sprays in the single- and multi-cylinder engines. The reviewer said that more details would be appreciated, otherwise, it is left to the interpretation of the reviewer.

The reviewer remarked that the go/no-go decision on the diesel part of the project was commended. The reviewer offered that it was a wise decision to not proceed and waste money, time, and resources in trying to execute a poorly scoped and unplanned project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the involvement of a major OEM and a Tier 1 supplier, along with research institutions such as NREL and SNL, suggests a reasonable level of collaboration between project participants and collaborators. The reviewer said that based on the presentation, it was clear that as the project partner Bosch was providing a lot of hardware support. The reviewer said that if Bosch's role extends beyond hardware and monetary support, that the project leads may want to comment on that as well.

Reviewer 2:
The reviewer said that there appears to be extensive and fruitful collaboration ongoing between the two national laboratory partners, University of Michigan, and the three industry partners, and that these collaborations involved both sharing of responsibilities and equipment and consultation on implications of results. The reviewer said that the results of all partners should ultimately be combined to show total efficiency gains possible from optimization of engines on the selected ethanol blends.

Reviewer 3:
The reviewer remarked that the project team suggested that they were collaborating and coordinating with several partners, but some of these relationships are unclear or seemingly irrelevant. The reviewer provided an example that the project team claimed that the SNL ECN was a collaborator, but the project team did not make a credible case that the Spray G imaging work is relevant to this program. The reviewer said that in fact, the project team barely paid lip service to that work. The reviewer offered that a second example was Horiba and said that it appears that the extent of that collaboration was a discount that offered to the project team on their equipment. The reviewer would not agree that this constitutes a collaboration.

Reviewer 4:
The reviewer said that the collaboration with the various organizations listed is fine and that they are mainly for the purpose of procuring hardware or information. The reviewer said that Bosch is playing a critical role in providing and possibly running the Daimler multi-cylinder engine tests. The reviewer remarked that the bulk of the responsibility of successfully demonstrating the goals of this project are upon the shoulders of the University of Michigan. The reviewer expressed the concern that the project team has bitten off more than it can chew.

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

Reviewer 1:
The reviewer remarked that the project has access to excellent facilities and investigative tools. However, as described in the presentation, the project scope is perhaps too wide, which may be driving work streams that are not necessarily the most effective use of the facilities. The reviewer stated that the project leads may want to identify research activities that are expected to contribute new information and to focus on those instead of trying to perform too many tasks. For instance, the impact of gasoline-ethanol blends on fuel spray and soot formation could be a work stream worthy of an in-depth study.

Reviewer 2:
The reviewer said that the future research identified was the extension of the work as planned into multi-cylinder engine testing, as well as other testing being extended with different CRs and spray strategies.

Reviewer 3:
The reviewer said that by the presenter's own admission, the single-cylinder engine studies (and spray and ignition studies) may very well point the project team in directions that it cannot necessarily go with the multi-cylinder engine. The reviewer remarked that the best approach would be to either focus on aspects that that the project team knows it can control/change in the multi-cylinder engine when doing the project's fundamental studies (but that work appears to be mostly complete), or to ensure that the project's multi-cylinder engine system can accomplish the conditions that the project team anticipates needing to achieve.

Reviewer 4:
The reviewer remarked that except for the time delay, this program will finally achieve all targets, within or without of this project.

Reviewer 5:
The reviewer said that the task list for future work was exhaustive and it probably will not be completed in the extended time requested. The reviewer commented that very little useful information or knowledge can be salvaged from the work done so far or from the future work.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said that clearly, achievement of significantly higher BTE would support the primary objective of petroleum displacement.

Reviewer 2:
The reviewer remarked that the project has access to appropriate tools and facilities that can be used for making valuable contributions towards meeting DOE's objectives. The reviewer stated that however, the scope of the project and deliverables need to be defined such that they are better aligned with DOE's goals

Reviewer 3:
The reviewer remarked that this project could ultimately help identify optimal ways of using ethanol supply in U.S. gasoline to maximize FE and equalize or improve miles per gallon (MPG) in contrast to gasoline, increasing overall FE and allowing for greater usage of ethanol than currently, as constrained by mileage penalty, cost per mile, frequency of refueling, etc.

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, as usual, the University of Michigan was well suited to complete the task, including both people and equipment.

Reviewer 2:
The reviewer said that the resources and time provided have been grossly underestimated.

Reviewer 3:
The reviewer said that resources appear sufficient based on work being performed. The reviewer noted that the budget for FY 2017 was reduced from previous years, apparently as an adjustment for discontinuation of the CI work on DME and propane.

Reviewer 4:
The reviewer said that the University of Michigan has significant resources and that therefore this is not expected to be an issue.

Reviewer 5:
The reviewer observed that the current budget is excessive in view of the existing work streams. However, this ranking may be changed to “Sufficient” if the project scope and deliverables are aligned better with DOE's goals

E85/Diesel Premixed Compression Ignition: Lyle Kocher (Cummins) - ft043

Presenter
Lyle Kocher, Cummins

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

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

Reviewer 1:
The reviewer remarked that this was an outstanding example of a well thought out project with aggressive objective, correct technical content, and the right resources to make it happen.

Reviewer 2:
The reviewer remarked that the project was scoped well and said that this may be the first RCCI attempt by an industry OEM. The reviewer further noted that because the team uses E85 as one of the fuels, it has potential for significant petroleum reduction.

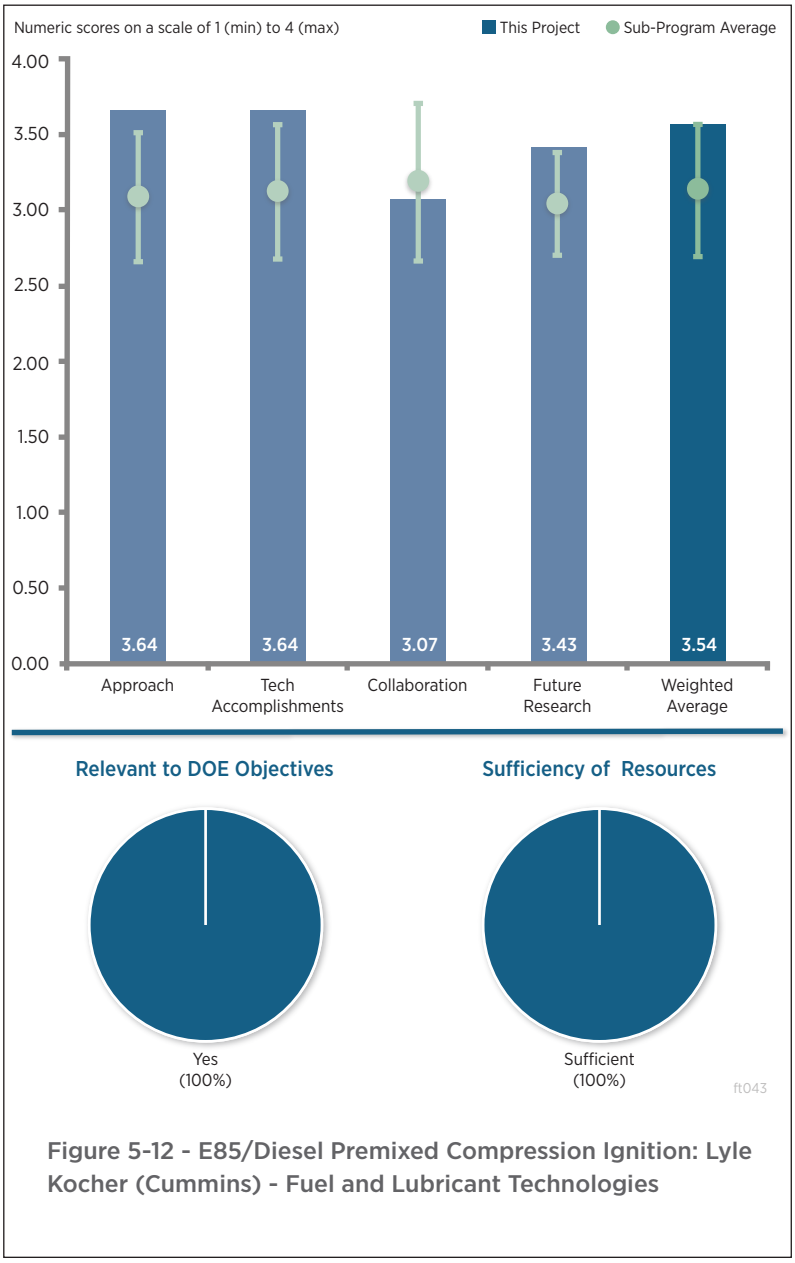

Figure 5-12 - E85/Diesel Premixed Compression Ignition: Lyle Kocher (Cummins) - Fuel and Lubricant Technologies

Reviewer 3:
The reviewer remarked that the approach to design a combustion and engine system to operate over the entire speed and torque map, to design the integration of a secondary fuel system, and the development of closed loop control during transient operation have been excellent. The reviewer commented that the final step of the approach will be to demonstrate the engine in a vehicle on a developed calibration. The reviewer said this final step was an excellent way to show that this technology will truly have an impact on petroleum reduction.

Reviewer 4:
The reviewer said that the project was well structured and the approach was very clear. The reviewer voiced that the project team was taking a very logical approach to addressing the project goals of reducing petroleum use by 50% while considering other emissions.

Reviewer 5:
The reviewer said that the approach was excellent and logical, as expected from a successful engine OEM. The reviewer commented that the team was properly considering hydrocarbon (HC) and PM emissions as a constraint

which was an improvement over many R&D projects that focus only on efficienc . The reviewer remarked that reducing HC with the low exhaust temps will be a problem that needs some aftertreatment consideration. The reviewer suggested that further work will be needed with varying ethanol levels, diesel cetane levels, and colder temperatures. The reviewer suggested that some demonstration that the system would still be viable with a glowplug to start or robust with the pressure feedback would be beneficial

Reviewer 6:
The reviewer said that the project team has a great approach to the project. The reviewer commented that the only things missing were DI of E85 and a deeper dive into the variability of E85 between the summer and winter, which the reviewer noted were beyond the scope of this project.

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

Reviewer 1:
The reviewer praised that the project has demonstrated excellent progress according to plan. The reviewer said that results to date were clearly articulated and the remaining challenges appropriately quantified. The reviewer commented that additional plans to address the remaining challenges were clearly articulated.

Reviewer 2:
The reviewer said that the objectives seem to have been fully met, with the remaining work well in hand.

Reviewer 3
The reviewer said that the project appears to progressing nicely. The reviewer commented that the hardware design was quite clever and that it seems production ready.

Reviewer 4:
The reviewer said that the project's technical accomplishments have been excellent and have met all of the required milestones to date. The reviewer remarked that Cummins has successfully designed and demonstrated a duel-fuel engine for a Class 8 heavy truck. The reviewer noted that Cummins has demonstrated over 50% petroleum reduction over a 13 mode and FTP and have also shown engine–out nitrogen oxides (NO_x) and PM reductions over its diesel counterpart.

Reviewer 5:
The reviewer remarked that the results for petroleum reduction have been reported, which are very good. The reviewer noted that it would have been informative to know how the absolute BTE with this two-fuel, E85 plus diesel, concept compared to the base engine operating on one fuel, diesel.

Reviewer 6:
The only area that this reviewer could find fault with was HC and carbon monoxide (CO) emissions from the end gasses, which is a common problem with this approach.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the project does not have collaborators or coordination outside of Cummins but because of the way the project was designed that it did not appear necessary to have outside collaboration. The reviewer said that there was collaborative work with Cummins Fuel Systems to provide an advanced direct injection fuel system.

The reviewer remarked that collaborations were mainly internal and that few other companies have such complete internal capabilities. The reviewer commented that because Cummins has the tools that this seems to be an appropriate level of collaboration. The reviewer said that much of this work was clearly informed by previous research at national laboratories and contractors.

Reviewer 2:
The reviewer said that there were no external partners but that external partners are not necessary for this project. The reviewer remarked that Cummins has the resources to complete the project.

Reviewer 3:
The reviewer stated that this project was internal to Cummins and not a team with academia or national laboratory participation.

Reviewer 4:
The reviewer commented that this project relies primarily on internal collaboration within the organization. The reviewer said that while the project was well thought out and the progress is strong that perhaps deeper interactions with the labs, universities, and other performers beyond attendance at the program meetings could generate additional ideas to tackle remaining 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.

Reviewer 1:
The reviewer remarked that the proposed future work of developing transient calibration and controls and also to build and test the vehicle, including emission validation testing, will complete the project and eliminate the barriers outlined in the project.

Reviewer 2:
The reviewer said the project path forward seems to systematically address the stated objectives. The reviewer commented that the project team has clearly thought through the project and carefully planned how to manage the hydrocarbon emissions challenge.

Reviewer 3:
The reviewer noted a strong plan.

Reviewer 4:
The reviewer said that the project team understood the deficiencies of this approach and suggested several areas and approaches, such as DI and low-pressure EGR, to overcome their problems.

Reviewer 5:
The reviewer remarked that the acknowledgement of the challenge and focus on HC emissions is good. The reviewer said that there could be more work on how such a fuel strategy could actually be implemented.

Reviewer 6:
Pending successful development of transient engine operation, HC emissions, and cold-start and warm-up calibration, the reviewer asked what some of the other barriers are that would prevent this concept from being commercialized. The reviewer asked what the issues are related to the use of E85 by Class 8 truck manufacturers.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer said that the project definitely supports the overall DOE objective of petroleum displacement, because the goal of the project was to meet 50% petroleum reduction in an E85 diesel premixed CI engine.

Reviewer 2:
The reviewer said large petroleum reduction on a relevant product platform.

Reviewer 3:
The reviewer said that the project was explicitly focused on displacing petroleum fuel by 50% by using E85.

Reviewer 4:
The reviewer said that there was a significant portion of petroleum displaced by E85

Reviewer 5:
The reviewer said that the project was meeting the goal of 50% petroleum reduction and noted that it was therefore relevant. The reviewer said that with current E85 and diesel fuel prices, there does not appear to be a business case for anyone to pursue this currently. The reviewer commented that future price swings could change the case.

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

Reviewer 1:
The reviewer said that the funding seems to be adequate to complete the project and meet the milestones.

Reviewer 2:
The reviewer commented that the project was adequately funded when considering the cost share from Cummins.

Reviewer 3:
The reviewer said the funding seems to be about right.

GEFORCE: Gasoline Engine and Fuels Offering Reduced Fuel Consumption and Emissions: Scott Sluder (Oak Ridge National Laboratory) - ft044

Presenter
Scott Sluder, Oak Ridge National Laboratory.

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

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

Reviewer 1:
The reviewer remarked that the project was scoped very well. The reviewer said that several appropriate changes have been made to the base engine to make it more relevant for evaluating high octane fuel performance. The reviewer commented that appropriate changes in the engine CR are planned, along with an appropriate selection of relevant fuels. The reviewer stated that the project has the potential of informing the community about the tradeoffs that need to be dealt with when designing engines for high octane fuel to realize high fuel efficienc .

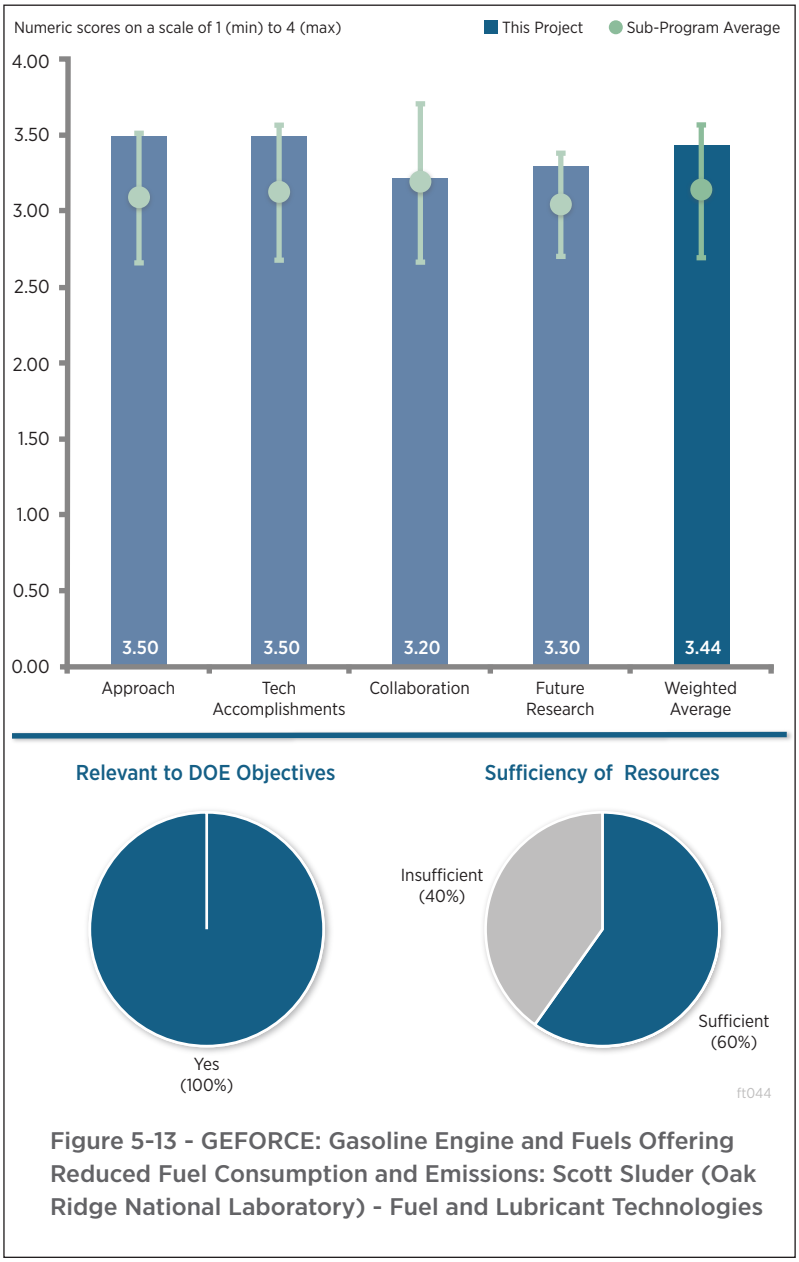

Figure 5-13 - GEFORCE: Gasoline Engine and Fuels Offering Reduced Fuel Consumption and Emissions: Scott Sluder (Oak Ridge National Laboratory) - Fuel and Lubricant Technologies

Reviewer 2:
The reviewer remarked that the approach was useful in anticipating engine designs for the 15 to 20 year horizon and in determining optimal fuel properties for efficiency and low emissions as used in such engines. The reviewer commented that various fuel mixtures in matrix of RON, ethanol, and final boiling point were to be tested at various operating conditions including, power densities and gear ratios initially, to find the optimum conditions for each fuel. The reviewer said that it provides the first step for future engine and fuel co-development

Reviewer 3:
The reviewer remarked that this CRADA was well thought out. The reviewer noted that it was set up to systematically evaluate potential future gasoline in terms of its potential to increase the efficiency of gasoline engines.

Reviewer 4:
The reviewer said that the approach used to determine what the dyno coefficients would be for a representative midsized car was clever. The reviewer commented that running simulations for an actual vehicle would also be

useful to compare the simulation results to the real world results. The reviewer said this would allow for additional vehicle testing if this project should receive additional funds.

The reviewer remarked that the project seemed to rely heavily on the experimental GM engine and cautioned that this limits the ability to test advanced technologies beyond those GM provides. The reviewer commented that it might have been better to start with a current state of the art engine so that the baseline data would be very reliable. The reviewer said that measuring the effect of the fuels on something like a 40% BTE Prius engine, or Mazda Skyactive, would eliminate engine unknowns. The reviewer said that if a boosted engine was really necessary, perhaps that one of the Coordinating Research Council (CRC) members could support with an engine and controller.

Reviewer 5:

The reviewer remarked that overall the approach was sound and quite interesting, and that it seemed highly appropriate when considering the context of many of the discussions that were taking place at this Peer Review meeting. The reviewer said that the only complaint was that the approach was slightly vague, in that it seemed as though the project team was going to try a bunch of stuff and see what happens. The reviewer stated that there does not seem to be a clear hypothesis, other than the idea that you will find ways to improve engine efficien . The reviewer noted that this was only a minor complaint considering how useful this work is likely to be.

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

Reviewer 1:

The reviewer said that progress was on track with program objectives.

Reviewer 2:

The reviewer remarked that very significant progress has been made in the area of procuring relevant engine hardware and fuel. In addition, the base engine has been calibrated. The reviewer noted that the OEM partner's ability to free up resources to support this project at ORNL was limiting further progress, but patience should be exercised as the payoff has the potential of having significant impact

Reviewer 3:

The reviewer noted that the project team was still setting up to do the experiments. The reviewer stated that the progress appears to be on track with the program schedule. The reviewer said that an appropriately representative modern engine was being used, which is critically important.

Reviewer 4:

The reviewer said that the project was in the early stages and that legal agreements took longer than anticipated. The reviewer noted that despite this, an advanced research engine was near operational and a baseline engine was operational. The reviewer stated that other key data have been obtained as a basis for initiating this research project.

Reviewer 5:

The reviewer said that the lengthy contracting process seems to have delayed the project quite a bit. The reviewer said that hopefully this coming year will be productive. The reviewer remarked that the fuel matrix and fuel formulations are done so one major hurdle has been overcome.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that the collaboration with GM appears to be excellent. The reviewer remarked that GM seemed heavily integrated into the project and that they are an excellent partner. The reviewer stated that the CRC allows access to more partners but that they do not appear to be heavily involved at this time.

Reviewer 2:
The reviewer stated that the fact that this project was partly CRC funded was a huge plus. The reviewer said that with the auto and oil company personnel working under the same umbrella, that the chances of success will be greater.

Reviewer 3:
The reviewer stated that the nature of a CRADA is strong collaboration.

Reviewer 4:
The reviewer stated that the project was a collaboration between ORNL and the CRC, and that key CRC individuals from GM and Chevron were identified as co-investigators. The reviewer noted that problems with legal agreements with each collaborator have occurred but that they were apparently resolved. The reviewer said that not much basis for evaluating extent of collaboration has been possible thus far.

Reviewer 5:
The reviewer indicated a slight downgrade on score, but only because it was not entirely clear what the role of CRC was. The reviewer noted that the CRC was the source of all collaboration on this project. The reviewer commented that the project team made it clear that CRC has provided money and resources. The reviewer expressed a lack of understanding about how this project specifically fits into CRC's plans and objective

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

Reviewer 1:
The reviewer stated that the hardware, fuels, and test plans seem to be in place. The reviewer said that it seemed like the main part of the work will begin in the middle of 2016 with support from the OEM partner.

Reviewer 2:
The reviewer remarked that the project team were setting up for fundamental thermodynamic analysis of the engine performance. The reviewer commented that this project seems like it would also be an excellent opportunity to interface with the Co-Optima program relative to fuel characteristics and associated engine performance. The reviewer asked if the project team would be able to obtain the generic composition of the chemical-molecular class distributions of the fuels being used and if that information could be incorporated into the database being developed by Co-Optima. The reviewer questioned if the octane index K factor could be determined for this engine, and if the OI could be determined for the range of fuels used. The reviewer asked if this could contribute to a baseline for the Co-Optima program. Then the reviewer stated that this could contribute to Thrust 1 activities.

Reviewer 3:
The reviewer remarked that comments on the proposed future research were essentially the same as comments on the project’s approach because real experimental work has not yet been initiated.

Reviewer 4:
The reviewer commented that engine calibration work seems to be a bit nebulous. The reviewer stated that developing a more defined plan for what engine map the project team will run should be part of the plan before running too many tests. The reviewer also noted that the limited funds will likely limit future work to less than desired, and referenced prior comments regarding resources.

Reviewer 5:
The reviewer stated that the future work plans were not specifically outlined, but rather left mostly general. The reviewer remarked that the project team may very well have a clear plan for your future work, but that it was not communicated clearly.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer remarked that this project has the potential of being the most relevant project in the DOE portfolio for some time now. The reviewer said that it is not a far-reaching research project that promises large hard-to-realize benefits, and yet it is not a project that is addressing insignificant efficie . Instead, it is going after the issue of high-octane fuel that has been severely limiting the potential of SI internal-combustion engines for two or three decades now.

Reviewer 2:
The reviewer remarked that the project meets the DOE goals and creates some necessary data for the influence of fuel properties with future engine technology.

Reviewer 3:
The reviewer remarked that the project clearly supports a primary objective of petroleum displacement.

Reviewer 4:
The reviewer stated that the project could provide a guide to auto and fuel industries regarding future engine fuel combinations for greater efficienc , hence, petroleum reduction. The reviewer remarked that the project could serve as a prelude to Co-Optima work. Focusing on fuel combinations (e.g., ethanol and gasoline) that are already available at commercial scales and supplies could be ramped up to progressively to meet demands of the future engines designed for these fuels as market penetration proceeds.

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

Reviewer 1:
The reviewer expressed the opinion that given the scope of the project, the funds for this project fall way short. The reviewer remarked that efforts should be made to increase the funding of this project.

Reviewer 2:
The reviewer stated that the calibration activity alone may use up most of the money. The reviewer stated that a 50% increase in funds seems more reasonable if CRC will come up with the additional cost share.

Reviewer 3:
The reviewer remarked that the resources were adequate for the initial phase of the work, but that it could be anticipated that additional work varying engine parameters further might be desirable with additional funding.

Reviewer 4:
The reviewer remarked that manpower seems appropriate and that the project was receiving reasonable direct and indirect support from CRC. The reviewer said that in addition, as the project team pointed out, associating with CRC enables broader indirect resources.

GDI Metrics: Scott Goldsborough (Argonne National Laboratory) - ft045

Presenter
Scott Goldsborough, Argonne National Laboratory.

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

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

Reviewer 1:
The reviewer stated that the approach to use ANL's RCM to acquire fundamental autoignition data, understand effects of fuel composition on LTC trends, and to formulate correlation based on data should prove to be very successful in addressing the barriers of this project.

Reviewer 2:
The reviewer remarked that the project was clearly addressing the need to have quantitative fuel quality metrics to characterize fuels across LTC operating modes. The reviewer noted that the approach was sound, using two complementary devices, RCM and GCI, to characterize the fuel blends and systematically vary the conditions.

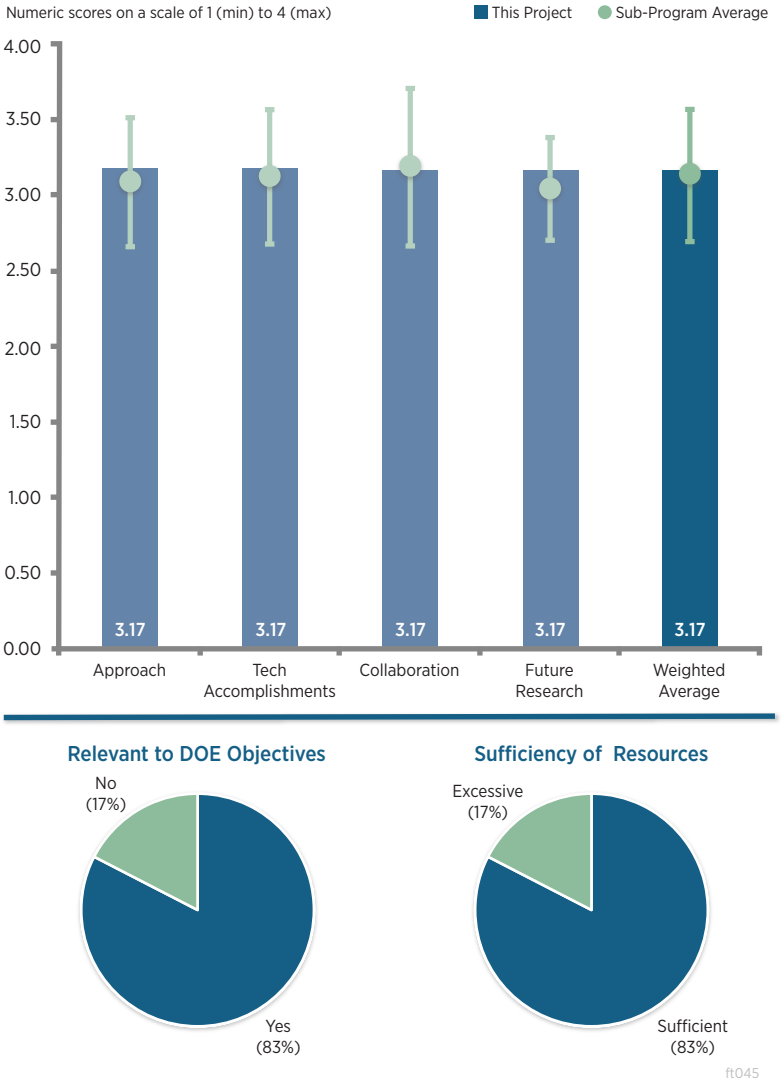

Figure 5-14 - GDI Metrics: Scott Goldsborough (Argonne National Laboratory) - Fuel and Lubricant Technologies

Reviewer 3:
The reviewer stated that the project has a good range of autoignition characteristics as well as fuel properties. The reviewer remarked that defining the low-temperature heat release (THR) and intermediate temperature heat release (ITHR) as a fraction of lower heating value (LHV) was a nice metric to evaluate LTHR and ITHR.

Reviewer 4:
The reviewer said good idea. The reviewer expressed that it was somewhat unclear exactly how the two data streams fit togethe .

Reviewer 5:
The reviewer remarked that the approach as listed on Slide 5 seems very short sighted. The reviewer said that much emphasis was given to understanding the fuel quality metrics for a LTC fuel, but that there seems to be little emphasis on how the project will employ a GCI engine to run on a variety of fuels, given that there was not much in the project about an engine calibration or development of an engine to run a transient cycle. The reviewer stated that quantifying the fuel performance on key engine points was only one part of the process in bringing the technology to market. The reviewer remarked that the project seems to overstate the planned accomplishments on

the Approach slide and in the title, but then clearly articulates the planned accomplishments on the Future Work slide.

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

Reviewer 1:
The reviewer commented that the project was on course and the data were extremely detailed and complete. The reviewer stated that the HCCI autoignition has a wide range of conditions that are hard to mimic outside of an engine. The reviewer said that the work linking the autoignition characteristics between the two was impressive.

Reviewer 2:
The reviewer commented that the characterization and testing of engines and fuels in FY 2015 has provided data for successfully meeting the project milestones. The reviewer remarked that there were several technical accomplishments this year: the project has shown excellent correlation between RCM and GCI engine data under quasi-HCCI conditions for baseline gasoline; fuels with a range of reactivity and molecular structure blended with physical-chemical properties were successfully characterized; and GCI engine experiments were used to quantify fuel influences over a range of operating conditions to validate fuel quality metrics

Reviewer 3:
The reviewer remarked on the nice initial progress and said that it seemed like there was something here to be learned.

Reviewer 4:
The reviewer stated that the project team presented a suite of test data and seemed to be on a solid path forward to identifying an approach for characterizing fuels with a quantitative quality metric. The reviewer remarked that the project team identified some interesting trends regarding intermediate heat release rates and reactivity trends that may inform the metric.

Reviewer 5:
The reviewer said that the technical accomplishments were just getting started with Phase II of this project, which included looking at fuel properties and the fuel quality metrics. The reviewer remarked that this is at the heart of the project. The reviewer stated that it was unclear why a proposed 20% vol./vol. would help support the objectives of the project, and that those are not listed on the project milestone slide. The reviewer stated that it was unclear why the chemicals were chosen for the 10% vol./vol. volume and what had been learned for the metrics, and that therefore it was also hard to understand the need for a second set of fuels.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that this project has great coordination between national laboratories and industry.

Reviewer 2:
The reviewer stated that the coordination and collaboration between ANL and Chevron was very good and that it will help to ensure a successful project completion.

Reviewer 3:
The reviewer commented that the primary partners on this project are ANL and Chevron. The reviewer remarked that the roles and responsibilities were clear and that the team seems well-coordinated in its efforts.

Reviewer 4:
The reviewer said it was good that the project team had a fuel supplier involved.

Reviewer 5:
The reviewer said that it seems that it would be helpful to have more collaborators for such a significant portion of DOE budget 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.

Reviewer 1:
The reviewer remarked that the proposed future work will continue to move the project towards meeting the milestones and overcoming the barriers of this project. The reviewer commented that it was very good that the future work will include a Phase III, which will include a 20% blended fuel.

Reviewer 2:
The reviewer stated that the key challenge associated with the project was whether a robust, quantitative metric or correlation could be obtained. The reviewer stated that the proposed work seems to provide a logical path forward.

Reviewer 3:
The reviewer stated that proposed future work seems like a good path. High-risk but potentially high-reward.

Reviewer 4:
The reviewer commented that isolating Phi sensitivity and EGR effects, as well as HOV, will make this work extremely useful in GCI and LTC fuel evaluation.

Reviewer 5:
The reviewer stated that the proposed future work follows the planned milestones for the project. The reviewer stated that it was still unclear why the Phase III was proposed 20% vol./vol. and how that will help support the objectives of the project, and pointed out those objectives were not listed on the Project Milestone slide. It was unclear why this is needed and how it will support the outcomes of the project. The reviewer said that it seemed too early to be planning for a Phase III, without the data for both Phase I and Phase II being completed. The reviewer remarked that the technical questions from the initial sets of data would be helpful to direct the Phase III.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer stated that yes, this project supports the DOE goal of petroleum displacement. The reviewer said the work in this project to develop new fuel quality metrics could be utilized to overcome barriers that inhibit the specification of fuels for low-temperature combustion engines in vehicle fleets, which will enable gains in engin efficiency to help achieve petroleum displacement

Reviewer 2:
The reviewer stated that having quantitative metrics to characterize fuels across LTC operating conditions was critical for characterizing these advanced combustion regimes. The reviewer remarked that characterizing fuels was critical to understanding the effectiveness of alternative fuels that can displace petroleum-based fuels.

Reviewer 3:
The reviewer remarked that this type of work leads to enhancing the basic understanding of LTC and autoignition. The reviewer commented that this will lead to better control of LTC engines and higher efficienc , hence lower petroleum consumption.

Reviewer 4:
The reviewer commented that a good ignition quality metric was needed for future fuel specifications

Reviewer 5:
The reviewer remarked that it was not clearly explained how the project can aid in the objective of petroleum displacement. The reviewer asked if there are data showing that this technology can enable improvements and suggested that, if the data exist, it would be helpful to highlight these in this project as the impetus for the 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 said that the funding for this project seemed to be sufficient to complete the project

Reviewer 2:
The reviewer noted that the funding seemed about right. The reviewer said it would be hard to contain the experiments with a smaller budget.

Reviewer 3:
The reviewer said that there were significant funds provided in this project, but the results seem rather light for the project goals. The reviewer stated that it was unclear how the project supported the goal of fuel economy improvements, and that no data were listed for expected results or improvements. The reviewer remarked that it was unclear how this project will be quantified

Efficiency-Optimized Dual Fuel Engine with In-Cylinder Gasoline/CNG Blending: Thomas Wallner (Argonne National Laboratory) - ft046

Presenter
Thomas Wallner, Argonne National Laboratory.

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

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

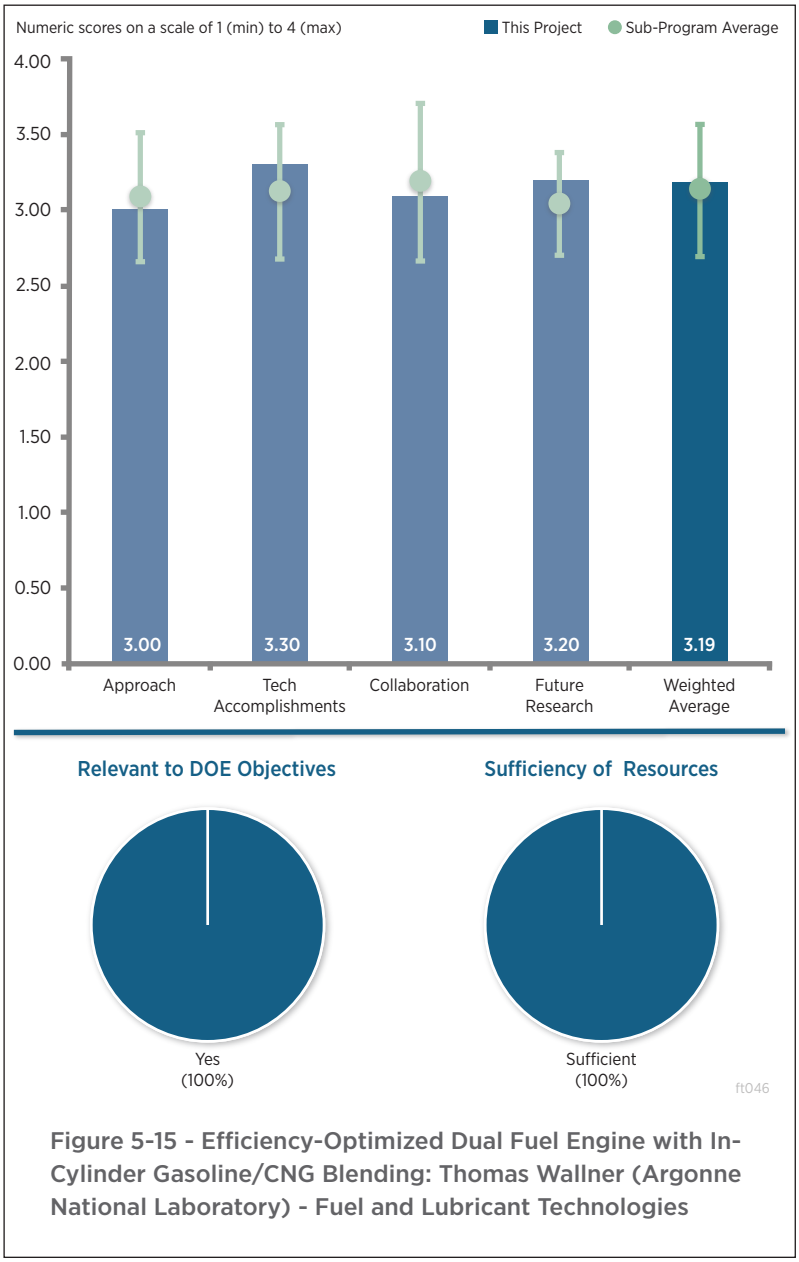

Figure 5-15 - Efficiency-Optimized Dual Fuel Engine with In-Cylinder Gasoline/CNG Blending: Thomas Wallner (Argonne National Laboratory) - Fuel and Lubricant Technologies

Reviewer 1:
The reviewer remarked that this was a well-defined project with some challenging goals. The reviewer commented that the project was moving quite well with some interesting learnings. The reviewer said that there were significant remaining challenges and barriers, noting Slide 20, but Slide 22 suggested that metrics were being met. The reviewer commented that it was not clear that the learnings will provide accurate vehicle level fuel economy data from single cylinder engine results. The reviewer said that this is usually a first step at an OEM for comparison of technologies and that it is not always accurate. The reviewer provided a few additional questions for the project team to add to the technical approach explanation: if a transient response is being comprehended somewhere, or only steady state points of an engine map; if an octane equivalent of the blends can be calculated; and if the aftertreatment needs to be changed as a result of methane use, and if that will be comprehended into the cost assessment.

Reviewer 2:
The reviewer remarked that overall the approach was sound and appropriate. The reviewer commented that the score was slightly downgraded because the project does not address the major barrier of infrastructure. The reviewer pointed out that admittedly, this was not something the research can address readily, but that the project team listed this as a major barrier, and thus put the project on the hook to address it.

Reviewer 3:
The reviewer said that the balance of simulation and experimental activities makes for a comprehensive approach

to the project. The reviewer stated that some aftertreatment studies of methane slip past the catalyst would be beneficial

Reviewer 4:
The reviewer remarked that the approach is sound in terms of the operating parameters, flame patterns, pressures, efficiencies, etc., that are being studied for various mixtures of a 10% ethanol blend with gasoline (E10) and NG using different direct injection (DI) NG injection types and placements to optimize engine efficiency utilizing the high anti-knock properties of the NGl, rather than running the vehicle on as much NG as possible and then switching to all-gasoline. The reviewer stated that some results presented were not clear as to whether a 25% NG mixture or 50% NG mixture was being used. The reviewer said it might have been better if the approach started with an examination of other constraints on the level of NG to be used. The reviewer said that efficiency gains are to be realized through increasing CR and otherwise exploiting the anti-knock properties of NG. The reviewer stated that this means that running on 100% gasoline, for example E10, will have to be avoided, apart from limiting the application of such engines to those not requiring fast refueling, such as long-distance. The reviewer remarked that in light of this constraint, available space for conforming tanks might determine limits on volume of natural gas to be utilized somewhere short of 50%.

Reviewer 5:
The reviewer said that as stated in this project's presentation, one of the barriers for NG was limited fueling infrastructure and refueling station availability. The reviewer asked what this project was doing to address this barrier. The reviewer asked why the project team would work on improving engine designs to run on NG when the limiting factor was the NG fueling infrastructure for LD engines. The reviewer noted that another barrier to the wider use of NG in internal combustion engines is the methane catalysis, and wondered if this barrier is recognized in this project. If this barrier is acknowledged, this reviewer asked why there is work on improving engine designs to run on NG when the limiting factor could be meeting emissions standards due to aftertreatment limitations. The reviewer commented that this presentation’s assessment of the Advanced Research Projects Agency – Energy (ARPA-E) Methane Opportunities for Vehicular Enhancement (MOVE) program seems dated. The reviewer said that DOE’s ARPA-E MOVE program started in 2012 and is almost completed. The reviewer asked if the conclusions of that program are suggesting that the infrastructure barrier for LD application of NG can be overcome.

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

Reviewer 1:
The reviewer remarked that the project seemed to be on track with the listed objectives and that an impressive amount of work has been completed so far.

Reviewer 2:
The reviewer said that the progress to date was impressive, including collection of data on key operating parameters with various mixtures, injection strategies, injector locations, etc. The reviewer said that the goals of 10% efficiency improvement have been exceeded but noted that it was not clear from the project team s presentation if that was with 25% or 50% NG. The reviewer also noted that some acronyms were not explained.

Reviewer 3:
The reviewer stated that the project was on time to according to plan. The reviewer expressed that this was encouraging because the project was almost 50% complete and the experimental work was well underway.

Reviewer 4:
The reviewer said that the technical approach on this project was good. The reviewer expressed that it was unclear how some of the items on Slide 20 of the project’s presentation will be accomplished. The reviewer asked if there was an octane model being developed for NG and an E10 fuel such as 87 anti-knock index (AKI).

The reviewer provided a few additional questions to add to the technical approach explanation. The reviewer asked if transient response was being comprehended somewhere, or only for steady state points of an engine map. The reviewer asked if an octane equivalent of the blends can be calculated. The reviewer also asked if the aftertreatment needs to be changed as a result of methane use, and if that will be comprehended into the cost assessment.

Reviewer 5:

The reviewer asked what the reasoning was behind blending compressed natural gas (CNG) and gasoline. The reviewer asked if it was because that blending was the status quo of limited on-board CNG supply constraints, or if it was because that approach provided the highest efficienc , or if there was some other reason. If it is already recognized that bi-fuel vehicles (e.g., due to a compromised CR) leave the overall fuel consumption potential of CNG untapped, the reviewer asked what or how this project will get around that barrier.

The reviewer said that the very large WOT efficiency and performance benefits of NG, due to more optimu phasing of the combustion process, that have been demonstrated is not surprising and it is well known. The reviewer remarked that at light load, when knock is not a problem, the data show that the blending strategy has very little benefit, approximately a 0.5% ITE benefit The reviewer further pointed out that at heavy load, when the engine is knock limited with E10, the data shows that the blending approach leaves a significant amount of efficiency untapped

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that it seemed like there was good collaboration between the members of the project based on the schedule of actions and project coordination meetings.

Reviewer 2:

The reviewer said that the collaboration with Fiat Chrysler Automobiles (FCA) and Ford makes for an excellent team. The reviewer remarked that a catalyst partner would be beneficial to address methane slip and the e fect on net GHG.

Reviewer 3:

The reviewer remarked that work was done as collaboration between ANL, Ford, and FCA, with automakers providing injection hardware and technical guidance. The reviewer commented that the nature and extent of technical guidance, mechanisms of consultation, etc., were not explained.

Reviewer 4:

The reviewer commented that overall, collaborations are good and appropriate, though not very broad. The reviewer said that there seemed to be some missed opportunities. For one, the reviewer thought that collaborations with academia would be possible (e.g., West Virginia University, University of Alabama, or Mississippi State University), as well as with the CNG industry.

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

Reviewer 1:

The reviewer commented that there was discussion of a vehicle level control strategy in the future work. The reviewer believed that this is to be able to comprehend a vehicle-level analysis of the project. The reviewer remarked that it will be interesting to see how a potential transmission shift schedule will accommodate an optimized fuel economy map between the fuels. The reviewer asked if the vehicle level analysis will assume a Federal Test Procedure and US06 cycle and be modeled. The reviewer is excited to see the outcome of this project.

Reviewer 2:
The reviewer remarked that the future work plan was appropriate to demonstrate the Funding Opportunity Announcement goals.

Reviewer 3:
The reviewer remarked that the plan looked fine. The reviewer expressed that the only comment was that it seemed like much work remained for a relatively short amount of time.

Reviewer 4:
The reviewer said that follow-up work would complete the engine optimization experiments and design a control strategy on actual vehicle. The reviewer stated that this could be an opportunity to integrate optimization with tank and refueling constraints, although that opportunity was not explicit in the presentation.

Reviewer 5:
The reviewer commented that the planned increase in CR and increase in tumble ratio were in the correct direction to maximize engine efficiency and performance potential with CNG. The reviewer expressed uncertainty why outwardly opening injectors were going to be investigated for side injection and inwardly opening for central injection. The reviewer asked if it would not be the other way around.

Question 5: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The reviewer remarked that the project clearly supports primary objective of petroleum displacement.

Reviewer 2:
The reviewer said, yes, the use of NG would aid in the displacement of liquid petroleum. The reviewer commented that using the high octane of NG has potential to aid in the efficiency improvement across the engine map of some advanced technologies.

Reviewer 3:
The reviewer said the project supports petroleum displacement by both increasing fuel economy and substituting NG for gasoline. The reviewer said but the relevance will ultimately be determined by how broadly it can be applied in terms of driving and refueling patterns.

Reviewer 4:
The reviewer stated that the project meets the DOE goals for petroleum reduction but meeting the goal for GHG reduction was questionable. The reviewer remarked that the CNG does not really help GHGs and methane slip may actually make the well-to-wheels greenhouse gases worse.

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 appropriate for current and proposed future work.

Reviewer 2:
The reviewer remarked that overall funding of $1 million appears adequate and the progress to date conforms well to the indicated timelines and annual budget levels provided.

Reviewer 3:
The reviewer stated that the current resources are sufficient and do not need to be increased

Reviewer 4:

The reviewer said that it was difficult to determine with the information provided if the funds are for hardware or headcount (or both) for the project, and what the collaborators are providing directly for the project.

Acronyms and Abbreviations

ACI	Advanced compression ignition
AKI	Anti-knock index
AMR	Annual Merit Review
ANL	Argonne National Laboratory
API	American Petroleum Institute
ARPA-E	Advanced Research Projects Agency - Energy
ASSERT	Analysis of Sustainability, Scale, Economics, Risk, and Trade
ASTM	American Society for Testing and Materials
BETO	Bioenergy Technologies Office
BMEP	Brake mean effective pressure
BTE	Brake thermal efficiency
°C	Degrees Celsius (Centigrade)
CA50	Crank angle position at which 50% of heat is released
CFD	Computational fluid dynamic
CI	Compression ignition
CN	Cetane number
CO	Carbon monoxide
CNG	Compressed natural gas
CR	Compression ratio
CRADA	Cooperative research and development agreement
CRC	Coordinating Research Council
DI	Direct injection
DISI	Direct injection spark ignition
DLC	Diamond-like carbon
DME	Dimethyl-ether

DOE	U.S. Department of Energy
E10	10% ethanol blend with gasoline
E15	15% ethanol blend with gasoline
E30	30% ethanol blend with gasoline
E85	85% ethanol blend with gasoline
E100	100% ethanol
ECN	Engine combustion network
EGR	Exhaust gas recirculation
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
FCA	Fiat Chrysler Automobiles
FE	Fuel economy
FOA	Funding opportunity announcement
FWG	Fuels Working Group
FY	Fiscal year
GCI	Gasoline compression ignition
GC-MS	Gas chromatography- mass spectrometry
GDI	Gasoline direct injection
GHG	Greenhouse gas
GSI	Gasoline spark ignition
HC	Hydrocarbon
HCCI	Homogeneous charge compression ignition
HD	Heavy-duty
HDV	Heavy-duty vehicle
HOV	Heat of vaporization
HFRR	High frequency reciprocating rig

IL	Ionic liquid
IL-NP	Ionic liquid nanoparticle
ILSAC	International Lubricants Standardization and Approval Committee
IP	Intellectual property
IQT	Ignition quality tester
ITHR	Intermediate temperature heat release
LD	Light-duty
LDV	Light-duty vehicle
LGGF	Low Greenhouse Gas Fuels team
LTHR	Low-temperature heat release
LLNL	Lawrence Livermore National Laboratory
LSPI	Low-speed pre-ignition
LTC	Low-temperature combustion
MIT	Massachusetts Institute of Technology
MON	Motor octane number
MOVE	Methane Opportunities for Vehicular Enhancement
MPG	Miles per gallon
MT	Market transformation
MTM	Mini traction machine
MW	Molecular weight
NG	Natural gas
NO_x	Oxides of nitrogen
NP	Nanoparticle
NREL	National Renewable Energy Laboratory
OBD	On-board diagnostics
OEM	Original equipment manufacturer

OI	Octane index
ORNL	Oak Ridge National Laboratory
PAO	Polyalphaolefin
PI	Principal Investigator
PM	Particulate matter
PMI	Particulate matter index
PNNL	Pacific Northwest National Laboratory
R&D	Research and development
RCCI	Reactivity controlled compression ignition
RCM	Rapid compression machine
RON	Research octane number
SCI	Stoichiometric compression ignition
SI	Spark ignition
SNL	Sandia National Laboratories
TGA	Thermal gravimetric analysis
TWC	Three-way catalyst
USCAR	United States Council for Automotive Research
U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Ene gy sustainability
VIE	Variable interest entity
VM	Viscosity modifie
VMT	Vehicle miles traveled
VTO	Vehicle Technologies Office
WOT	Wide open throttle
ZDDP	Zinc dialkyldithiophosphate