5. Fuels and Lubricants Technologies

As transportation accounts for two-thirds of the nearly $1 billion the U.S. spends daily on foreign oil, it is vital to increase our use of alternative fuels. Increasing the fuels available to drivers reduces price volatility, supports domestic industries, and increases environmental sustainability. The U.S. Department of Energy (DOE) Vehicle Technologies Office (VTO) supports research to improve how vehicles use these many of these fuels in the future, as well as activities to increase their availability today.

Reaching VTO's goals will help the country meet the Renewable Fuel Standard's goals for use of biofuels in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007. These goals require the use of as much as 36 billion gallons of renewable fuels annually by 2022.

To reach these goals, VTO supports activities to:

- Research fuels' effects on combustion: Improves understanding of how fuels from new sources can affect advanced combustion systems.
- Research lubricants: Works to develop lubricants that can improve the fuel economy of vehicles in the current fleet.
- Research natural gas: Works to support the development of natural gas engines and renewable natural gas projects.
- Research biofuels and their effects on combustion: Works to determine the impact of biofuels' properties on engines' efficiency, performance, and emissions. Activities include examining ways to increase alternative fuel vehicles' fuel economy, investigating the potential effects of upcoming blends, and improving the quality of current and future biofuel blends, especially biodiesel and E85.

The Fuel and Lubricant Technologies subprogram supports research and development (R&D) to provide vehicle users with cost- competitive options that enable high fuel economy (FE) with low emissions, and contribute to petroleum displacement. This is accomplished through exploitation of fuel properties to enable advanced combustion, development of efficiency-improving lubricants compatible with new and existing engines and vehicles, and fit-for-service evaluations of low-carbon alternatives to petroleum-based fuels. Future transportation fuels will be produced from refinery feedstocks derived increasingly from non-conventional sources including heavy crude, oil sands, shale oil, coal, and renewable resources such as biomass, vegetable oils, and waste animal fats. The impact of changes in refinery feedstocks and processes on finished fuels is an area of interest in terms of impacts on engines, emissions regulations, and end uses. Additionally, new lubricants will require increasingly sophisticated additive packages and higher-quality base fluids that can deliver higher efficiency with better engine protection.

Subprogram activities are intended to: (1) enable future advanced combustion regime engines and emission control systems to be more efficient while meeting future emission standards; (2) develop efficiency-improving lubricants including products compatible with legacy vehicles (i.e., enabling lubricant retrofits); and, (3) reduce reliance on petroleum-based fuels through direct fuel substitution by non-petroleum-based fuels. These activities are coordinated with and supportive of the U.S. Environmental Protection Agency's fuels- and emissions-related activities, as mentioned in their strategic plan.

The major subprogram goals for Fuel and Lubricant Technologies are:

- By 2015, expand operational range of low-temperature combustion to 75% of light-duty Federal Test Procedure (FTP).

- By 2015, demonstrate-cost effective lubricant with 2% FE improvement.

The Energy Independence and Security Act of 2007 (EISA, P.L. 110-140) mandates the use of enormous amounts of renewable fuels (36 billion gallons annually by 2022). Current ethanol markets are not able to absorb the volumes mandated; use of intermediate blends may be required. In addition, future feedstocks for fuel production are expected to come from alternative fossil sources. Understanding the impact of these fuels and fuel blends on current and advanced combustion engines is critical to increasing their use. Technical issues that need to be addressed include: lack of data and tools for predicting fuel and lubricant property effects on engine operation; fuel and lubricant effects on emissions and emission control systems. This subprogram is developing data and tools, in collaboration with many partners in industry, academia and government impacting new and old vehicles, as well as small non-road engines.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2015 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

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

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

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

Question 3. Were important issues and challenges identified?

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

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

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

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

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

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

Question 10. Has the program area engaged appropriate partners?

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

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

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

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

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

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

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

Subprogram Overview Comments: Kevin Stork (U.S. Department of Energy) – ft000

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

Reviewer 1:
The reviewer said yes, overall strategies in the areas of fuels, engines, and lubricants were clearly explained with focus on reducing dependence on petroleum, meeting increased fuel economy standards, and further reducing exhaust emissions to meet future regulations.

Reviewer 2:
The reviewer said that the overall strategy in the fuels and lubricant area of predictive modeling development, development of science mechanistic based models, lubricant technology development, engineered surface technology development, and validation of modeling and technologies was adequately discussed.

Reviewer 3:
The reviewer said yes, the overall strategy was developed and explained very well. The history of compression ratio and fuel octane was covered well.

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

Reviewer 1:
The reviewer said that the strategy spans the spectrum from near-term to longer-term R&D. The nearer-term includes lubricant improvements that could be taken advantage of by current vehicles (i.e., small improvements x large number of vehicles = large benefits). The longer term includes R&D on advanced low-carbon fuels and engines to significantly improve fuel economy (and thus lower petroleum dependence) and further reduce engine-out emissions.

Reviewer 2:
The reviewer said that future direction included fiscal year (FY) 2020 long term goals to demonstrate a lubricant system with 4% fuel economy improvement relative to 2013 fluids. The reviewer noted that near- and mid-term future activities were also identified through the development of retrofittable low-friction lubes for drop-in replacement in existing vehicle engines. Continue fit for service evaluations of alternative fuels with emphasis on drop-in biofuels.

Reviewer 3:
The reviewer said that existing projects and their time horizon was not covered well, and so the reviewer could not get a good idea about the balance.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer said yes, and detailed that especially the challenges associated with developing advanced combustion engines that could be operated full-time using lower carbon, mass market fuels.

Reviewer 2:
The reviewer said yes. Issues and challenges were identified through the discussion of the need to raise octane in future fuels to enable a maximum compression ratio. Three automotive challenges were identified of emissions reduction, fuel economy increases and meeting the renewable fuels standard.

Reviewer 3:
The reviewer said that issues were identified in a big picture way. However, the reviewer noted that what issues and challenges projects currently underway were addressing was not adequately covered.

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

Reviewer 1:
The reviewer said yes, clear programs and plans are in place to attempt to overcome the challenges.

Reviewer 2:
The reviewer said yes, in a big picture (i.e., OPTIMA) way.

Reviewer 3:
The reviewer said that there was a good discussion about the near-term approach to increase fuel economy through the use of fuels that includes reduced engine displacement, reduced engine speed, and the requirement to improve engine power density. The reviewer noted that because power density is limited by octane rating it will be important to work on increasing octane rating.

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

Reviewer 1:
The reviewer detailed that several recent accomplishments were mentioned, including 2% fuel economy improvement from development of advanced additives in lubricant oils, and expansion of the potential engine operating range in reactivity controlled compression ignition (RCCI) advanced combustion.

Reviewer 2:
The reviewer said yes, and detailed that accomplishments demonstrated 2% fuel economy improvement with advanced additives. In addition, the RCCI operating range of 75% of city and highway light-duty federal drive cycles was demonstrated.

Reviewer 3:
The reviewer asserted that most time was devoted to setting up and developing the big picture, which was done well. However, very little time was devoted to clearly benchmark progress against the previous year. When the reviewer went to last year's overview presentation to prepare, the reviewer was surprised to find that there was very little difference between the 2014 and 2015 presentations. The reviewer understands the big picture does not change in one year, and the reviewer is not contesting that part. The reviewer is noting that hardly any time was spent in both 2014 and 2015 to cover progress of current projects against issues and challenges.

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

Reviewer 1:
The reviewer said yes, projects are focused on reducing dependence on petroleum, meeting increased fuel economy standards, and further reducing exhaust emissions to meet future regulations, which are key goals of the Vehicle Technologies Office (VTO).

Reviewer 2:
The reviewer said that the projects in this technology area adequately address both fuels and lubricants and how they affect emissions and fuel economy.

Reviewer 3:
The reviewer could not conclude from this overview presentation. The reviewer would have to go to each individual principal investigator’s (PI) presentation to know that.

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

Reviewer 1:
The reviewer said yes, for the limited budget the program is well focused and effective. With additional funds more progress would be possible, which would help address DOE's goals faster.

Reviewer 2:
The reviewer said that yes, the program does appear to be focused, well managed, and effectively address VTO's needs.

Reviewer 3:
The reviewer questioned whether the program seems to be in transition. The reviewer elaborated that the program seems to be in a mode of anticipation, like something big is going to change. The reviewer gathers it is the idea of co-optimizing engines and fuels. The reviewer pointed out that most time was spent selling that idea (i.e., OPTIMA).

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 said that projects led by the national laboratories looking at fuel effects on advanced combustion engines continues to be a very positive part of the program.

Reviewer 2:
The reviewer said that key strengths are focusing on both the engine and the fluid components (fuels and lubricants), and focusing on a spectrum of projects from near-term to long term. The reviewer said that a possible weakness is that ultimate success depends on development of cost-effective technologies that can be implemented in the marketplace and accepted by the majority of consumers. Also, recent experience suggests that some alternative fuel candidates have other potential, higher value uses (i.e., cosmetics and specialty chemicals) and will likely not ultimately be used in fuels.

Reviewer 3:
The reviewer said that the projects in this area were not listed, overviewed, or described in any way in this presentation, and so the reviewer could not get an idea of their strengths and weaknesses.

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

Reviewer 1:
The reviewer said yes, especially the focus on developing advanced combustion engines and the fuels that would enable them.

Reviewer 2:
The reviewer said yes, the work performed at the national laboratories continues to be very innovative and a major part of the program.

Reviewer 3:
The reviewer cited comments made for question eight.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer said that there seems to be good engagement with industry and cited as an example the U.S. DRIVE initiatives.

Reviewer 2:
The reviewer said yes, the program has a good selection of partners including the national laboratories and some automotive and additive companies. The reviewer said that some of the laboratories are involved with the Coordinating Research Council (CRC), which helps bring good industry input into the projects.

Reviewer 3:
The reviewer said that none of the slides gave any idea of the partners involved, and the oral presentation did not give any idea either.

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

Reviewer 1:
The reviewer said yes, appears to be effective collaboration with industry, particularly the original equipment manufacturers (OEMs), although less so with the energy companies.

Reviewer 2:
The reviewer said that there seems to be good collaboration with all of the partners.

Reviewer 3:
The reviewer referenced comments made in question 10.

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

Reviewer 1:
The reviewer did not identify any gaps.

Reviewer 2:
The reviewer said no, there do not appear to be any gaps in the portfolio.

Reviewer 3:
The reviewer was not able to get an idea of the portfolio of projects from the presentation.

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

Reviewer 1:
The reviewer said no topics are not being adequately addressed.

Reviewer 2:
The reviewer said that it would be good to begin more work in the area of co-development of engines and fuels to help increase fuel economy.

Reviewer 3:
The reviewer could not get an idea of topics from the presentation for fuels. The reviewer said Slide 16 gave a broad topic area for lubricants, but could not get an idea if these areas are being covered well.

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

Reviewer 1:
The reviewer said there are no other areas that this program should consider funding.

Reviewer 2:
The reviewer said that the big idea discussed of co-optimizing fuels and engines to reduce per-vehicle consumption 30% versus 2030 base case should be considered for funding. The reviewer noted that it was not clear in the presentation if it was funded or not.

Reviewer 3:
The reviewer said fuels for spark-ignited, gasoline, down-sized, boosted, dilute combustion, high-efficiency engine pathways should be included in the portfolio if they are not already included. The reviewer indicated that there are research areas like the effect of fuel sensitivity (research octane number and motor octane number (RON-MON)), heat of vaporization (HOV), and particulate matter index (PMI) in which industry will be very interested.

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

Reviewer 1:
The reviewer had no recommendations.

Reviewer 2:
The reviewer said that the new reality discussed that fuel octane rating now influences fuel economy should definitely be factored into the program.

Reviewer 3:
The reviewer noted that the U.S. DRIVE Advanced Combustion and Emissions Control (ACEC) Tech Team has recently completed their roadmap for future fuels. The reviewer noted that there is enough research content even in the near term gasoline fuels, like those mentioned in the response to question 14.

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

Reviewer 1:
The reviewer had no suggestions, and clarified that for the funding available, the program seems to be very effective.

Reviewer 2:
The reviewer had no suggestions.

Reviewer 3:
The reviewer said that the effect of biofuels on blended fuel properties and the response of downsized, boosted gasoline engines, and dilute gasoline combustion should be added to the portfolio if it is not already in there.

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.

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Advanced Combustion and Fuels	Zigler, Brad (NREL)	5-11	3.25	3.17	3.25	3.17	3.20
Performance of Biofuels and Biofuel Blends	McCormick, Bob (NREL)	5-16	3.67	3.50	3.67	3.33	3.54
Fuel Effects on Mixing-Controlled Combustion Strategies for High-Efficiency Clean-Combustion Engines	Mueller, Chuck (SNL)	5-19	3.50	3.70	3.60	3.20	3.58
Advanced Lean-Burn DI Spark Ignition Fuels Research	Sjoberg, Magnus (SNL)	5-23	3.40	3.60	3.40	3.40	3.50
Fuel Effects on Emissions Control Technologies	Toops, Todd (ORNL)	5-27	3.38	3.25	3.50	3.13	3.30
Gasoline-Like Fuel Effects on Advanced Combustion Regimes	Szybist, James (ORNL)	5-31	3.50	3.25	3.50	3.25	3.34
Engine Friction Reduction Technologies	Fenske, George (ANL)	5-35	3.38	3.50	3.75	3.50	3.50

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Polyalkylene Glycol (PAG) Based Lubricant for Light- and Medium-Duty Axles	Gangopadhyay, Arup (Ford)	5-38	3.67	3.50	3.50	3.33	3.52
A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement	Wang, Q. Jane (Northwestern University)	5-41	3.63	3.25	3.63	3.25	3.39
Improve Fuel Economy through Formulation Design and Modeling	Wu, Gefei (Ashland)	5-44	3.38	2.88	3.25	3.25	3.09
Developing Kinetic Mechanisms for New Fuels and Biofuels	Pitz, Bill (LLNL)	5-47	3.38	3.63	3.50	3.38	3.52
Unconventional and Alternate Fuels Research	Bays, Tim (PNNL)	5-50	3.17	3.17	3.00	3.00	3.13
Additive and Basefluid Development	Ajayi, Oyelayo (ANL)	5-53	3.38	3.38	3.63	3.38	3.41
Overall Average			**3.44**	**3.37**	**3.48**	**3.27**	**3.39**

Advanced Combustion and Fuels: Brad Zigler (National Renewable Energy Laboratory) - ft002

Presenter

Brad Zigler, National Renewable Energy Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed an excellent project approach and strategy of developing techniques, tools, and data to quantify critical fuel effects to help development of advanced combustion engines that use alternative fuels.

Reviewer 2:

The reviewed remarked that the approach of extending the capabilities of the ignition quality tester (IQT) instrument to obtain more fundamental information about the properties and combustion characteristics of fuels is very good.

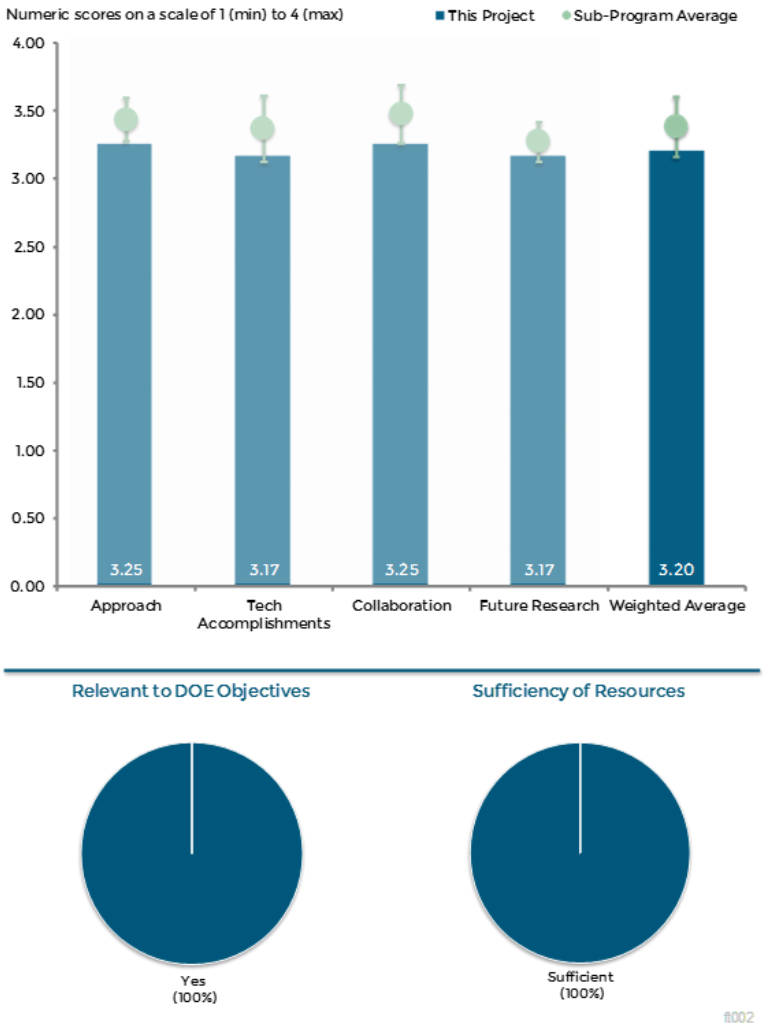

Figure 5-1 Advanced Combustion and Fuels: Brad Zigler (National Renewable Energy Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer noted that the project continues work on and with the IQT and introduces a new single cylinder engine for fuel efficiency studies. These are both useful areas of research.

The National Renewable Energy Laboratory (NREL) has spent many years developing and modifying the IQT and has made great progress in broadening its application and providing more accurate, consistent data.

Reviewer 4:

The reviewer found that the combination of facilities and collaborations makes this a strong approach to improving understanding of the ignition and combustion behavior of fuels. The IQT being used as a primary tool is limited in some respects, due to its pressure limits and limited range of operability. According to the reviewer, this weakness is being addressed through collaboration with other facilities that can consider a broader range of temperature and pressure conditions. Given the vagaries of cetane number (CN) and derived cetane number (DCN) ratings, relying on a combination of cetane rating and ignition delay measurements, and reporting and comparing on the basis of ignition delay, is a good approach too. The reviewer applauded that the project has responded very well to reviewer feedback to date.

Reviewer 5:
The reviewer observed that the approach considers modelling/ tools development, empirical data, collaboration and info sharing.

Reviewer 6:
The reviewer observed that the IQT device has some weaknesses in the quality of the ignition delay data. Nevertheless, it is an accepted approach by the community. The reviewer commented that the use of a modern turbocharged engine to supplement the fuels work is encouraged and should be continued.

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

Reviewer 1:
The reviewer observed that despite the funding cutback in 2015, the project appears to be continuing to make very good progress and contribute to the fuels and combustion community. The growing understanding of the ignition behavior of ethanol-based fuels, and fuels for advanced strategies such as gasoline compression ignition (GCI) are strong contributions. The expansion of collaboration with Argonne National Laboratory (ANL) is a good development, because there is natural overlap between these ignition studies and the GCI engine studies at ANL.

The reviewer applauded that an update of the CN Compendium is a significant outcome and valuable service/deliverable from this project. The results explaining ignition behavior of model fuel mixtures (isooctane blends, ethanol blends) is valuable fundamental ignition research.

Reviewer 2:
The reviewer commented that technical accomplishments in the areas of engine studies for high octane fuels, kinetic studies of octane references, and kinetic studies of ethanol blends has been very good.

Reviewer 3:
The reviewer remarked the IQT data on the different ethanol blends is very interesting and will be useful going forward.

Reviewer 4:
The reviewer commented that DCN is a key industry standard testing coming from NREL for little known fuels/compounds. Regarding octane, the reviewer commented that kinetic studies of ignition delay via IQT to better quantify research or motor octane numbers (RON/MON) are very important because data gaps exist to the true effects of oxygenates with physics of fuel spray, thermodynamics of fuel evaporation, along with delay associated with octane rating. The reviewer observed excellent insights into reduced ignition delay at higher temps versus primary reference fuel for ethanol fuel blends, HOV effect versus octane as well as negative temperature coefficient behavior at E20+.

Regarding single cylinder gasoline direct injection (GDI), the reviewer commented that upstream injection in combination with direct injection to eliminate HOV impact could truly assess fuel chemical effects. The reviewer applauded excellent isolation of octane from injection strategy/HOV effects.

Reviewer 5:
The reviewer commented that NREL has provided a valuable update and expansion of the CN Compendium.

Extending the IQT to gasoline range fuels allows the ability to study a continuum between gasoline and diesel fuels.

The reviewer noted that the graphs presented indicate that the IQT provides interesting and consistent measurements, but more comparisons with and application to kinetic modeling results need to be seen. The

reviewer thought that it is an interesting observation that IQT needs a complex computational fluid dynamics (CFD) model for short ignition delays but transitions to a 0-D premixed model for long ignition delays.

Reviewer 6:

The reviewer observed good progress on measuring the ignition delays of various fuel formulations, including blends with ethanol. Interesting trends obtained that depend on fuel formulation and not necessarily solely by octane number. The reviewer commented that value of this data will be greatly enhanced when a better understanding of the reasons for the fuel behaviors and their relevance to engine combustion is elucidated.

The use of the single cylinder engine to separate out the effects of octane and heat of vaporization looks interesting and promising.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that this project has strong connections to multiple other institutions, including the CRC. This project has very good visibility due to the extensive collaboration and coordination with industry, government and academic partners. The reviewer remarked that the partnerships also enable this project to have a long lasting a wide impact that can benefit many other DOE projects by filling data voids and promoting improvement of kinetic mechanisms and thereby predictive tools.

Reviewer 2:

The reviewer observed collaboration mostly with the other national laboratories and universities. Some collaboration with industry through participation and contribution to the CRC Fuels for Advanced Combustion Engines (FACE) Working Group.

Reviewer 3:

The reviewer complimented that collaboration in this project continue to be excellent. Coordination with Lawrence Livermore National Laboratory (LLNL), ANL and universities such as Colorado School of Mines, University of California-Berkeley and University of Michigan all help to make this project a success. The reviewer noted that interactions with the CRC bring input from industry, which is valuable to the project.

Reviewer 4:

The reviewer noted key collaboration with academia and pointed out as collaborators the Colorado School of Mines and the University of Michigan.

Reviewer 5:

The reviewer commented that sharing and complementing work with universities broadens usefulness of results, including the excellent collaboration with Colorado School of Mines.

The reviewer pointed out that there seems to be a lack of collaboration with industry except through the Advanced Engine Combustion (AEC) Memorandum of Understanding (MOU). Sharing results with LLNL is very good, but there needs to be more information about how the results are being used and what has improved as a result.

Reviewer 6:

The reviewer suggested that more direct input should be received from engine original equipment manufacturers (OEMs) to make sure that the big picture is correct. For example, the reviewer asked why is the GCI low-temperature combustion (LTC) concept quoted as the choice for LTC fuels work, and inquired if that is the voice of the auto 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 plans seem to build on progress to date and moving towards accomplishing objectives.

Reviewer 2:
The reviewer said that the presentation identified the remaining challenges and barriers, and the future research proposed to continue to work on these barriers seems reasonable.

Reviewer 3:
The reviewer recommended that key research needs to continue, especially in the isolation/better determination of octane effects versus other effects such as HOV and sensitivity. The reviewer suggested that the project needs to address impact of GDI strategy (wall guided versus spray guided) on results (e.g., spray guided effectiveness on low-speed pre-ignition).

Reviewer 4:
The reviewer commented that the plans to separate the effects RON, sensitivity, and HOV effects will be extremely useful going forward. The reviewer suggested that biofuel blends should be included in this matrix of fuels. Also, while it is not the focus, routine measurements of engine emissions, particularly particulate emissions, engine efficiency, etc., should be measured and reported.

Reviewer 5:
The reviewer asked what the real benefit is of evaluating fuels in micro-liter quantities. NREL has been talking about alternate rating methods for RON and MON for years but to this reviewer's knowledge has not proposed anything yet.

The reviewer would like to know how NREL proposes to complement the AVL/Ford and Oak Ridge National Laboratory (ORNL) studies, and what advanced biofuels are being proposed for evaluation.

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

Reviewer 1:
The reviewer found that this project is highly relevant to both improving fuel economy to meet higher mile per gallon targets, and reducing petroleum usage through implementation of alternative fuels.

Reviewer 2:
The reviewer said that the development of alternative experimental techniques such as the IQT to obtain fundamental kinetic information is very important to development of improved predictive tools needed for development of advanced combustion engines and fuels which support DOE goals.

Reviewer 3:
The reviewer commented that the project provides further insight into fuel properties and chemistry.

Reviewer 4:
The reviewer commented that this project is very relevant to the DOE objectives of petroleum displacement. The objective of the project, to address the technical barriers of inadequate data and tools for fuel and lubricant effects on advanced combustion engines, will in the long run help introduce advanced combustion engines into the market that will have higher fuel economy and help displace petroleum.

Reviewer 5:
The reviewer remarked that the project supports DOE mandate to reduce fossil fuel component from transport fuel.

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

Reviewer 1:
The reviewer commented that resources appear sufficient, but barely so. The funding drop from 2014 to 2015 is unfortunate. The reviewer recommended that it would be wise to keep this program funded at its original request.

Reviewer 2:
The reviewer said that funds appear sufficient for research proposed.

Reviewer 3:
The reviewer remarked resources appear to be adequate for this project.

Reviewer 4:
The reviewer commented need funding for software/hardware to enable engine control independent of any original equipment manufacturer (OEM) support.

Performance of Biofuels and Biofuel Blends: Bob McCormick (National Renewable Energy Laboratory) - ft003

Presenter

Matt Ratcliff, National Renewable Energy Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that the approach covers much ground, fuels from a wide variety of feedstocks, from a variety of producers and for the range of applications (spark ignition [SI] and compression ignition [CI] engines). Considering conventional biofuels (first generation) and advanced biofuels from cellulose. The reviewer noted that through partnerships and outreach, covering a broad range of practical field work and laboratory studies.

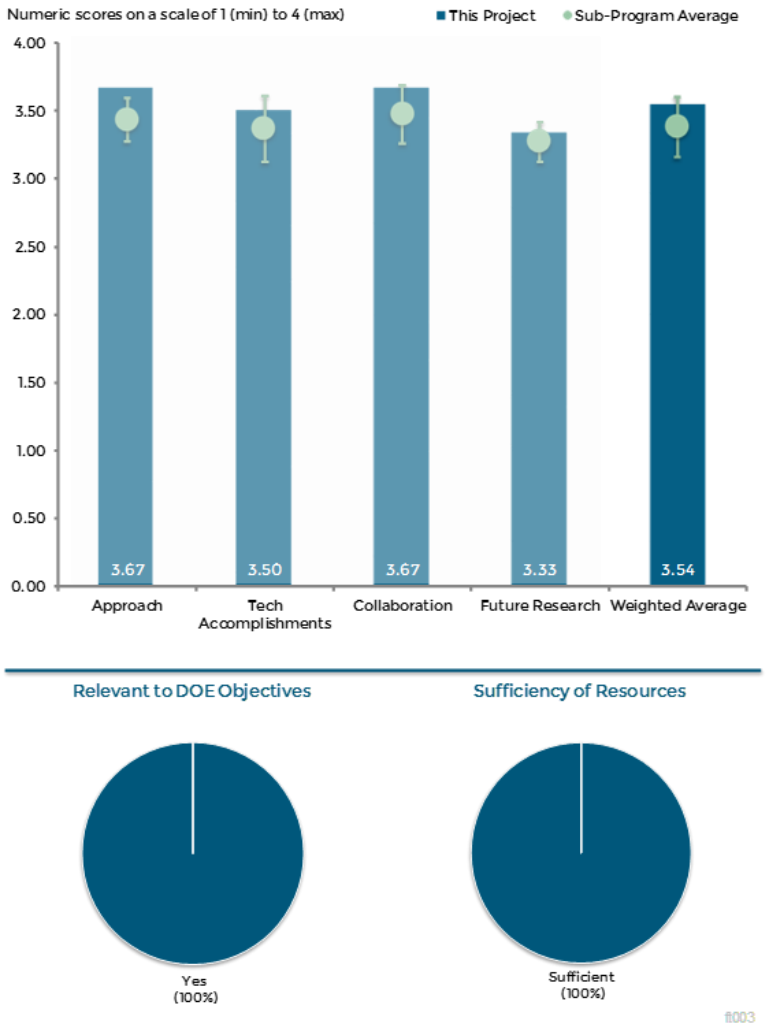

Figure 5-2 Performance of Biofuels and Biofuel Blends: Bob McCormick (National Renewable Energy Laboratory) – Fuel and Lubricant Technologies

Reviewer 2:

The reviewer noted as conventional approaches commercial samples – provides realistic look at practical issues. The research issues raised at American Society for Testing and Materials (ASTM) and Coordinating Research Council (CRC) contribute real world experiences. As advanced approaches, the reviewer noted employing industry standard tests, metrics for real world applicability.

Reviewer 3:

The reviewer remarked that conventional biodiesel work is being conducted in a very practical manner, as appropriate. The reviewer observed that lack of real samples for new fuels is hindering the research, but some progress is being made using model compounds.

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 explored the impact of alkali contaminants on emissions control systems. The project is comprehensively exploring the oxygenates that one could produce from cellulose. The

reviewer remarked that this is a good concept, that the oxygen in the biomass-derived molecules should be used versus trying to drive all the oxygen out of pyrolysis oils, for instance. The reviewer enthused very interesting and valuable new results on 2,5-dimethylfuran (DMF) behavior in fuels.

Reviewer 2:

The reviewer commented it is a useful suggestion to not remove all oxygen from biofuels, however only studying model compounds will not uncover all the potential problems of this approach. The reviewer recommended that results should be presented with more certainty regarding new fuels, either our tests indicate that A is better than B and C is unsuitable, or, we recommend the following screening tests for new fuel compounds.

Reviewer 3:

Regarding the National Biodiesel Board (NBB) CRADA, the reviewer observed a very extensive dossier of information. About the oxygen content cost benefit, the reviewer made an interesting observation that it is not desirable commercially to completely hydrotreat out oxygen. Regarding the PMI versus oxygenate, the reviewer commented that this is very critical info for current auto/engine industry. The reviewer wondered if the statement "suggests no impact of fuel oxygen on particulate matter" contradicts prior research. The reviewer noted that the relationship of T90 to knock performance is interesting, but asked if it does not volatilize or burn completely, why does knock performance suffer. According to the reviewer, the answer to question was not satisfactory.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer found that for the biofuels aspect, great collaboration with general automotive, and the heavy-duty truck OEM industry. The cellulosic aspect displayed good collaboration.

Reviewer 2:

The reviewer observed good outreach over the years to the biofuels industry, and the team has made critically important contributions to shaping and improving the biodiesel industry. The project is helping the emissions control industry understand the impact of biofuels on deactivation and poisoning. The reviewer noted good university collaboration, and suggested that collaboration could expand to include other schools and research groups, via student visitors and interns.

Reviewer 3:

The reviewer commented very good long-term collaboration with NBB to keep the work focused on practical issues. According to the reviewer, a lack of collaboration with biofuel producers except an association level hinders research. The reviewer noted good collaborations with various associations, companies, and universities.

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

Reviewer 1:

The reviewer commented work is planned to expand, continue and complete the ongoing efforts.

Reviewer 2:

The reviewer found that research is very applicable to current industry fuel/emission related issues.

Reviewer 3:
The reviewer suggested that if the project team is not removing all the oxygen from pyrolysis oil, there is a need to study problems with stability, gum, corrosion, cold flow, etc. Pure surrogate compounds will not duplicate all the effects.

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

Reviewer 1:
The reviewer remarked that the project addresses achieving displacement of petroleum using biofuels.

Reviewer 2:
The reviewer found that expansion of knowledge about fuel chemistry, properties, and performance for new biofuels supports DOE goal of petroleum displacement.

Reviewer 3:
The reviewer noted that the presentation stated that the objective is 5% petroleum displacement per DOE's mandate.

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

Reviewer 1:
The reviewer commented that it appears that the funding level is sufficient.

Reviewer 2:
The reviewer commented that the budget seems a little small to support both lab and engine work, so some more limited focus may be required.

Fuel Effects on Mixing-Controlled Combustion Strategies for High-Efficiency Clean-Combustion Engines: Chuck Mueller (Sandia National Laboratories) - ft004

Presenter

Chuck Mueller, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that a largely experimental approach is appropriate for studying fuels and combustion.

Reviewer 2:

The reviewer remarked that this optical engine facility and related facilities being used under the project are excellent, and abundant significant outcomes have been produced through these facilities. The project team provides uniquely authoritative results that have informed and improved many other researchers work over the years. The studies of lean lifted-flame combustion (LLFC) are well suited to this facility and the work has produced some significant outcomes, as are the soot measurements studies.

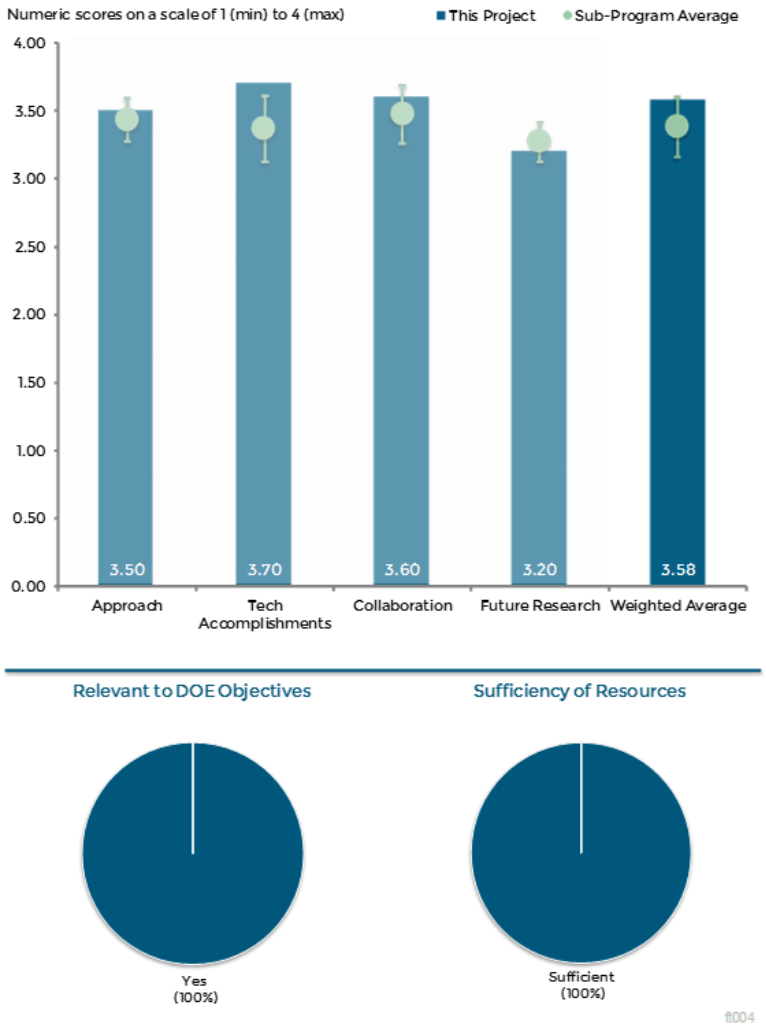

Figure 5-3 Fuel Effects on Mixing-Controlled Combustion Strategies for High-Efficiency Clean-Combustion Engines: Chuck Mueller (Sandia National Laboratories) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer found that the approach to work on eliminating the barriers of inadequate and predictive tools for understanding fuel-property effects on combustion, engine efficiency and emissions is excellent. In addition, utilizing the unique and comprehensive diagnostic capabilities at the combustion research facility along with the collaboration with key stakeholders is an approach that has proven successful.

Reviewer 4:

The reviewer observed an excellent combination of industries (OEMs, fuels, engine manufacturers) with existing research.

Reviewer 5:

The reviewer applauded that generally the approach and focus areas are excellent. This program focuses on a number of key aspects that will advance knowledge and development of cleaner, high efficiency engines. The

reviewer noted that this includes the collaborative work with CRC on development of diesel surrogate fuels; the development of an optical diagnostic to determine total in-cylinder soot mass; and the scoping work on a novel technique for mixing enhancement to improve the performance of the LLFC strategy (ducted fuel injection).

The one aspect of the work that did not make sense to the reviewer (and this reviewer therefore lowered the rating) is the testing of diesel fuels containing either 100% methyl decanoate or 50% tripropylene glycol methyl ether (TPGME) in the LLCF work. According to this reviewer, the probability is vanishingly low that either of these compounds would ever be commercially available in the quantities required for the transportation industry. Although theoretically the argument could be made that these compounds are just being tested as model compounds, work in this area has never progressed beyond those two compounds and there is no indication that that is the intent.

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

Reviewer 1:
The reviewer observed that the project did an excellent job coordinating with the CRC project for diesel surrogate fuels. Soot measuring tool looks like it will be very useful. The reviewer observed interesting preliminary results for ducted fuel injection; need more results and in-depth data.

Reviewer 2:
The reviewer commented that there has been good technical progress this year in this project, including testing of improved diesel surrogate fuels and evaluated the use of oxygenated fuels to achieve LLFC. The reviewer observed that the milestones to fabricate hardware to evaluate ducted fuel injection concept and a paper summarizing results of testing methyl decanoate as a means to achieve LLFC have been met.

Reviewer 3:
The reviewer noted that the project has generated many papers and presentations. Very productive effort. The reviewer noted that the surrogate fuels work under this project can benefit the entire diesel fuels and engines community, so the potential for high impact is great. The LLFC work shows promise for defining how fuels can enable LLFC combustion. This is similar to prior work in this same facility (deemed Dilute Clean Diesel Combustion previously). The reviewer noted that fuel screening for LLFC can provide a significant step toward utilizing LLFC practically.

The reviewer remarked that the ducted injection studies are interesting, although they may be of limited practical value. It is unclear how this can be achieved in practice without greatly risking engine reliability.

Reviewer 4:
The reviewer described the ducted in-cylinder fuel injection concept as very intriguing, and recognized the potential breakthrough to load expansion of LLFC in conjunction with well managed injection timing. The reviewer also highlighted the possibility of minimizing particulate filters, increasing fuel economy by eliminating the need for regeneration, and adding net heating value (NHV) back in via aromatics. The reviewer observed the direct application to current engines, which could result in possible implementation sooner than homogeneous charge compression ignition (HCCI), RCCI, etc. Specific to the optical soot estimate, this reviewer suggested that a crank angle map can provide accurate feedback for injection strategies. The reviewer inquired as to whether the claim of specific oxygenates promoting zero smoke is applicable to the current crop of fatty acid methyl ester (FAME) fuels. With regard to the ducted fuel injection, the reviewer stated that the proof of concept needs follow-up with potential duct failure modes such as deposits.

Reviewer 5:
The reviewer observed excellent progress in the development of the surrogate diesel fuel formulations, the optical diagnostic tool to estimate total in-cylinder soot mass, and scoping of the novel idea of ducted fuel

injection to improve the feasibility and performance of the LLFC concept. Future results on the engine testing of the diesel surrogates will be very interesting. However, according to the reviewer no effort has been made to move beyond unrealistic oxygenate blends containing 100% methyl decanoate or 50% TPGME for the LLFC concept.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed lots of collaboration with an energy company and automakers through the activities with the CRC, as well as with a heavy-duty OEM through a work-for-others project and with the other national laboratories.

Reviewer 2:
The reviewer commented that the collaboration and coordination continues to be very good. The guidance received on combustion research from the advanced engine combustion working group is valuable to the project especially because is it includes input from OEMs and energy companies as well as national laboratories and universities.

Reviewer 3:
The reviewer remarked CRC project collaboration with industry (OEM, oil companies, component manufacturers).

Reviewer 4:
The reviewer concluded that collaborations are good, and that more university involvement would be beneficial. Only listed university partner is Yale University through a National Science Foundation-DOE project. The reviewer commented that on each of the thrusts of this project, university partners could be engaged and expand the value for training and experience for students.

Reviewer 5:
The reviewer observed an excellent set of partners that is going beyond the combustion MOU. The reviewer asked is there further collaboration for ducted fuel injection. It would be good to know that someone believes it can work in a real engine.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating 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 will extend the surrogate work to engine studies – will help break the barrier to predictive simulation. The experimental plans are sound and should contribute to complete the project objectives.

Reviewer 2:
The reviewer commented that the proposed work on diesel surrogate fuels and the experiments identified to determine if LLFC can be sustained at higher loads with an oxygenated fuel seems to be appropriate.

Reviewer 3:
The reviewer anticipates that the matching of surrogate fuels with actual engine testing will be most revealing. Potential to take the burden off fuel design and transfer to mechanical design as technical solution to LLFC.

Reviewer 4:
The reviewer remarked that the proposed plans for the diesel surrogate fuels, soot model assessment, and continued assessment of the ducted fuel injection concept are excellent and should continue the progress made

in those areas. However, according to the reviewer continued work on oxygenated diesel blends containing 50% TPGME or 100% methyl decanoate does not make any sense as those compounds have almost 0% probability of being manufactured on a commercial scale for the transportation industry. The lack of plans to focus on other oxygenates (such as biodiesel rather than just the one component of 100% methyl decanoate) suggests that the program investigators do not think that more realistic oxygenates will work.

Reviewer 5:
The reviewer commented that the researchers made claims for ducted fuel injection that should be better explained and verified (i.e., tolerance of higher aromatic fuels, use of lower injection pressure, and use lower cost after-treatment). The reviewer further remarked that it will be a good step of progress to move lifted flame to a six-hole nozzle, and it will be very useful to apply a soot tool to a variety of fuels and combustion situations to see how results can be applied.

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

Reviewer 1:
The reviewer remarked that the project is highly relevant to DOE's mission: to improve efficiency and displace petroleum.

Reviewer 2:
The reviewer commented that the project expands knowledge of fuels, fuel mixing, and combustion.

Reviewer 3:
The reviewer found that the focus on various high efficiency, clean combustion engines and fuels is aligned with DOE objectives.

Reviewer 4:
The reviewer remarked that the project is very relevant to the DOE objective of petroleum displacement. Through the development of a science base that will enable cost-effective high-efficiency clean-combustion engines this project will help reduce fuel consumption.

Reviewer 5:
The reviewer commented that the project follows DOE mandate to promote energy security and petroleum displacement in transportation.

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

Reviewer 1:
The reviewer said that the funding is level and sufficient.

Reviewer 2:
The reviewer said the project team seems to be able to sustain progress in all areas undertaken with current resources.

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

Advanced Lean-Burn DI Spark Ignition Fuels Research: Magnus Sjoberg (Sandia National Laboratories) - ft006

Presenter

Magnus Sjoberg, Sandia National Laboratories.

Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer found that the approach of progressing from metal engine to optical engine to modeling is a good way to conduct this research.

Reviewer 2:

The reviewer commented that the approach of combining experiments in optical and metal engines takes advantage of the benefits both platforms.

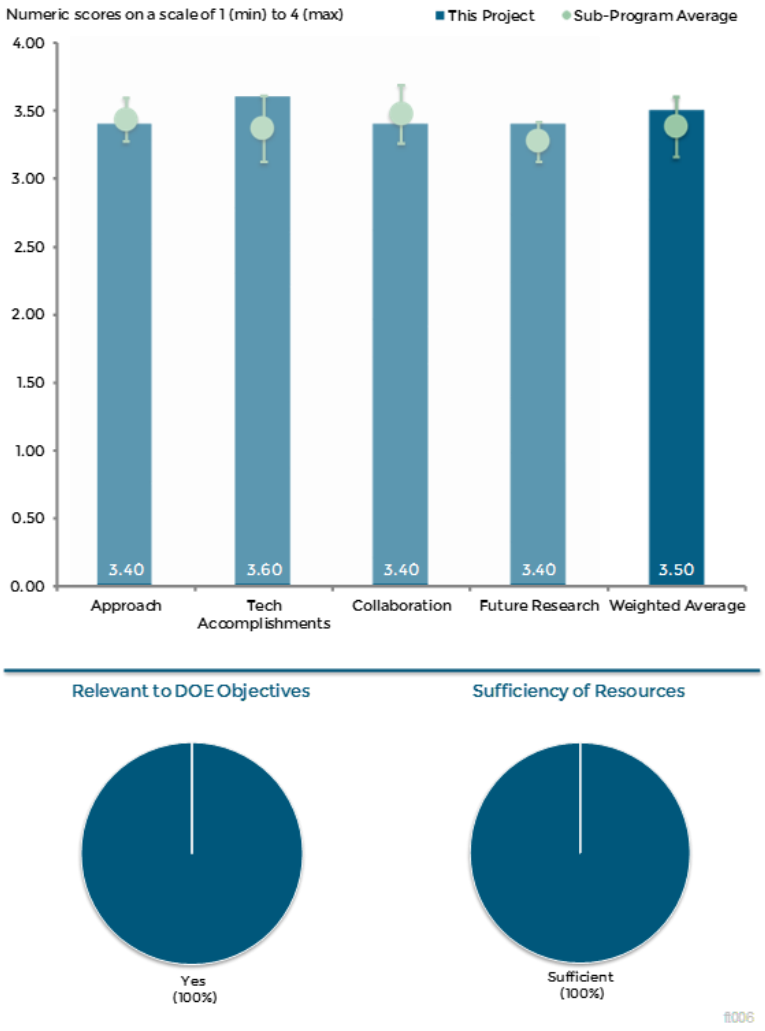

Figure 5-4 Advanced Lean-Burn DI Spark Ignition Fuels Research: Magnus Sjoberg (Sandia National Laboratories) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer commented the approach of combining metal and optical engine experiments and modeling to develop a broad understanding of the impact of fuel properties on direct injection spark ignited (DISI) combustion has been successful. This approach addresses the barriers to high efficiency and low emissions by increasing the knowledge base and developing predictive models.

Reviewer 4:

The reviewer commented very appropriate given that the combustion modes are extensions of current SI engines with current and near-future fuels. Modelling combined with experiments to develop understanding. The reviewer commented applicable to current market engine (Mercedes-Benz) and upcoming OEM products.

Reviewer 5:

The reviewer commented that the project is considering both spray guided stratified combustion and dilute, lean well-mixed combustion to understand how fuels interact with these processes. This experimental facility is able to provide both fundamental insights and very practical knowledge via the optical access and ability to probe how structure of the burning mixture relates to performance and emissions. The reviewer remarked that focusing on ethanol blends for now is fine, and is responsive to national needs, but eventually, this activity should expand to include other practical (isobutanol) and emerging oxygenates. The reviewer commented supporting modeling through collaborations with individuals and national laboratories.

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 technical accomplishments in this project related to DISI with spray guided stratified charge combustion system and with well-mixed lean combustion system have been very good. In addition, diagnostic development to use flame spectroscopy to measure fuel stratification for E30 and gasoline was accomplished. The reviewer found that the project continues to meet the milestones specified.

Reviewer 2:
The reviewer commented very good progress in the two key project areas of spray-guided stratified charge DISI and well-mixed lean or dilute DISI. Accomplishments include: developed a conceptual model of spray-swirl interactions; performed initial mapping of ignition limited with regular spark system and role of autoignition for highly boosted stratified charge operation; particle image velocimetry showed repeatable flow is required for stable combustion; E0-E30 blends appeared compatible with highly efficient boosted stratified operation; for well-mixed lean or dilute DISI, the fuel economy gain is higher for E0 gasoline than for E30 and E85.

Reviewer 3:
The reviewer praised highly productive project that has potential for significant commercial impact. This project is expanding understanding of how to optimize the GDI combustion process and to leverage biofuels to enable higher efficiency. The reviewer observed a very interesting result that for lean combustion some amount of autoignition is needed for good combustion efficiency under ultra-dilute conditions. Obert mentioned in his textbook that optimal fuel economy requires mild knock (in vehicles of the 1960's and 1970's vintage of the time when Obert was writing and updating his text). The reviewer noted that HCCI operational broadening was demonstrated via spark assisted compression ignition in DOE-funded work. The reviewer asked what fraction of fuel needs to autoignite to ensure good combustion efficiency. The reviewer observed that the project demonstrated significant improvement in lean operation with multi-pulse spark approach.

Reviewer 4:
Regarding DISI spray guided, the reviewer noted E30 stratified combustion as an accomplishment. For DISI well mixed lean, the reviewer specified lean stability limits for E30, E85 and gasoline important information as OEMs push for higher oxygenate levels. The reviewer asked how deep into U.S. Environmental Protection Agency procedures (e.g., US06) is possible, lean and/or stoichiometric. Regarding the DISI swirl pattern, the reviewer noted key info that swirl stabilizes combustion indicated mean effective pressure (IMEP) coefficient of variance (COV). About lean boosted E30, the reviewer inquired about the effect of higher octane on end gas autoignition and whether octane from oxygenate functions differently than petroleum-based octane. The reviewer noted that exhaust gas recirculation (EGR) results in lower combustion stability, and asked is that load dependent or uniform across operating points. Regarding advanced ignition, the reviewer asked if there is any information on lean spark strategy versus cold start/deceleration fuel shut off conditions (air cooled combustion chamber).

Reviewer 5:
The reviewer acknowledged that all the results appear to be interesting and valuable, but according to the reviewer it is difficult to tie things together in a coherent picture because so many variables are being studied. The reviewer noted that the purpose of the project is to study fuel effects on combustion, but much of the results appear more engine related with only minor fuel variations. Variables being studied include lean versus stratified versus dilute, with and without enhanced ignition, and use of intake heat.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked excellent collaborations for several aspects of the project.

Reviewer 2:
The reviewer observed several collaborations with OEMs (GM, Toyota, and the U.S. Council for Automotive Research [USCAR] Advanced Combustion and Emissions Control [ACEC]), and two universities.

Reviewer 3:
The reviewer commented that the project has excellent group of collaborators, including 15 industry partners in the AEC MOU, national laboratories, and universities.

Reviewer 4:
The reviewer noted excellent cross-functional collaboration, and specified GM, Tongji University, Sandia National Laboratories, USCAR, LLNL, and University of Michigan.

Reviewer 5:
The reviewer noted that through the AEC MOU, this project is connected to industry. The facility is supported by GM in the form of hardware (this project) and Toyota (non-VTO funds). But only two university connections are listed, through a Fulbright Scholar and a visitor, neither with a U.S. university. The reviewer identified this is the only significant weakness of the project. The reviewer asked if there are ways to connect with U.S. universities more extensively.

The reviewer reiterated that industry is involved (GM through providing hardware and Toyota through direct funding), but asked is there directly a customer for the outcomes from this work. The reviewer would like to know what the pathway is for technology transfer and implementation, apart from publication and presentation. This aspect still is not clear.

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

Reviewer 1:
The reviewer commented that boosted E30 DISI stratified work is key information needed

Reviewer 2:
The reviewer commented that the planned work nicely builds on progress and advances program toward objectives.

Reviewer 3:
The reviewer noted that the project will continue the ongoing work on fuel, ignition hardware and combustion process, and suggested that it may be valuable to include studies of model fuels and gasoline surrogates to enhance understanding of how fuel formulation influences these combustion processes.

Reviewer 4:
The reviewer remarked that the future work identified, especially to continue studying effects of E0-E30 fuels on boosted stratified SI operation and to continue the collaboration on CFD and flame modeling, seems appropriate.

The reviewer commented end-gas autoignition—key for lean dilute combustion but how to simultaneously protect against knock but promote end-gas autoignition.

Reviewer 5:
The reviewer suggested that because this is a fuels project, it might be more useful to settle on a few fixed combustion strategies and then study a wider range of fuels.

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

Reviewer 1:
The reviewer pointed out that this project focuses on both efficiency improvement and biofuel utilization. Thus the project is highly relevant to the DOE objective to displace petroleum.

Reviewer 2:
The reviewer commented that the project promotes the advancement of substitution of petrol with oxygenate.

Reviewer 3:
The reviewer remarked that the concept this project is exploring (advanced lean-burn DI) has the potential to significantly reduce fuel consumption and thus supports the DOE objective of reducing or displacing petroleum.

Reviewer 4:
The reviewer commented that this project is very relevant to DOE's goal of petroleum displacement. The project goals to provide the science base needed for determining fuel characteristics that enable current and emerging advanced combustion engines that are as efficient as possible will ultimately provide for a reduction in fuel consumption.

Reviewer 5:
The reviewer commented that the project is relevant for understanding advanced engine concepts, which could reduce petroleum consumption. The reviewer found that in current form, it is more of an ACE project rather than a fuels project.

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

Reviewer 1:
The reviewer remarked that the funding is level and appears sufficient to support the project. However, according to this reviewer, this project has such potential for transition of insights into products in the field (fuel and engine) that increasing the budget would be wise in subsequent years.

Reviewer 2:
The reviewer commented sufficient resources for fuels progress shown.

Reviewer 3:
The reviewer confirmed that the resources appear to be sufficient to complete this project.

Fuel Effects on Emissions Control Technologies: Todd Toops (Oak Ridge National Laboratory) - ft007

Presenter

Todd Toops, 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 project combines engine testing and validation of models to fully understand fuel and lubricant effects.

Reviewer 2:

The reviewer commented that the project is mainly experimental, with engine and bench experiments combined with materials analysis. This is a good approach for this type of work. The reviewer found that the project supports multiple independent subprojects, which broadens impact.

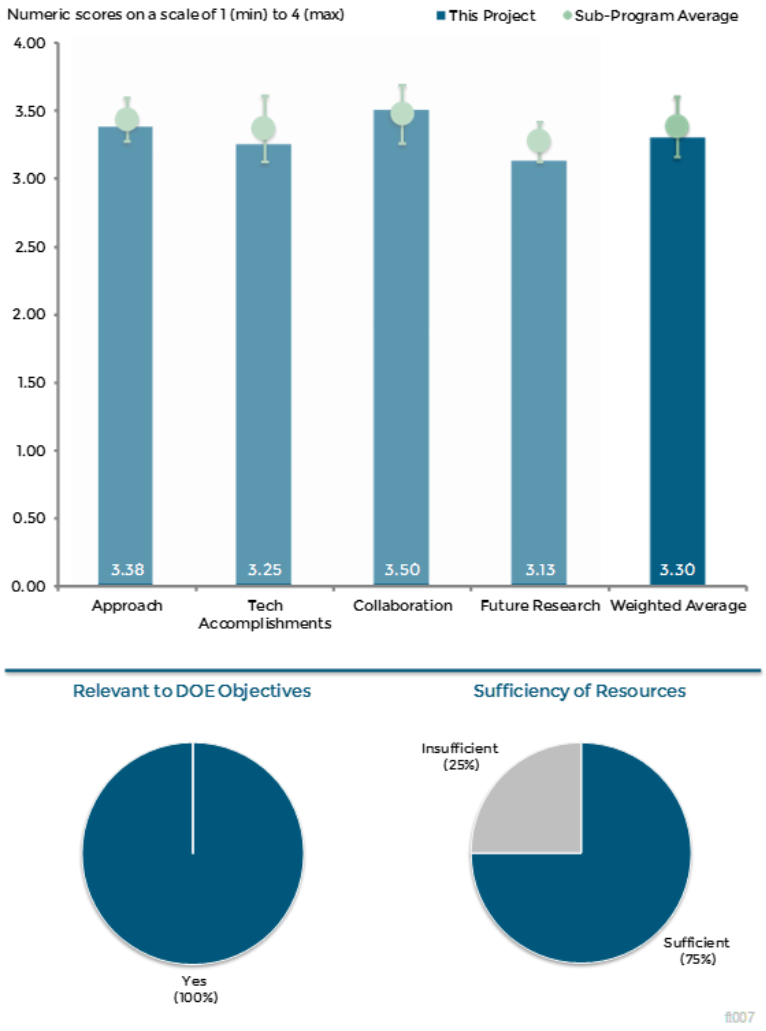

Figure 5-5 Fuel Effects on Emissions Control Technologies: Todd Toops (Oak Ridge National Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer found that the approach of targeted, engine-based and flow reactor studies with in-depth characterization of particulate matter (PM), HCs and emissions control devices to better understand fuel and lubricant effects and interactions has proven to be successful.

Reviewer 4:

The reviewer acknowledged that the authors cover a lot of fundamental work, but questioned why each year a new sub-project is being started. The reviewer inquired if the authors can create two major subprojects: addressing gasoline/alcohol fuels and lubricants, and addressing diesel/biodiesel plus lubricants performance. This will help in setting/addressing technical goals.

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

Reviewer 1:
The reviewer pointed out that technical accomplishments including confirming the potential for lean oxides of nitrogen (NO_x) control with ethanol blends, determining start-stop does not have a major impact on PM formation on E0 or E30, and showing fuel chemistry to have a significant effect on PM chemistry, have addressed the barriers of inadequate data on emissions. The reviewer noted that milestones continue to be met in a timely fashion.

Reviewer 2:
The reviewer observed that significant progress was made in assessing impact of alcohol containing gasoline fuels on NO_x controlling catalysts. No data was reported regarding exhaust and control of HC emissions. The reviewer also noted interesting fundamental data showing oxidative character of GDI PM. The reviewer commented no data reported on HD diesel catalyst performance.

Reviewer 3:
The reviewer pointed out that results referenced for dual selective catalytic reduction (SCR) are dated 2009, and asked if there are more current work available. The reviewer observed a good demonstration of ethanol lean NO_x catalyst, but no discussion of what level of conversion is actually needed or targeted. The reviewer noted interesting results about fuel effects on particulates and changes in activation energy (Ea) but no quantitative information about real effects on regeneration, just the qualitative statement "difficult or requiring more energy." The reviewer would like to know how much.

Reviewer 4:
Regarding lean NO_x control with ethanol, the reviewer noted silver alumina non-platinum group metal load, non-urea NO_x is critical pathway to combine oxygenate plus lean operation; higher HC still requires oxidizing catalyst. About this, the reviewer asked what the relative efficiency of HC addition versus HC savings in lean operation is. Furthermore, the reviewer asked how feasible is ammonia storage at high-load SS operation for lean NO_x mitigation. The reviewer also noted dual fuel membrane separation for reductant. Regarding GDI start-stop PM with biofuels, the reviewer noted that E30 is most reactive at lowest temperature for soot oxidation. The reviewer also inquired as to whether the trend follows for E85, and asked about the difference in fuel addition on soot burn-off cycle of oxygenate versus gasoline.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent collaboration with other laboratories, universities, and industry. Lots of presentations and publications to share results.

Reviewer 2:
The reviewer observed that the project has a very comprehensive list of collaborators and partners including industry, national laboratories and universities.

Reviewer 3:
The reviewer noted as collaborators Shell, GM, Ford, Cummins, Manufacturers of Emission Controls Association (MECA), NBB, NREL, University of Michigan, and Chalmers University. The reviewer also observed industry, OEM, and academia support

Reviewer 4:
The reviewer pointed out a wide spectrum of collaborative organizations contributing to this project, and asked if most contributions are in-kind.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating 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 plans for future research will continue to address the barriers identified in the project and will help to provide the necessary data to evaluate the impact of alternative fuels on emission control devices.

Reviewer 2:
The reviewer pointed out that for ethanol-lean NO_x, need to consider what levels of emissions conversions are actually needed and operation of system on lower ranges of ethanol content. The reviewer asked what if the driver chooses E0 or E10 all the time. Need some concrete results for membrane separation of ethanol.

The reviewer inquired can Ea and light-off differences between different soot be plugged into a soot filter regeneration model to estimate how much difference they will cause.

Reviewer 3:
The reviewer noted that durability effects on PM including sulfur and biodiesel production metals (sodium, potassium, etc.) are important to understand.

Reviewer 4:
The reviewer commented that there is no clear definition which subprojects will be completed sooner than others and inquired if all sub-projects have the same timeline and priority.

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

Reviewer 1:
The reviewer said that understanding fuels/lubricants interaction is very complex phenomena and requires a lot of effort to provide guidance regarding its impact on fuel consumption.

Reviewer 2:
The reviewer pointed out that new or improved after-treatment is needed to enable new engines or fuels. The project directly supports that goal, and also provides a more in-depth picture of catalyst fundamentals, which can guide other researchers in the topic.

Reviewer 3:
The reviewer commented that this project supports the DOE objective of petroleum displacement by providing data on advanced combustion engines and alternative fuels that in the future will allow these advanced technologies to be used.

Reviewer 4:
The reviewer said that the project directly assesses oxygenate for gasoline and diesel as petrol displacement

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

Reviewer 1:
The reviewer commented that funding in 2015 has been reduced, while completion of proposed goals may require a lot of money, e.g., heavy-duty testing.

Reviewer 2:
The reviewer found that resources seem about right for this topic.

Reviewer 3:

The reviewer commented the resources provided for this project appear to be adequate.

Gasoline-Like Fuel Effects on Advanced Combustion Regimes: James Szybist (Oak Ridge National Laboratory) - ft008

Presenter

James 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 found that the approach is very good, and remarked many important aspects of fuel effects on relevant combustion regimes and engine pathways are being studied in a relevant multi-cylinder engine.

Reviewer 2:

The reviewer noted that the project is a largely experimental approach to fuels research with emphasis on engine efficiency. The project is divided into three or four discrete topics with little coordination or overlap between them.

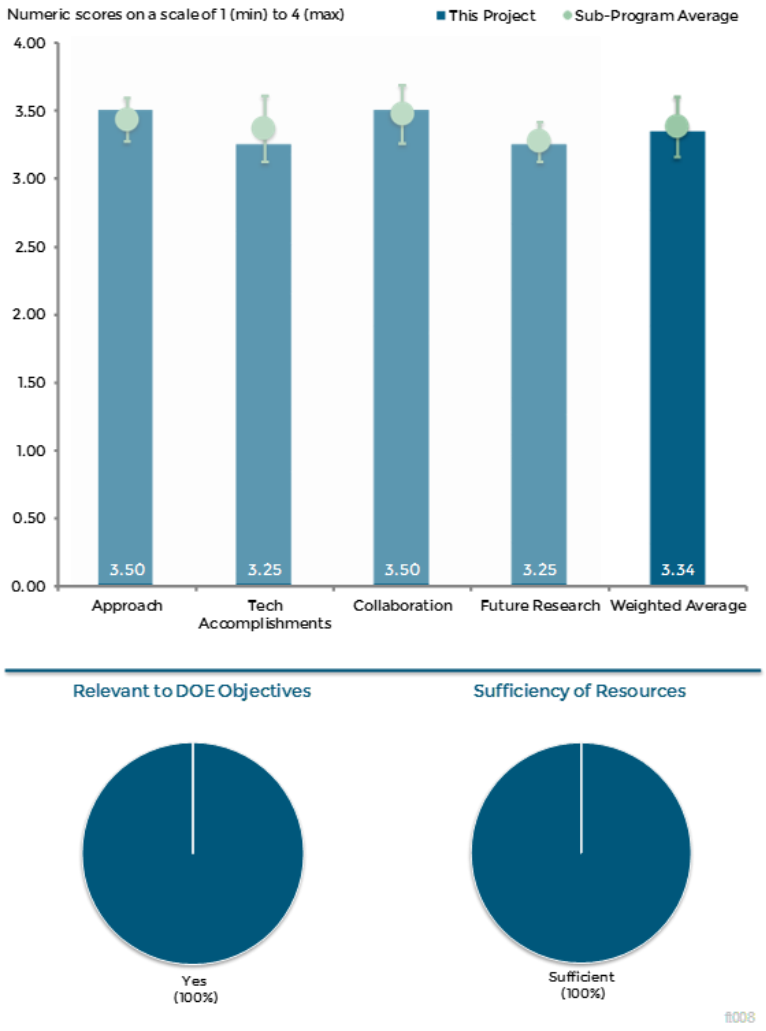

Figure 5-6 Gasoline-Like Fuel Effects on Advanced Combustion Regimes: James Szybist (Oak Ridge National Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer remarked that the EGR and high octane studies each attempt to quantify impact on combustion and efficiency. A combined study would be appropriate given that each study alone has issues, but in combination, they complement each other.

Reviewer 4:

The reviewer found that the approach of evaluating several different combustion strategies on the same base engine platform is excellent as it enables an apples-to-apples comparison. Also looking at the effects of fuel composition at a fixed RON level is valuable. The reviewer found that the work comparing the engine efficiency (brake thermal efficiency versus load brake mean effective pressure) for various fuel formulations is interesting, but should include testing of a high octane premium (91/92 anti-knock index [AKI] - 96/98 RON) E10, which is widely available in the market. The reviewer believed it is not fair to just compare the 101 RON E30 fuels with a 93 RON (presumably 87 AKI) E0 fuel.

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 a good amount of progress has been made. New information has been generated in three areas of interest, viz., knock-resistant fuel, dilution tolerant fuel, and low-temperature combustion fuel. The reviewer pointed out that the effect of fuel octane on engine efficiency and max load capability has been well known for a 100 years, but it is good to see the data in this study as expected in a modern relevant engine. The reviewer concluded that the effects of biofuels on the three areas are very interesting and encouraging.

Reviewer 2:
The reviewer noted that the focus on the ability to easily control combustion is important. According to the reviewer, the study of how the knock sensor affects engine timing and efficiency over a wide range of fuels is interesting and important, but the experiments may be pushing the engine control system into areas of operation that are not well developed. The reviewer observed that there is no detailed discussion of NO_x or PM, and asked as an example does NO_x go up with fuel stratification. The reviewer also remarked that each set of experiments have clear, easy to understand results and should be very useful in choosing between different fuel and combustion strategies.

Reviewer 3:
The reviewer noted very good progress in all three areas. The reviewer specifically pointed out the following: Demonstration that RCCI can meet 2020 ACEC stretch efficiency goal of 36% at 200 rotations per minute, 20% load; confirmation that the partial (low) fuel stratification approach has diesel-like efficiency, very low engine-out NO_x and soot emissions, but limited ability to control combustion phasing; and an interesting finding that at the nominal 97 RON level, the hydrocarbon (HC)-based fuel containing 30% toluene had lower tendency to knock than fuels containing 20% ethanol or 24% isobutanol. The reviewer noted that although one might be tempted to attribute the better performance to the slightly higher reported RON of the HC-based fuel (one unit higher than the fuels containing the oxygenates), at the nominal 91 RON level, the ethanol containing fuel had one RON higher value than the HC-based E0, but did not perform better. The reviewer presumed that octane effects on knocking prevention would be most important at the lower RON level.

Reviewer 4:
The reviewer inquired as to whether requiring high EGR to mitigate NO_x is the only solution to the highly stratified GCI challenge. Further, the reviewer asked if SCR or lean NO_x traps are plausible. Regarding the high-octane study, the reviewer asked what is the impact of revised piston geometry (to provide desired compression ratio [CR]) on fuel spray volatility and wall impingement, fuel pool fires, etc. The reviewer understands there are limitations in performing the experiment, but asked if these are significant considerations. The reviewer wondered does the conclusion that 13:1 CR marks an efficiency limitation imply that effective CR achieved through turbocharging also faces similar limitations. Regarding the reformate project, the reviewer observed very good info that the presence of carbon monoxide impacts IMEP COV, and that spark to 5% is the important metric.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked it looks like an impressive list of partnerships and collaborations, and observed excellent engagement with industrial partners.

Reviewer 2:
The reviewer pointed out collaboration with the CRC, OEMs, and fuel providers, and that cross industry collaboration is obvious.

Reviewer 3:
The reviewer noted a significant amount of collaboration with industry (OEMs and energy companies), including collaboration with CRC.

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

Reviewer 1:
The reviewer commented that the proposed future research looks to address some looming and existing concerns, and remarked excellent presentation overall.

Reviewer 2:
The reviewer commented plans are to continue progress.

Reviewer 3:
Regarding high-octane fuels for SI combustion, the reviewer recommended that cooled EGR, high-ignition energy, turbulence enhancement, and other means that industry is employing should be included in the study to see if efficiency and max-load capability can be further improved with higher compression ratios. The reviewer asked can the other possible effects (e.g., volumetric efficiency) of HOV be separated from its RON-like effects on knock. Any vehicle fuel economy estimations should include a downsized version with high output, and a rightsized version with high efficiency.

Regarding fuel effects on dilute combustion, the reviewer suggested that higher levels of EGR, high-ignition energy, optimal mixture motion, higher turbulence levels, etc., should be added in the plans so that the engine can operate at a state-of-the-art high level of dilution tolerance. The reviewer asked will the composition of the fuel have the same effects then.

Reviewer 4:
The reviewer remarked that studying reformate effects is not very useful unless ORNL has a way to generate reformate in a vehicle. The reviewer would like to know how ORNL intends to do this. There is a good progression of planning for each of the three topics. The reviewer noted that the focus on studying a wide range of realistic fuels to gain further understanding of chemistry effects is valuable.

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

Reviewer 1:
The reviewer pointed out that the project studies interaction of fuels and combustion strategies relative to efficiency and stability, and that this topic is very relevant to DOE program goals.

Reviewer 2:
The reviewer said that the evaluation of fuel properties on performance of various advanced combustion strategies helps to identify the approaches which have the most promise for improving engine efficiency and lowering emissions, which are key DOE objectives.

Reviewer 3:
The reviewer commented that the project adheres to the DOE goal to reduce/replace petroleum in transportation fuel in the future.

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

Reviewer 1:

The reviewer said that resources appear sufficient, but may be split between too many separate projects.

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 commented that the project is mainly experimental work in the areas of tribofilm formation, test protocols, base fluids, additives, and coatings. This is a good focus when supplemented with surface analysis and some modeling.

Reviewer 2:

The reviewer observed an innovative approach using analytical instruments for tribofilm analysis. The project can potentially provide great fundamental tribology information.

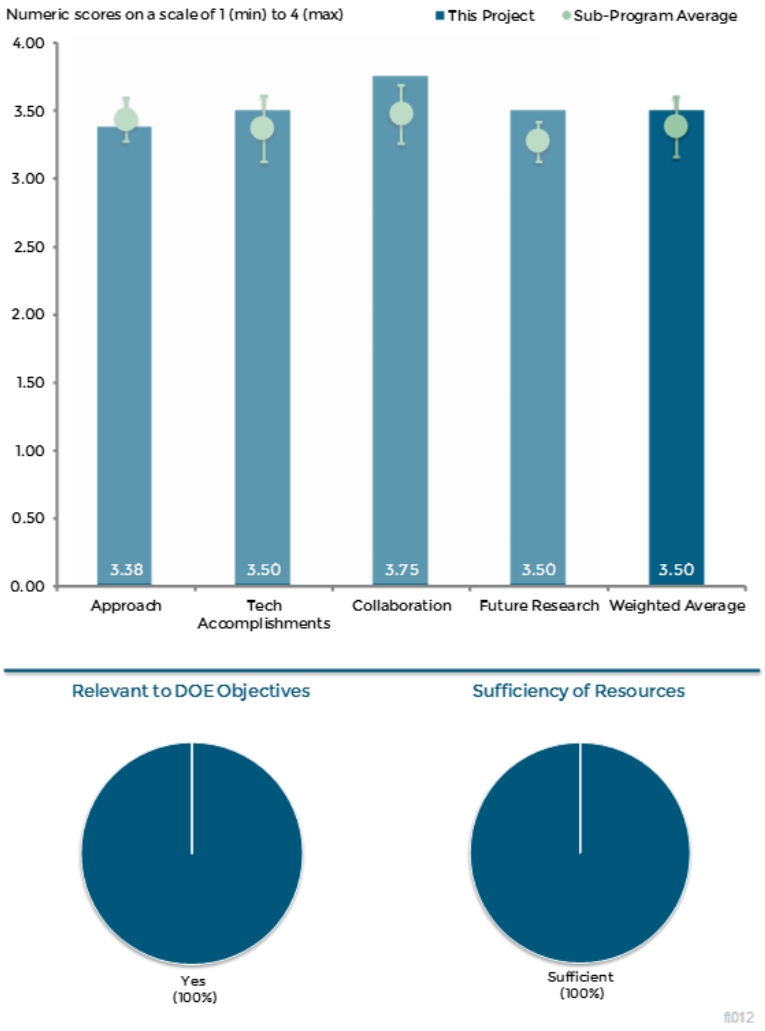

Figure 5-7 Engine Friction Reduction Technologies: George Fenske (Argonne National Laboratory) – Fuel and Lubricant Technologies

The reviewer commented that benchtop testing correlative to effective fuel economy is a large technical risk; however, developing more standardized ways to quantify tribological performance is definitely a fruitful effort.

Reviewer 3:

The reviewer observed a good review of needs, technical barriers and currently conducted projects. However, no publication and presentations list was given. It is hard to judge how well findings are communicated among technical community. The reviewer recommended that national laboratories need to offer their contributions to technical community via presentations and publications.

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 concluded that researchers have made good progress in all areas of research.

Reviewer 2:
The reviewer praised that innovative methodologies are being developed to analyze tribofilms. The reviewer noted that boundary lubrication (BL) additives and coatings to augment the Stribeck curve in the boundary lubrication regime is feasible with good preliminary results. The reviewer remarked that standardizing performance using proven and consistent benchtop test methodology is a must.

Reviewer 3:
The reviewer observed excellent progress in coatings area, especially in catalytically active coatings. The test protocols development area is moving forward nicely, although it still needs better description regarding what types of engine tests are being modeled and when publications on available data will be available to technical community. The reviewer is waiting to see a silver bullet being created in this area. The reviewer remarked that a side by side comparison of benefits of using Micro Xanes technique versus traditional surface analysis techniques could be a good addition to the data presented.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer detailed that academia, vehicle OEMs, engine OEMs, component OEMs, lubricant suppliers, additive suppliers, and small businesses are all involved in their respective areas of expertise. The project seems to be wide ranging, but well organized.

Reviewer 2:
The reviewer observed good participation and collaboration with OEMs, additive industries and other national laboratories. Participation in the Massachusetts Institute of Technology consortium adds extra value to predict critical frictional/wear/scuffing testing performance phenomena.

Reviewer 3:
The reviewer commented very good collaboration with industry with funding opportunity announcements (FOA) and CRADAs, and funds in research. ANL appears to be the go-to national laboratory for tribology research.

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

Reviewer 1:
The reviewer is looking forward to future sets of excellent results. The reviewer recommended that the project team plan on publishing data in technical journals.

Reviewer 2:
The reviewer remarked that it would be nice to know more about the Ricardo engine model and how it could be accessed to support and verify other DOE funded research, in a similar manner to the GREET model for greenhouse gases. The reviewer sees a need to include some engine and vehicle modeling in order to predict how fundamental changes affect overall performance. The reviewer acknowledged that there is much hype about improving the legacy fleet with new lubricants. This should be demonstrated, including a study of durability, oil film thickness, and wear. The reviewer wonders how far we can really go.

Reviewer 3:
The reviewer's only major concern lies within the correlation between benchtop testing and fuel economy equivalency. More applied component testing may alleviate some of the technical risk, but it is still a large barrier to overcome.

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

Reviewer 1:
The reviewer said that investigating the fundamentals of tribology and state-of-the-art additives and coatings will enable the tailoring of lubricant, coating and additive package to the system, thus increasing fuel efficiency and supporting DOE objectives.

Reviewer 2:
The reviewer noted a good focus on critical gaps, and identified fundamental knowledge, bench test to real life tests correlations, development of novel techniques, etc.

Reviewer 3:
The reviewer commented that the project provides a potential for improving legacy fleet performance and new vehicles.

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

Reviewer 1:
The reviewer commented it is critical that sufficient funds are provided in a future, so these important studies can continue to completion.

Reviewer 2:
The reviewer found that resources seem adequate to continue level of progress.

Reviewer 3:
The reviewer commented that considering the vast scope of this experimental work, the funding level seems appropriate.

Polyalkylene Glycol (PAG)-Based Lubricant for Light- and Medium-Duty Axles: Arup Gangopadhyay (Ford Motor Company) - ft023

Presenter

Arup Gangopadhyay, Ford Motor Company.

Reviewer Sample Size

A total of three reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that the project is a very practical approach to improving lubricants using standard tribology tests, bench tests, manufacturers' qualification tests, and full vehicle tests. It focuses on polyalkylene glycol (PAG) formulated base oils with additives for reducing axle and gear energy losses.

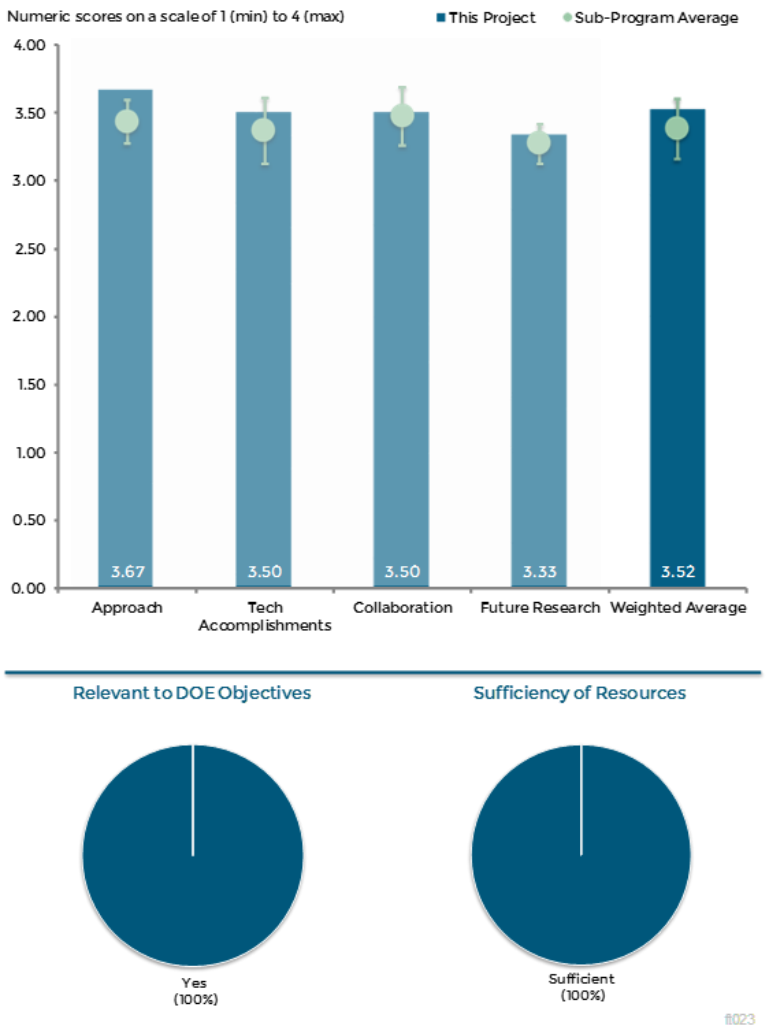

Figure 5-8 Polyalkylene Glycol (PAG)-Based Lubricant for Light- and Medium-Duty Axles: Arup Gangopadhyay (Ford Motor Company) – Fuel and Lubricant Technologies

Reviewer 2:

The reviewer remarked candidate additive pack approach feasible. Selection of well-balanced additive pack to pursue with iterative additive levels. The reviewer observed a good mix of extreme pressure, friction and wear benchtop testing. The project can give an indication as initial screening but not for quantitative fuel economy gains, which will be addressed in future work.

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

Reviewer 1:

The reviewer remarked that researchers have successfully selected base oils and additive package that provide targeted improvements and are now moving to optimizing and verifying the performance.

Reviewer 2:

The reviewer noted that the reported benchtop test data is incomplete, and that the baseline sample not thoroughly investigated (missing ball on disk friction and wear data to directly correlate with current best PAG candidates). The reviewer noted that wear and rippling appeared to be a problem in the L-37 testing, but the tested PAG 17-2 formulation was not the best performing candidate from preliminary benchtop testing. The

reviewer remarked that testing candidates PAG 70-9 and/or PAG 71-5 (samples that performed better in all conducted bench tests) in L-37 could alleviate the wear and rippling issues without the need for ultimate reformulation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted that the project team is leveraging Dow Chemical for PAG oil formulation, which is an absolute necessity. The reviewer remarked that ANL is a great selection for tribology testing and post-test tribofilm analysis via X-ray photoelectron spectroscopy (XPS) and Raman spectroscopy.

Reviewer 2:
The reviewer observed very useful teamwork with Dow for base fluids and with ANL for bench tests and characterization. The reviewer recommended that the project would definitely benefit from more direct involvement with an additive company, although the project team has access to some formulation variations.

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

Reviewer 1:
The reviewer said that the project will be addressing a few performance problems uncovered as well as running full vehicle tests. This is a logical and appropriate plan.

Reviewer 2:
The reviewer pointed out that seal chemical compatibility is an immediate issue with PAG, which is being sufficiently addressed. Some of the preliminary datasets are currently incomplete but will be conducted in the near future. The reviewer would have liked to see the L-37 test conducted on the best PAG candidates instead of the baseline PAG formulation. Potentially that will be conducted in the future. The reviewer noted that superior wear protection of these candidates validated with benchtop testing could alleviate the wear and rippling exhibited in the PAG 17-2 L-37 testing. The reviewer suggested that the project team may want to investigate environmental properties because there is some potential for toxicity and biodegradability issues. The reviewer noted that friction data on the benchtop scale via ball on disc thus far, and it will be interesting to see block-on-ring, mini-traction machine (MTM) data, etc.

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

Reviewer 1:
The reviewer commented that reducing energy losses in axles and gears can improve vehicle fuel economy.

Reviewer 2:
The reviewer opined that AG potentially has a place in the commercial market. A lot of technical barriers have to be addressed before such a technology can be implemented, many of which, are/will be addressed in the scope of this project.

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

Reviewer 1:
The reviewer commented that resources appear adequate to achieve project goals.

Reviewer 2:

The reviewer found that there is sufficient funding for the scope of the project. DOE cost share was matched by the contractor, which illustrates the interest from the involved parties.

A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement: Q. Jane Wang (Northwestern University) - ft024

Presenter

Q. Jane Wang, Northwestern University.

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted that the project combines multiple approaches to friction reduction including heterocyclic additives, nanoparticles, and viscosity modifiers. This is a very complex experimental space, but needed for real world research.

Reviewer 2:

The reviewer opined that this is an important program addressing key knowledge needs expressed by the lubricants industry: balance between providing lower fuel consumption without negatively impacting hardware durability.

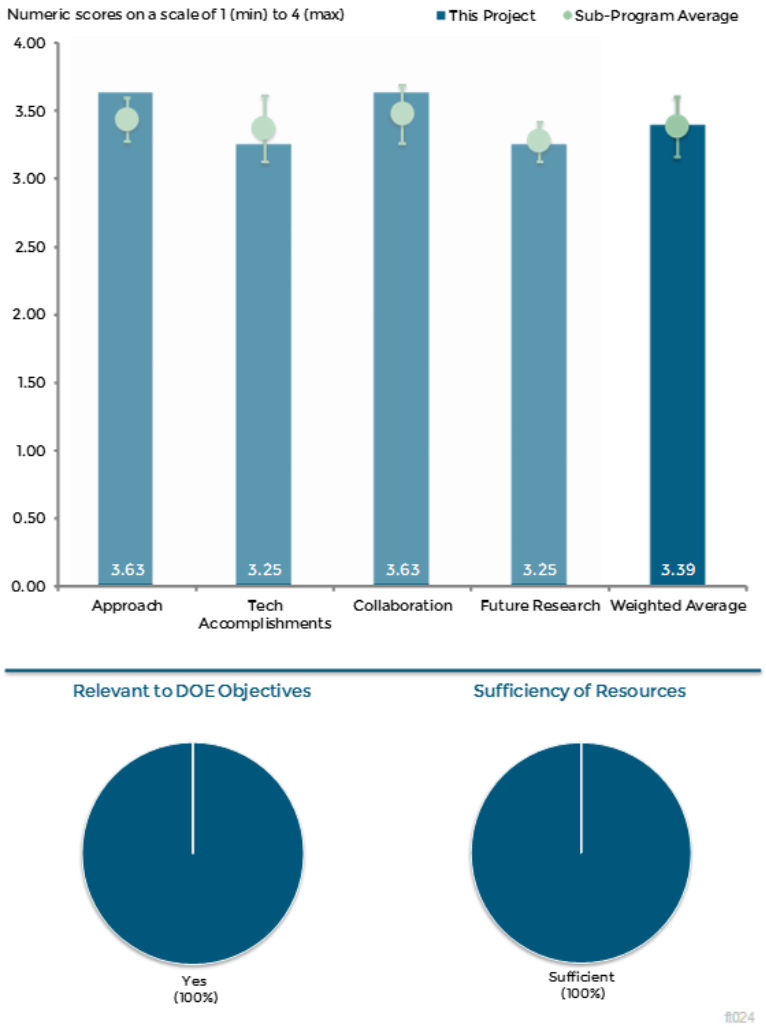

Figure 5-9 A Novel Lubricant Formulation Scheme for 2% Fuel Efficiency Improvement: Q. Jane Wang (Northwestern University) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer expressed some concern about integrating all of the novel lubricant additives together in a fully formulated lubricant, but this will be addressed in future work.

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

Reviewer 1:

The reviewer found that progress appears good, advances were made in all three areas of friction reduction. The reviewer acknowledged that further work will be needed to formulate final lubricant and the balancing of additives to achieve desired result.

Reviewer 2:

The reviewer observed that the team has already demonstrated the technology feasibility of friction modifiers, viscosity improvers and nanoparticle additives individually against neat base stock. According to the reviewer,

how the additives behave when introduced into a fully formulated lubricant has not been conducted yet, but will be addressed in near future work.

Reviewer 3:

The reviewer remarked that because this is a new project, there is insufficient data provided to judge progress made. The reviewer noted there is no data on novel viscosity modifier (VM) performance, and no wear assessments were provided. The reviewer would like to know if the reference oil, 5W-30, contains any friction modifier technology, and if yes, which type. The reviewer asked what validation engine tests will be performed, dyno or field trials. The reviewer asked what is the contribution of silicone particles to sulfate ash, and if there are any antagonistic interactions with exhaust catalysts. The reviewer asked if the new VM approach is actually totally novel technology, and if an intellectual property search was carried out.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted a great balance of academia and industry from premier groups, and good coordination between the several interested parties.

Reviewer 2:

The reviewer remarked that having Ashland and GM as a part of the technical team offers good leverage in guidance towards important industry needs.

Reviewer 3:

The reviewer observed a good set of partners for the collaboration, including GM, Ashland, and Argonne.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating 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 goals are well defined. The reviewer is excited to see experimental performance results.

Reviewer 2:

The reviewer observed that the project is following logical progression: combining additives, transitioning to real base oils, and transitioning to fully formulated lubricants. The reviewer pointed out that durability of viscosity modifiers needs to be verified, and that additives need to be verified with other materials in addition to steel.

Reviewer 3:

The reviewer is concerned about the friction modifier and nanoparticle additive competition for surface area. A correlation may have to be developed to relate the effective area consumed by each representative additive unit acting on the metal surface and vary the ratio between these additives but leaving the additive total effective area coverage value constant. Thus, according to the reviewer an optimized ratio between friction modifiers and nano-additives could potentially be reached. The reviewer noted there is much interest in the analysis of the tribofilm generated from this proposed testing to investigate the surface chemistry complexity via XPS depth profiling, Raman, etc.

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

Reviewer 1:

The reviewer said that proposed technologies could improve fuel economy and increase the robustness of the lubricant, both of which align well with the DOE objectives.

Reviewer 2:
The reviewer acknowledged a good alignment with DOE objectives.

Reviewer 3:
The reviewer said that reducing viscous and boundary friction with additives will improve vehicle fuel economy and may be retrofit-able to current 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 that funds are sufficient, and it is good to see Ashland's financial commitment.

Reviewer 2:
The reviewer found that resources should be sufficient to complete project and achieve goals.

Reviewer 3:
The reviewer pointed out that no cost added testing from interested parties enables a large scope of work at a feasible funding level.

Improve Fuel Economy through Formulation Design and Modeling: Gefei Wu (Ashland, Inc.) - ft025

Presenter

Gefei Wu, Ashland, Inc.

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 is impressed with a holistic approach to assess fuel consumption by including performance contributions from engine oils, driveline fluids, and bearings.

Reviewer 2:

The reviewer observed a comprehensive approach of all three main lubrication requirements for a vehicle, engine, transmission, and axle. Use of in-house models to project results to vehicle should help with progress and selection. The reviewer asked is it realistic to compare new 5W oils to a 15W-40 baseline.

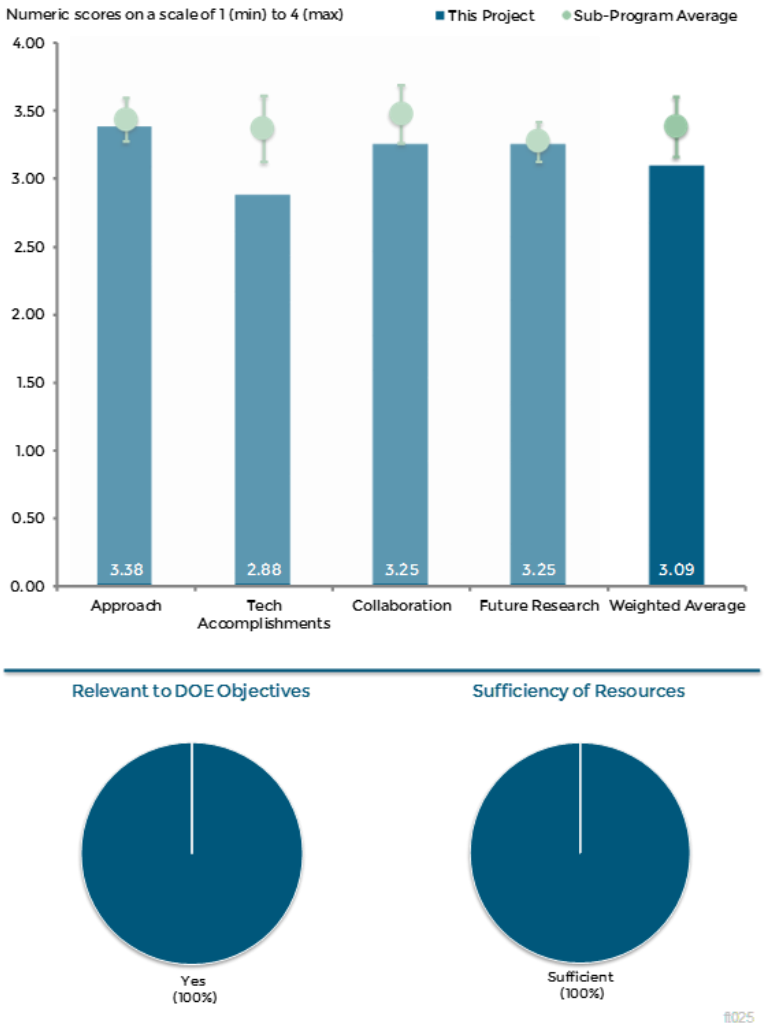

Figure 5-10 Improve Fuel Economy through Formulation Design and Modeling: Gefei Wu (Ashland, Inc.) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer is concerned about the validity of the proprietary modelling. The reviewer asked if this model has been verified through previous research projects, and how correlative can this predictive model be expected.

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 bench data and fluids selection process lack significant fundamental value, because authors do not share any information regarding formulation approaches used, modelling approach details or testing conditions, e.g., conditions for MTM traction data not given. Some delayed testing raises a concern for this reviewer about completing testing within expected timeline.

Reviewer 2:
The reviewer noted that the project has met goals for oil formulations but are behind on engine verification test. The reviewer asked when this is scheduled. The reviewer noted that the presentation gives very little information about the relative importance of viscosity versus additives for friction reduction.

Reviewer 3:
The reviewer found that modelling work shows promise but only addresses hydrodynamic lubrication. Boundary lubrication may prove to be a huge contributor to fuel economy. The reviewer noted that this will be addressed experimentally, but not through modelling.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observe a good team of contributors selected.

Reviewer 2:
The reviewer noted a good combination of in-house research & development along with collaboration from Cummins, NREL, and additive suppliers.

Reviewer 3:
The reviewer observed a good balance of industry and national laboratory partners, and their respective capabilities have been properly utilized.

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

Reviewer 1:
The reviewer found that the project is following the project plan as written, which should achieve desired results.

Reviewer 2:
The reviewer remarked that the authors need to timeline to complete all tasks on time.

Reviewer 3:
The reviewer said that experimental data are lacking in the current effort, but will be addressed in great detail in future research.

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

Reviewer 1:
The reviewer pointed out that improved lubricants can improve fuel economy now, and that the project is aimed at existing engines rather than a future engine.

Reviewer 2:
The reviewer commented that the program addresses all DOE objectives.

Reviewer 3:
The reviewer concluded that reducing vehicle energy loss due to friction without sacrificing anti-wear performance aligns perfectly with DOE objectives.

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

Reviewer 1:
The reviewer said that the funding share is excellent on this project, which enabled an increased work scope.

Reviewer 2:
The reviewer concluded that resources should be sufficient to complete the research.

Reviewer 3:
The reviewer said that contributions from Ashland will help with conducting appropriate tests.

Developing Kinetic Mechanisms for New Fuels and Biofuels: Bill Pitz (Lawrence Livermore National Laboratory) - ft026

Presenter

Bill Pitz, 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 applauded that this project is one of the few cases where the chemical kinetic, CFD, and experimental groups are working together in a cohesive way so that the total overall benefit is realized faster.

Reviewer 2:

The reviewer found that the project approach of developing several different tools (predictive chemical kinetics models, reduced mechanisms for improved CFD simulations, and equipment) to help identify fuel property/composition impacts on engine efficiency and emissions is a very good.

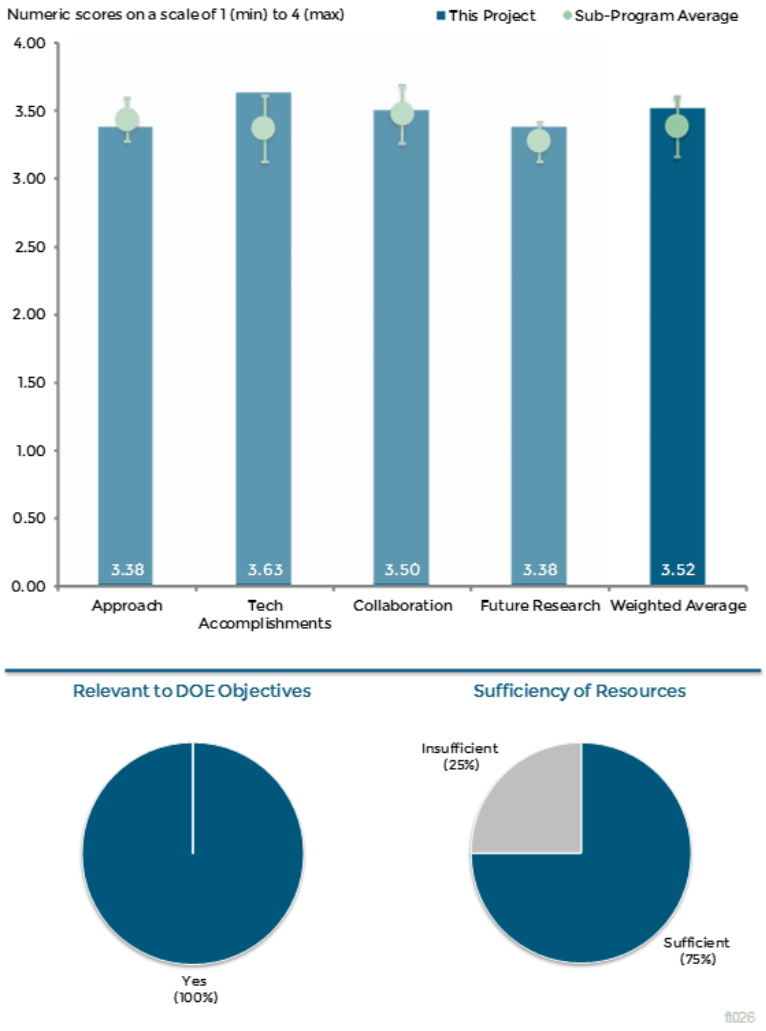

Figure 5-11 Developing Kinetic Mechanisms for New Fuels and Biofuels: Bill Pitz (Lawrence Livermore National Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer said that the project builds on a long successful history and methodology of mechanism development. Additionally, the project is beginning to acquire experimental tools for validation and calibration data.

Reviewer 4:

The reviewer observed a very thorough approach with chemical kinetic models both for practical and future fuels.

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

Reviewer 1:
The reviewer said that several applications and experiments too numerous to mention have been targeted and simulated, and concluded very good progress.

Reviewer 2:
The reviewer found that the project is meeting milestones and deliverables. The project's reduced mechanisms and speed CFD calculations are publically available on LLNL's website. The reviewer pointed out that LLNL is providing CFD support for Sandia engines, which helps both programs.

Reviewer 3:
The reviewer found that the project is making excellent progress on meeting milestones, and specifically pointed out the following: Construction and initial testing of a micro fuel tester for ignition and extinction behavior and flame speed measurement; validating a surrogate model that can be used to obtain octane number correlations for gasoline surrogate fuels containing ethanol; evaluating burning velocities of a reference gasoline and E85 at conditions corresponding to spark timing in DISI engine; and from flame speed calculations, showed why higher intake temperatures improve combustion stability and efficiency for lean DISI.

Reviewer 4:
The reviewer said that micro-FIT is an important breakthrough to experimental fuel volumes/cost. Fuel fingerprints are a unique and novel analysis of fuels and properties, especially ignition delay time (IDT)/octane, and particularly ethanol/IDT quantification. Regarding burning velocity, the reviewer wonders why E85 flame speed is very close to gasoline. The reviewer's understanding is one of the functions of ethanol was higher flame speed. Regarding E85 stratified combustion, the reviewer would like to know what the lean limit is for combustion stability.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer pointed out a good relationship with Sandia for data and with the CRC for application of results. The reviewer also observed excellent partnering with several universities and national laboratories to obtain experimental data for developing and verifying mechanisms.

Reviewer 2:
The reviewer observed collaboration with an OEM and the energy industry through active participation in the CRC FACE Working Group, and collaborations with several universities and colleagues at the national laboratories. The project also allows their mechanisms to be available to the public through posting on their website.

Reviewer 3:
The reviewer said very good collaborations exist with advanced combustion work occurring in other laboratories.

Reviewer 4:
The reviewer observed very good industry collaboration through CRC, universities, laboratories, and OEMs.

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

Reviewer 1:
The reviewer commented that plans will lead to wider applicability of the micro-FIT instrument and further development and improvement of gasoline surrogates.

Reviewer 2:
The reviewer recommended that continued micro-FIT is key for more easily performed research, at a lower cost. The end gas auto ignition research vital to better assess how much octane is enough and what is too much.

Reviewer 3:
The reviewer said that next year's work is a good continuation of this year's work, but recommended the number of topics may need to be limited to ensure sufficient depth of results.

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

Reviewer 1:
The reviewer remarked that improved mechanisms allow simulation of combustion processes for better understanding and more efficient development of new fuels and engines. CFD modeling helps in understanding of experimental engine results and can be used to extend the studies.

Reviewer 2:
The reviewer found that the development of tools (predictive chemical kinetics models, reduced mechanisms for improved CFD simulations, and equipment) to help identify fuel property/composition impacts on engine efficiency and emissions supports DOE's objectives.

Reviewer 3:
The reviewer observed that the project provides models and understanding of the chemical kinetic behavior of fuels for advanced combustion concepts. The reviewer believed that this is much needed going forward.

Reviewer 4:
The reviewer said that the project overtly states that its goal is to quantify petroleum displacement with biofuels.

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

Reviewer 1:
The reviewer said that the budget appears to be sufficient to develop two or three topics per year. However, an increased budget could allow more in-depth studies and more modeling collaboration to be done. The reviewer said that it would be very valuable if LLNL could do more CFD modeling to support experimental programs at other national laboratories.

Unconventional and Alternate Fuels Research: Tim Bays (Pacific Northwest National Laboratory) - ft027

Presenter

Tim Bays, 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 found that given the objectives of this work – correlating fuel substructures to fuel properties – the approach is effective.

Reviewer 2:

The reviewer remarked that two-dimensional nuclear magnetic resonance (NMR) is a very appropriate tool for assessing carbon spectra, and that the application to real-world fuels and crudes is very timely. The reviewer said that predictive fuel characterization is a great upstream tool to assess and model fuel properties before resources are expended in the market and field issues arise.

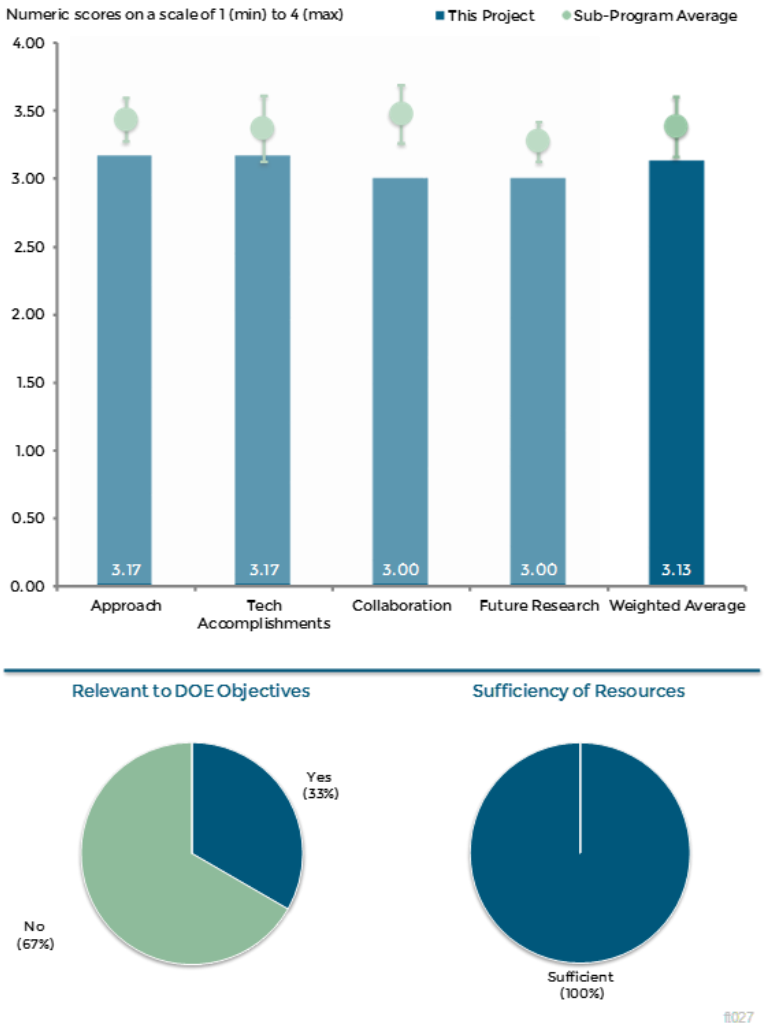

Figure 5-12 Unconventional and Alternate Fuels Research: Tim Bays (Pacific Northwest National Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer detailed that this project has the objective of enabling better understanding of performance and compatibility impacts of fuels derived from unconventional HC resources. The deliverables will be detailed chemical analysis information, obtained with highly sophisticated techniques, and correlations of fuel properties based on these chemical analyses. The reviewer said that the approach is sound, but would be more comprehensive if it included experimental studies of fuel combustion and performance. The reviewer gathered that apparently this will be accomplished instead through connection with CRC working groups and CanmetENERGY.

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 detailed that very valuable fuel chemical analyses are now being correlated to important fuel properties, such as lubricity. These results are valuable in and of themselves, but also may enhance understanding of how fuel sub-structures influence fuel properties. The reviewer concluded that this study could have far-ranging benefits beyond the focus of the project, and also noted that the project has generated publications and reports, with archival journal papers in preparation.

Reviewer 2:
The reviewer commented that shale oil characterization is important given the burgeoning U.S. market (tight oil, Marcellus shale). The reviewer remarked that the qualitative spectra (Complete Reduction to Amplitude Frequency Table [CRAFT]) is really an intriguing quantification of fuel makeup, and is similar to Fourier Transform digital signal processing in acoustics.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that it appears similar or related work at CRC and other organizations is recognized, and connections have been established.

Reviewer 2:
The reviewer pointed out that collaboration with CRC and CanmetENERGY represent very good collaboration with industry standard organizations.

Reviewer 3:
The reviewer pointed out that there is no university involvement, and acknowledged a connection to the larger community through CRC working groups.

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

Reviewer 1:
The reviewer said that the project will be wrapping up by examining and completing fuel property correlations.

Reviewer 2:
The reviewer pointed out that CRAFT testing in representative fuels will be valuable to the success of CRAFT. The reviewer observed that the shale oil dataset is key information regarding potential fuel properties of the U.S. market.

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

Reviewer 1:
The reviewer pointed out that the project's stated objective is to reduce dependence on foreign resources.

Reviewer 2:
The reviewer detailed that by the wording of the question related to relevance, one must answer no. However, this project, by focusing on chemical and property characterization of unconventional fuels (historically this equals tar sand fuels, but now includes shale oil via fracking), this project can help in the process of displacing foreign (i.e., Organization of Petroleum Exporting Countries) oil. The reviewer observed that the project does

not displace petroleum per se, and does not necessarily displace foreign oil, if one considers our major economic partner to the north, Canada, as being a problematic foreign petroleum supplier. The reviewer concluded that because strategically we differentiate between Canadian oil as foreign oil, the only concern with such oil resources is their carbon footprint.

Reviewer 3:

The reviewer noted that correlating fuel substructure properties to fuel properties for fuels from unconventional sources is probably very important. However, the reviewer found that the connection of this project to advanced combustion, high-efficiency engines is not clear. The reviewer asked on what basis were the test fuels chosen. It is not clear if the fuels chosen for characterization are good candidate fuels for low-temperature combustion or for some other type of advanced combustion concept. The reviewer pointed out that Slide Three refers to advanced combustion engines. The reviewer asked if it can it be made more specific as what these advanced combustion regimes are, and if it can be related to the U.S. DRIVE ACEC Roadmap, for example.

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

Reviewer 1:

The reviewer found that resources seem sufficient.

Additive and Basefluid Development: Oyelayo Ajayi (Argonne National Laboratory) - ft029

Presenter

Oyelayo Ajayi, Argonne National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed an innovative approach using analytical instruments for tribofilm analysis, and that the project can potentially provide great fundamental tribology information.

Reviewer 2:

The reviewer commented that the program seeks to develop base oil and additive technologies using lab experimental techniques.

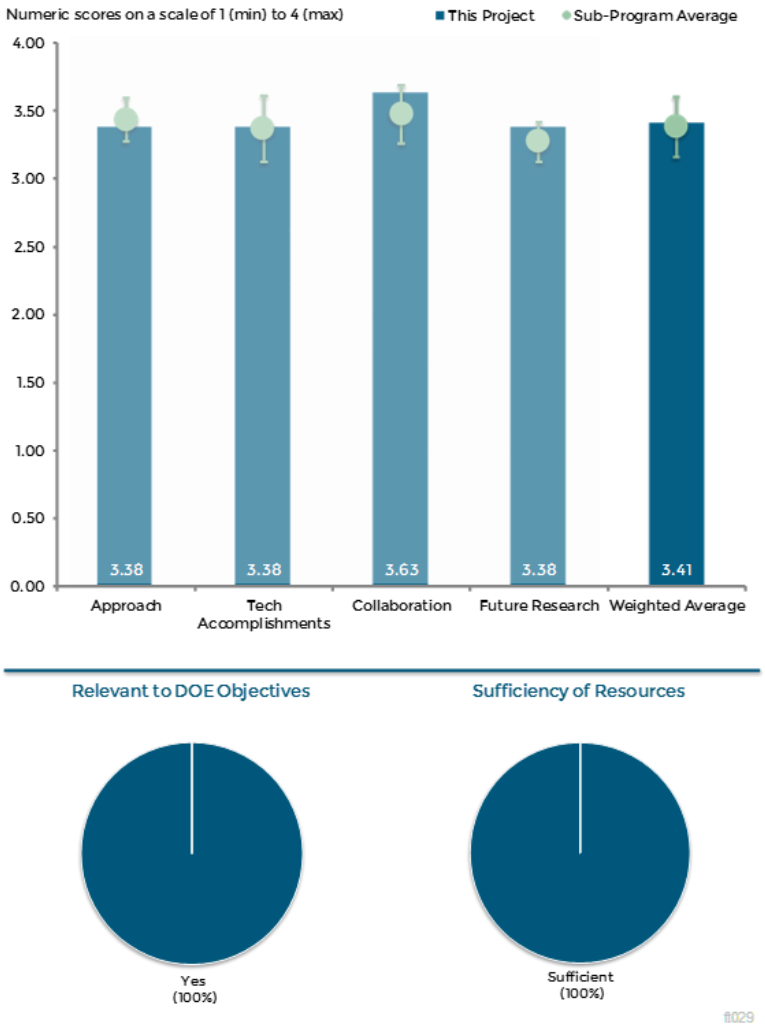

Figure 5-13 Additive and Basefluid Development: Oyelayo Ajayi (Argonne National Laboratory) – Fuel and Lubricant Technologies

Reviewer 3:

The reviewer noted well-defined goals and technical barriers. However, there was no listing of patent/literature searches regarding studied base stock chemistries provided. The reviewer asked if the binary mixed matrix of base stocks studied is really a unique area to be examined. The reviewer would like to know what the actual chemistry is of the ester base stock studied.

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 large scope of the project is covering a wide variety of state-of-the-art lubricants and lubricant additives. The project developed innovative methodologies to analyze tribofilms.

Reviewer 2:

The reviewer noted interesting work with encapsulates, but no physical evidence was presented to indicate that the particles are actually behaving according to the hypothesis/theory. The reviewer noted good progress with ester base fluids and solid lubricants, covering a broad range of oils and additives. The reviewer said that it is

difficult to judge this project on its own because it lists the same budget and collaborators as other ANL lubricant projects.

Reviewer 3:
The reviewer noted interesting sets of friction reduction and wear control results. However, no description of ester chemistry was provided. The reviewer asked if it is unique or widely commercially available. The reviewer noted that colloidal dispersion work needs to include storage stability results. Oleic acid solutions are probably very corrosive towards copper and lead surfaces. The reviewer said that additional examination to control this phenomenon is needed.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer detailed that academia, vehicle OEMs, engine OEMs, component OEMs, lubricant suppliers, additive suppliers, and small businesses are all involved in their respective areas of expertise. The project seems to be wide ranging, but well organized.

Reviewer 2:
The reviewer observed good collaboration among various organizations.

Reviewer 3:
The reviewer noted an excellent group of collaborators through FOAs, CRADAs and funded research.

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

Reviewer 1:
The reviewer identified a need to the combine technologies developed, and verify and evaluate performance in more complex tests. The reviewer observed that these lubricant combinations should also be screened for possible problems in the areas of corrosion, oxidation, water, and seal compatibility. The reviewer commented that it would be interesting to see images that show the encapsulated nanoparticles acting according to the theory (i.e., release as needed).

Reviewer 2:
The reviewer suggested including long-term (greater than three months) storage stability assessments, and including corrosion control assessments.

Reviewer 3:
The reviewer's only major concern lies within the correlation between benchtop testing and fuel economy equivalency. The reviewer cautioned that more applied component testing may alleviate some of the technical risk, but it is still a large barrier to overcome.

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

Reviewer 1:
The reviewer found that investigating the fundamentals of tribology and state-of-the-art lubricants and additives will enable the tailoring of lubricant and additive package to the system, thus increasing fuel efficiency and supporting DOE objectives.

Reviewer 2:
The reviewer said that novel approaches to formulating future lubricants are needed by the industry. Fundamental understanding of tribofilm formation is a critical part in making significant progress.

Reviewer 3:
The reviewer said that the program provides a more fundamental understanding of additives and lubricants.

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

Reviewer 1:
The reviewer said that resources are sufficient for progress reported.

Reviewer 2:
The reviewer concluded that considering the vast scope of this experimental work, the funding level seems appropriate.

Acronyms and Abbreviations

AEC	Advanced Engine Combustion
AKI	Anti-knock index
ANL	Argonne National Laboratory
ASTM	American Society for Testing and Materials
BL	Boundary lubrication
CFD	Computational Fluid Dynamics
CI	Compression Ignition
CN	Cetane number
COV	Coefficient of variance
CR	Compression ratio
CRADA	Cooperative Research and Development Agreement
CRAFT	Complete Reduction to Amplitude Frequency Table
CRC	Coordinating Research Council
DCN	Derived cetane number
DISI	Direct Injection Spark Ignited
DMF	2,5-Dimethylfuran
DOE	Department of Energy
E0	0%t ethanol blend with gasoline
E10	10% ethanol blend with gasoline
E20	20% ethanol blend with gasoline
E30	30% ethanol blend with gasoline
E85	85% ethanol blend with gasoline
Ea	Activation energy
EGR	Exhaust Gas Recirculation
FACE	Fuels for Advanced Combustion Engines
FAME	Fatty acid methyl ester
FOA	Funding opportunity announcements

GCI	Gasoline compression ignition
GDI	Gasoline Direct Injection
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression Ignition
HOV	Heat of vaporization
IDT	Ignition delay time
IMEP	Indicated mean effective pressure
IQT	Ignition quality tester
LLFC	Lean lifted-flame combustion
LLNL	Lawrence Livermore National Laboratory
LTC	Low-temperature combustion
MECA	Manufacturers of Emission Controls Association
MIT	Massachusetts Institute of Technology
MON	Motor octane number
MOU	Memorandum of Understanding
MTM	Mini-traction machine
NBB	National Biodiesel Board
NHV	Net heating value
NMR	Nuclear magnetic resonance
NOx	nitrogen oxides
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PM	Particulate matter
PMI	Particulate matter index
RCCI	Reactivity controlled compression ignition
RON	Research octane number
SCR	Selective catalytic reduction

SI	Spark Ignition
TPGME	tri-propylene glycol methyl ether
VM	Viscosity modifier
VTO	Vehicle Technologies Office
XPS	X-ray photoelectron spectroscopy