5. Fuels & Lubricants Technologies

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 2020, 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.

Benefits

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 of 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.

Different fuels meeting the same specifications can have widely-varying impact on engine performance and emissions.

Subprogram Feedback

The U.S. Department of Energy (DOE) welcomed optional feedback on the overall technical subprogram areas presented during the 2013 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 who volunteered to provide subprogram overview comments responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE Vehicle Technologies Office (VTO) subprogram's

activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1: Was the subprogram area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Question 3: Does the subprogram area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Office's needs?

Question 4: Other Comments.

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., as reviewer responses were optional.

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

Question 1: Was the sub-program area adequately covered? Were important issues and challenges identified? Was progress clearly presented in comparison to the previous year?

Reviewer 1:
The reviewer stated yes, and that there was a good explanation of mission and strategy. This reviewer acknowledged to not having attended the plenary.

Reviewer 2:
The reviewer noted it was a very brief overview, but with good coverage. This reviewer further acknowledged a useful discussion of fuel versus lubricant philosophy.

Reviewer 3:
The reviewer remarked that the sub-program area was adequately covered, and that important issues and challenges were identified. This reviewer added that the previous year's project status (for the purposes of comparison) was not provided.

Reviewer 4:
The reviewer acknowledged that the sub-program area was quite adequately covered. However, it was noted that enabling advanced combustion to improve the efficiency would be a challenge. At this time, next generation biofuels and developing efficiency-improving lubricants would pose some difficulties, especially in the timeframe envisioned. This reviewer added that the progress toward the goals seemed a little unclear as well.

Question 2: Are plans identified for addressing issues and challenges? Are there gaps in the project portfolio?

Reviewer 1:
The reviewer commented that important research on the impact of fuel on spark-assisted homogeneous charge compression ignition (HCCI) and on reactivity controlled compression ignition (RCCI) had been addressed. The lubricant strategies and tasks were identified, and these covered a large area of current interests in lubrication. The lubricant area appeared to be well covered and the goals were admirable.

Reviewer 2:
The reviewer acknowledged good coverage within the budget. This person added that the fuel/combustion interactions were strong with other offices.

Reviewer 3:
The reviewer pointed out that it was a good idea to have expanded the emphasis on lubricant technologies, because these could result in immediate FE savings.

Reviewer 4:
The reviewer observed that low-temperature combustion was listed as an efficiency improvement option. This reviewer added that RCCI was touted and the major efficiency enabler. However, the reviewer noted that these posed very difficult real-world integration paths.

Question 3: Does the sub-program area appear to be focused, well-managed, and effective in addressing the DOE Vehicle Technologies Program's needs?

Reviewer 1:
The reviewer said yes, further mentioning the good focus and clear directions.

Reviewer 2:
The reviewer asserted that the sub-program appeared to align with the DOE VTO needs.

Reviewer 3:
The reviewer affirmed that the sub-program area appeared to be well planned and that many of the challenges were identified. This reviewer further noted that it was impossible to assess the management of the overall sub-program with the current information, although individual programs presented appeared to be well managed and were addressing important fuel and lubricant research needs.

Reviewer 4:
The reviewer stated yes, but cautioned that some of the projects being supported by this program were experiencing disruptions in funding, which was highly counterproductive. Oscillations in funding levels impeded the ability to get the maximum benefit from the previous years' investments in facilities, personnel, and research.

Question 4: Other Comments

Reviewer 1:
The reviewer emphasized that dimethyl ether (DME) was poised to become a practical pathway for the utilization of natural gas, biogas, and solar energy in the transportation sector. This reviewer went on to say that there was an accumulated need for research on key areas of the use of DME in diesel engines. The sub-program should work with stakeholders involved in DME production and utilization in transportation systems to address these needs through new projects in 2014.

Reviewer 2:
The reviewer explained that there was more information on the slides than could be followed in such a short time.

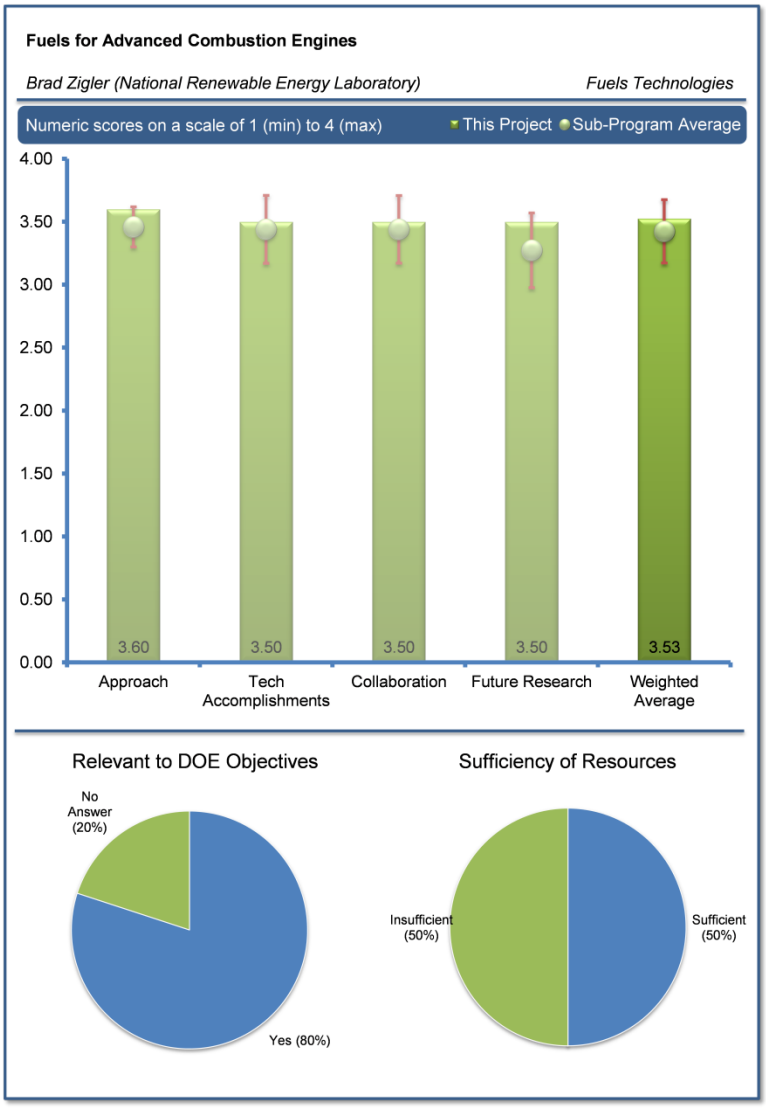
Reviewer 3:
The reviewer expressed that the timeline was tight. More progress was needed that would mean more resources.

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, as well as numeric scoring responses *(on a scale of 1 to 4)*. 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 summary 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
Fuels for Advanced Combustion Engines	Brad Zigler (National Renewable Energy Laboratory)	5-5	3.60	3.50	3.50	3.50	3.53
Performance of Biofuels and Biofuel Blends	Bob McCormick (National Renewable Energy Laboratory)	5-8	3.29	3.33	3.33	3.33	3.32
Fuels and Combustion Strategies for High-Efficiency Clean-Combustion Engines	Chuck Mueller (Sandia National Laboratories)	5-12	3.33	3.67	3.67	3.33	3.54
Advanced Lean-Burn DI Spark Ignition Fuels Research	Magnus Sjoberg (Sandia National Laboratories)	5-17	3.33	3.50	3.50	3.33	3.44
Fuel Effects on Emissions Control Technologies	Scott Sluder (Oak Ridge National Laboratory)	5-22	3.50	3.83	3.83	3.00	3.65
Gasoline-Like Fuel Effects on Advanced Combustion Regimes	James Szybist (Oak Ridge National Laboratory)	5-26	3.50	3.25	3.25	2.75	3.25
Lubricants Activities	Jun Qu (Oak Ridge National Laboratory)	5-29	3.67	3.00	3.00	3.67	3.25
Overall Average			3.46	3.44	3.44	3.27	3.43

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



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that the combination of engine, bench scale, and numerical simulation studies is an excellent approach to identifying and selecting fuels to support advanced combustion. The reviewer noted that the project has broad collaboration and is producing valuable insights, which is a reflection of a well-constructed project and technical approach. The reviewer stated that the project's collaboration with a broad group of partners helps to advance predictive capabilities and understand how evolving fuels behave in the combustion processes.

Reviewer 2:

The reviewer observed a strong systematic approach for improving the accuracy of the ignition delay model for biofuels. The reviewer stated that using the same combustion chamber as another National Lab, and sharing the knowledge for different aspects of combustion and emission studies, seems very effective.

Reviewer 3:

The reviewer noted that the project was well organized and had been reprioritized according to budgetary constraints.

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

Reviewer 1:

The reviewer commented that a number of papers have been produced or are in progress. The reviewer noted specific progress on direct injection spark ignition (DISI) engine studies of ethanol and particulate matter (PM) emissions and on autoignition and simulation of autoignition in an ignition quality tester (IQT) (cetane rating instrument). This reviewer indicated that data on PM/nanoparticulate emissions are quite valuable in understanding the impacts of operating conditions and fuel formulation on PM number emissions. The reviewer added that this can help automakers define how to control PM number emissions, either via in-cylinder or exhaust aftertreatment strategies. This reviewer also noted that strategies to reduce PM number emissions were identified and shared with original equipment manufacturers (OEMs).

The reviewer concluded that the simulation and comparison to the IQT results for ignition delay are both impressive and a very valuable outcome, because they can provide rapid feedback on kinetic mechanism reduction and tuning of kinetic parameters.

Reviewer 2:
The reviewer observed valuable information correlating ethanol content and injection strategy with particle number (PN). This reviewer noted a study based on wall guided direct injection (DI). Further, wall guided is available now and additional work to compare both may be valuable. This reviewer stated that IQT is now a useful research tool.

Reviewer 3:
The reviewer noted very interesting results, but that the project has not directly shown the results for tackling the following barriers: inadequate predictive tools for fuel property effects on engine efficiency optimization (providing the link for this direction would be valuable); and inadequate predictive tools for fuel effects on emissions and emission control.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that there was very strong collaboration among the team of 24 industry, university and National Laboratory partners.

Reviewer 2:
The reviewer stated that this was a broad team that included industry and universities as well as National Labs, considering the interaction, the principle investigator (PI) and project have with the Advanced Engine Combustion (AEC) Memorandum of Understanding (MOU).

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating 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 believed that the work on the single-cylinder gasoline direct injection (GDI) engine will close the loop for this study. This reviewer also said that it is important to coordinate the work in such a way that a predictive tool for fuel effects on engine efficiency is obtained.

Reviewer 2:
The reviewer noted that the project will continue GDI engine emissions work with high octane oxygenated fuels to look into optimization, and added that it was unclear how the emphasis on efficiency is differentiated from the ongoing work at Oak Ridge National Laboratory (ORNL). The reviewer did not feel that this redundancy would be a problem, but believed that there should be more clarity on the uniqueness that the National Renewable Energy Laboratory (NREL) work will provide.

Reviewer 3:
This reviewer commented that the General Motors Corporation (GM) 2.0L LNF Ecotec is a side injected gasoline turbocharged direct injection (GTDI) engine, and the reviewer believed more information might be gained by comparing with a wall guided and spray guided lean burn technology.

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

Reviewer 1:
This reviewer stated that the project's relevance to PM reduction and mid-blend ethanol is important.

Reviewer 2:
The reviewer believed that advanced combustion can lead to improvements in thermal efficiency, thereby reducing petroleum demand. The reviewer added that advanced/renewable fuels can displace petroleum, depending on their renewable content. The reviewer commented that the data support simulation and predictive capabilities for engine design by providing validation of chemical kinetics mechanisms.

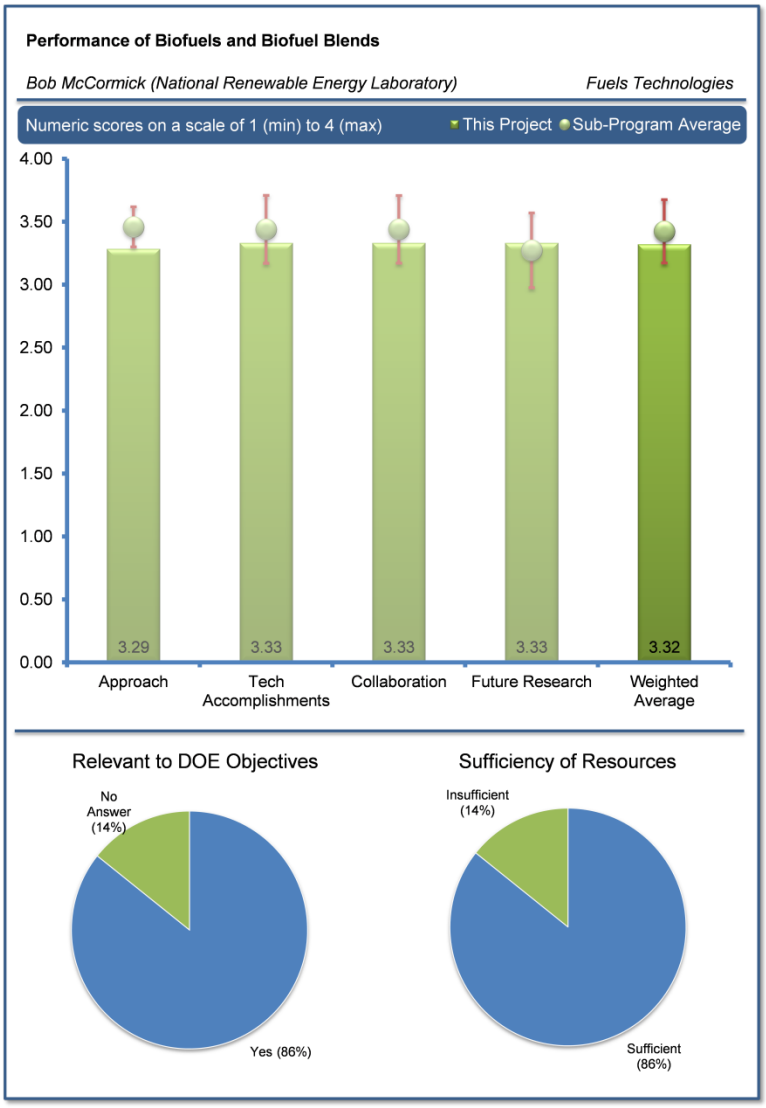
Reviewer 3:
The reviewer believed that this project provides an understanding of and a tool for optimizing engine performance based on fuel characteristics, leading to fuel saving in internal combustion (IC) engines and includes a study of biofuels that reduces the dependency on petroleum fuels.

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

Reviewer 1:
The reviewer observed that this valuable program appears to have suffered a significant disruption in its funding. This reviewer added that this is quite unfortunate, and the disruption in funding erodes the value of investments made in previous years to develop personnel and facilities being used in this project.

Reviewer 2:
The reviewer noted that portions of the project were delayed due to insufficient funds.

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



Reviewer Sample Size

A total of seven reviewers evaluated this project.

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

Reviewer 1:

The reviewer thought this was a very widely-focused program with excellent execution.

Reviewer 2:

The reviewer noted that the project is considering a spectrum of biofuels and has recently had a focus on levels and types of oxygenates that can be used as drop-in fuels in practice. This reviewer also thought the scope of fuels and considerations is excellent, and is providing valuable input to stakeholders. The reviewer indicated, in particular, that the interaction with the American Society for Testing and Materials (ASTM) has high impact and has provided significant guidance to the biofuel and fuel industries.

Reviewer 3:

The reviewer commented that the presentation focused on a number of issues important to the feasibility of commercial deployment of various bio-derived fuels. Some of the issues included the long-term stability of biodiesel, and properties of specific components, some of which contain higher oxygen content and different components than traditional fatty acid methyl ester (FAME) biodiesel. The reviewer also mentioned the interesting concept of only removing some of the oxygen from bio-derived fuel components, but concluded that it will need to be thoroughly tested to evaluate the impacts on emissions and engine systems, and on the performance, durability, and materials compatibility of aftertreatment systems. This reviewer also said that blends of various alcohols that are not co-produced (i.e., ethanol and butanol) could conceivably complicate or add expenses to commercial fuel blending. The reviewer went on to say that from a logistical and economic perspective, it is likely better off to just select one alcohol to use for any fuel formulation (unless it is manufactured as a blend).

Reviewer 4:

The reviewer acknowledged several different projects, each one a year in duration. The reviewer recounted that the approach focuses on solving technical problems which are preventing expanded markets, and pointed out that both current and emerging biofuels are considered with some novel approaches. Lastly, the reviewer confirmed that drop in fuels are hydrocarbons (HCs).

Reviewer 5:

This reviewer noted that it would have been nice to see more cars, but recognized the limitations on the budget. The reviewer also thought a wider range of fuels would have been of interest. The reviewer indicated that the use of OEM strategy is appropriate, but if the budget permitted, a recalibration would be interesting for determining the best candidate 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 toward DOE goals.

Reviewer 1:
The reviewer commended solid results despite a limited sample of vehicles. The reviewer also said that it was nice to see real test data on biodiesel aging in a carefully controlled manner.

Reviewer 2:
This reviewer expressed that the project had very interesting results. The reviewer also cautioned that the emission results on a vehicle, located on Slide 10 of the presentation, have been performed at a superficial level, which makes it hard to accept any strong conclusion from this work. The reviewer applauded the very impressive range of activities, and suggested that an integration of these activities would be very valuable in illustrating the impact of this project on addressing the technical barriers. The reviewer went on to say that this will help to better evaluate the impact of this project.

Reviewer 3:
This reviewer explained that the project examined the chemical composition of pyrolysis oil to understand how much it must be upgraded in order to be a functional feedstock or fuel. The reviewer thought it addressed an important consideration for the cost-effective production of pyrolysis oil for fuels and biocrude production. The project made progress on acid content and composition, which the reviewer considered valuable, because acid content is an impediment to stability, performance, and refining. The reviewer also described that the project examined oxygenates from pyrolysis oil in diesel mixtures in order to assess impacts on fuel performance, deposits, elastomers, and other factors. The reviewer believed this to be a valuable approach for gauging drop-in capability.

The reviewer highlighted that the project made new observations of the impact of alcohol blends, including butanol, on emissions, and performed hydrogenation of potential biofuel precursors to produce better fuels for diesel applications. The reviewer remarked that this was very interesting, because some of the fuels and precursors show potential from the production side, such as bisabolene. The reviewer also highlighted very interesting results on the impact of diesel composition in the production process on the storage stability in biodiesel blends.

Reviewer 4:
The reviewer indicated an improved approach to acid characterization that differentiated between weak and strong acids, and observed that phenol shows a poor detection limit while acknowledging that the work is ongoing. This reviewer also noted a detailed characterization of oxygenated compounds, and remarked that the properties of fuels are not altered at 2% by-volume concentrations. The reviewer mentioned the milestone project involving gasoline, ethanol, and butanol blends. The reviewer pointed out that only one car was tested due to budget constraints, and carbonyl emissions increased. The reviewer stated that terpenes were characterized. The reviewer explained that hydrogenation to open the rings resulted in 2,6-dimethyl octane and farnesane. The reviewer was concerned that long term storage of biodiesel is an issue. The reviewer summarized that the project measured the oxidation stability, and that accelerated storage of 13 weeks is equivalent to 1 year. The reviewer recounted that the project is currently being finished and the last project is concerned with low temperature operability. Lastly, the reviewer remarked that FAME content influences the cloud point.

Reviewer 5:
This reviewer observed that progress was made in a number of areas. The reviewer pointed out the following to support the concept of using partially hydrotreated bio-products: an improved approach to acid characterization; and the evaluation of the effects of adding low levels of pure model compounds of residual oxygenates present in hydrotreated biomass. The reviewer also found interest in findings that older flex-fuel vehicles (FFVs) cannot or may not readily adapt to mid-level ethanol blends. Lastly, the reviewer highlighted the importance of finding that a significant fraction of the blend of 85% ethanol with gasoline (E85) that was sampled from stations around the United States did not meet ASTM Reid vapor pressure (RVP) specifications, and wondered what was being done about it.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer applauded the excellent collaboration among a team of university, National Labs, and industry, including startups.

Reviewer 2:
The reviewer commended this project for providing real leadership over a broad range of concerned parties, and thought this was a major strength.

Reviewer 3:
The reviewer thought the project showed good collaboration with bio-industry such as the National Biodiesel Board (NBB), Renewable Fuels Association (RFA), and biofuels startup companies. The reviewer also noted collaboration with OEMs through the Engine Manufacturers Association (EMA) and the Coordinating Research Council (CRC).

Reviewer 4:
This reviewer appreciated that the project is working with a long list of partners and that the team is comprehensive.

Reviewer 5:
The reviewer pointed out the fairly long list of collaborators.

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

Reviewer 1:
The reviewer remarked that the broad range of activities ranging from fundamental to practical was excellent. The reviewer observed that Impact of High Octane Biofuels on DI Engine Efficiency does not seem to be a new topic. The reviewer offered that an extensive literature survey before doing the work and comparison with other works will be very valuable.

Reviewer 2:
The reviewer commented on continuing efforts to emphasize drop-in fuel requirements and impacts. The reviewer also mentioned work on ASTM specifications, which the reviewer expressed is essential to ensure that fuels perform effectively in the marketplace. The reviewer also pointed out that the program has been responsive to AMR input.

Reviewer 3:
The reviewer suggested that the project should keep this work going.

Reviewer 4:
The reviewer highlighted future research which focuses on pyrolysis oil. The reviewer reported that ASTM specifications, high-octane biofuels, and lubricants will be evaluated.

Reviewer 5:
This reviewer thought that the plans seem reasonable.

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

Reviewer 1:
The reviewer explained that biofuels can directly displace petroleum, provided they have sufficient renewable content. However, biofuels can create a spectrum of compatibility issues. The reviewer went on to say that the work of this team is essential to find and fix the problems that biofuels can create, or to capitalize on benefits of biofuels.

Reviewer 2:
This reviewer expressed that this is a key part of the alternate fuel process.

Reviewer 3:
The reviewer asserted that the focus of this program is biofuels and biofuels blends which are non-petroleum based fuels. The reviewer indicated that if cost-effective commercial deployment of these fuels is successful, they would directly displace petroleum, which is a primary DOE goal.

Reviewer 4:
The reviewer reinforced that this project provides understanding that can be used to optimize engine and vehicle performance based on fuel characteristics, leading to fuel savings in vehicles. The reviewer added that this project centers on biofuels, which reduces the dependency on petroleum fuels.

Reviewer 5:
The reviewer stated that the project is quite relevant.

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

Reviewer 1:
The reviewer stated that the project funding was sufficient in the previous year. The reviewer emphasized that because of its significant impact on the fuels industry, this project should be insulated from funding disruptions in the present and next project years. The reviewer went on to recommend that the VTO should continue to support this project to ensure progress on this important activity.

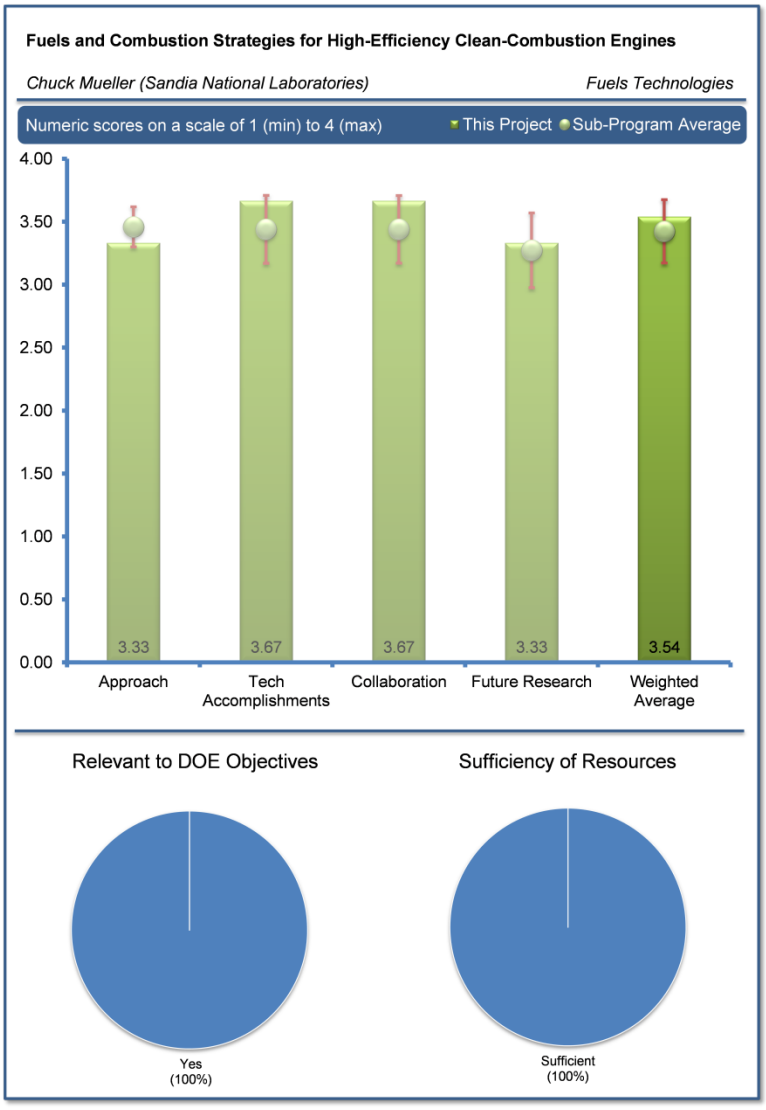
Reviewer 2:
The reviewer said that sufficient budget was available.

Reviewer 3:
The reviewer expressed that resources seem sufficient.

Reviewer 4:
The reviewer said the project had a generally appropriate level of funding, although a larger test fleet would be nice.

Reviewer 5:
The reviewer suggested that more cars should be tested in gasoline, butanol, and ethanol blends. The reviewer cautioned that the data are too preliminary to draw conclusions.

Fuels and Combustion Strategies for High-Efficiency Clean-Combustion Engines: Chuck Mueller (Sandia National Laboratories) - ft004



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

This reviewer affirmed a good approach of selecting fuels from the Fuels for Advanced Combustion Engines (FACE) Diesel matrix to study the effects of fuel properties on mixing controlled combustion in an optical engine with a variety of diagnostic tools. The reviewer observed that development of a fuel-flexible high pressure common rail system sounded like it filled an existing gap.

Reviewer 2:

The reviewer reinforced that the approach of using existing diagnostic capabilities, in collaboration with key stakeholders and the technical expertise from the laboratory, has proven to be an excellent technique to evaluate fuel effects on combustion for high efficiency clean combustion (HECC) engines.

Reviewer 3:

The reviewer recounted that the project had used the heavy-duty optical engine to probe fuel and combustion process impacts on efficiency. The reviewer mentioned that through partnerships with engine and fuels companies, as well as labs and universities, the project is considering fuel impacts on mixing controlled combustion, and pyrolysis oils as fuels in addition to looking at lean lifted flame combustion (LLFC). The reviewer emphasized the project's use of optical diagnostics and conventional combustion studies to achieve project objectives and add a unique ultra-high-pressure common rail. The reviewer noted that the project developed a comprehensive approach for studying the effects of fuels on mixing controlled combustion, which involves a combination of diagnostics and a two-hole injector to eliminate jet-jet interactions. The reviewer described that for LLFC and conventional combustion, the project is using P-trace, thermodynamics, emissions (including laser-induced incandescence [LII] of exhaust soot), and in-cylinder diagnostics to characterize effects of fuel and injection strategy on the spray and the combustion processes.

Reviewer 4:

The reviewer stated that the project is well organized, and based on 2011 comments, the project is on track.

Reviewer 5:

The reviewer commented that the approach is good in looking at the interplay between fuels and engine combustion parameters, and in developing methodology that can be used for evaluating fuels and mixing controlled engine strategies. However, the reviewer noted that presentations are sometimes confusing in distinguishing whether leaner lift-off is a key parameter to be targeted in all mixing control strategies, or simply the initial strategy being evaluated – and the reviewer wondered whether it will apply to all fuels. The

reviewer cautioned that despite the response to last year's comment, it is still not clear the extent to which fuel parameters of alternative and renewable fuels will be amenable to engineering versus pre-determined by the feedstocks and economics of processing them. The reviewer suggested that what may be amenable to such designing could be more conventional fuels and possibly blends of conventional fuels with renewable fuels, or possibly mixtures of different renewable fuels, etc. The reviewer recounted that in response to an oral question, the PI confirmed that such blends are planned to be looked at after heavy esters but it was not identified in the presentation slides. The reviewer offered that presentations might benefit from using less generic or abstract language and describing more specifically how the tools being developed would be used – other than in theoretical exercises indicating that a fuel with ideal properties used in an engine designed and optimized specifically for that fuel would not produce soot. The reviewer explained that many alternative and renewable fuels have been promoted as beneficial when used in such purpose-built engines but such engine-fuel combinations are simply not feasible. Lastly, the reviewer indicated that the presentation talked about a parametric study of five fuels, but did not identify what they were and did not mention the results.

Reviewer 6:

The reviewer said that the project approach is reasonable, though integration with modeling efforts will help to better address the technical barriers of creating predictive tools for fuel property effects on engine efficiency and emissions.

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

Reviewer 1:

The reviewer applauded the technical accomplishment of quantifying fuel effects on mixing controlled combustion, saying it was excellent. The reviewer emphasized that showing how fuel property changes can significantly affect emissions and showing that differences cannot be offset by changing combustion phasing were both important results. The reviewer also asserted that the development and building of a high pressure common rail fuel supply system is a major accomplishment and will be used in future analysis of fuels.

Reviewer 2:

The reviewer thought that the LLFC information was very valuable. The reviewer explained that spray geometry, coupled with designer diesel fuels, could potentially obviate the need for particulate filters. The reviewer explained that this approach is comparable to particulate benefits seen in the Mercedes Benz (MB)/Bosch spray-guided fuel injection and stratified lean burn combustion.

Reviewer 3:

The reviewer mentioned that progress has been good. The reviewer acknowledged that diesel fuel property effects on engine performance and emissions were studied under mixing controlled conditions. The reviewer pointed out the assessment based on available literature data, concluded that the use of raw liquids from fast pyrolysis of woody biomass was not very feasible in current compression ignition (CI) engines because of issues such as instability, corrosion, and poor injection quality. The reviewer also highlighted the modified engine that enabled injection pressures up to 3,000 bar.

Reviewer 4:

The reviewer remarked that high-pressure common-rail fuel-supply system (HCFS) is valuable equipment set for the fuel research community. The reviewer noted that the results on the Slide 3 (i.e., Quantifying Fuel Effects on Mixing- Controlled Combustion) were very interesting, and pointed out that further work to better understand the results is essential.

Reviewer 5:

The reviewer noted that the detailed impacts of fuel on emissions using FACE and reference fuels were demonstrated, and new understanding and careful measurements of sensitivity of diesel combustion to fuel variations were generated.

The reviewer reported that pyrolysis oil was assessed for direct use as a diesel fuel. The reviewer indicated that the fuel has a great deal of water, high corrosivity, and other problems; and it needs to be refined or upgraded before use.

The reviewer also acknowledged development of a fuel-flexible high-pressure common rail system that is hydraulically driven.

Reviewer 6:
The reviewer acknowledged that data and analysis is still in progress on the fuel parametric study. This reviewer commented that the literature search on pyrolysis oils seems to be somewhat of a diversion from the project itself. The reviewer indicated that it was apparently responding to the instigation of one of the industry partners, whom the reviewer thinks should probably have conducted such a literature search on its own, outside of this project. The reviewer commended the development of a robust fuel delivery system and characterized it as an important achievement pre-requisite to future experiments but cautioned that that achievement alone appears to fall short of the expectations of what was to be accomplished over this year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer expressed that collaboration and coordination with other institutions is excellent in this project. The reviewer stated that combustion research with the AEC working group helps provide for improvements to the project. The reviewer acknowledged that discussing the projects with OEMs and energy companies is a very good practice. The reviewer applauded the project for working with the CRC on surrogate diesel fuel research, which brings a high quality of technical expertise to the project.

Reviewer 2:
The reviewer noted very strong collaboration among a team of 27 industries, universities, and National Laboratory partners.

Reviewer 3:
The reviewer said that through the Advanced Combustion MOU and other partnerships, this work links to industry, other labs, and university partners. The reviewer noted that this project holds a leadership position in CRC work on diesel fuel research, and that there are many fruitful collaborations in place.

Reviewer 4:
The reviewer thought it seems like a good, direct, collaboration with Ford and Caterpillar. The reviewer also mentioned collaboration with the members of the CRC's Project 18 under Advanced Vehicle/Fuel/Lubricants (AVFL-18) on development of improved surrogate diesel fuels. The reviewer noted that the members of the AEC MOU were mentioned, but no specifics were given on how extensive those collaborations are beyond the time period for the two presentations made at those meetings per year.

Reviewer 5:
The reviewer remarked that the broad group of project partners appears to include members from all key industries, but described the reference to energy companies as a broad and vague term. Further, because the individual companies were not named, it could not be determined by the reviewer if they reflected an adequate base within the industry or merely a group of companies interested in promoting their own alternative fuels and identifying opportunities in alternative fuels, rather than a realistic perspective on the following: extent to which identified fuel parameters are economically achievable; required critical mass/economies of scale; and chicken-and-egg issues between fuel and engine availability, etc. The reviewer commented that these issues do not negate the desirability of developing the analytical tools being developed in the project, but that they are important in setting priorities for future research directions, applications, etc.

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

Reviewer 1:
This reviewer remarked that evaluation of the effects of oxygenated fuels and engine testing of diesel surrogate fuels in the future will provide valuable data, and continuation of the work with CRC Project AVFL-18a is important.

Reviewer 2:

This reviewer claimed to be looking forward to the study being performed on FAME to assess the oxides of nitrogen (NO_x) and soot effects. The reviewer suggest that additional studies may benefit from the combination of the new high pressure fuel pump system developed, since there may be interactions between FAME stability or polymer formation and fuel pressure and temperature during adiabatic expansion during injection.

Reviewer 3:

The reviewer mentioned that the project will survey fuel and combustion processes using the evaluation strategy, including biofuels and surrogates, and will continue the development of surrogate diesel fuels in collaboration with CRC. The reviewer wondered whether this effort can help guide the formulation and production of next generation fuels (i.e., an ultimate biodiesel) and noted that this point was not addressed in this year's presentation. The reviewer highlighted that the work from this engine could guide fuel production, not just formulation and that the work from this facility has had great impact in the past and should also have impact on the future work that is planned.

Reviewer 4:

The reviewer commented that the focus on fuel surrogates is plausible because it can provide a more general approach for creating predictive tool to characterize fuel effects on engine emissions and performance.

Reviewer 5:

The reviewer described that plans to complete the analysis of the engine test results of the FACE Diesel fuels, engine testing of the CRC AVFL-18a diesel surrogate fuels, and development of a better understanding of in-cylinder soot formation, distribution, and oxidation, are good and worthwhile. The reviewer commented that the value of testing biodiesel esters and heavy ethers will depend on the specific compounds and the concentrations investigated. For example, the reviewer explained that it is well known that FAME has properties that limit concentration that can be used. Another issue the reviewer brought to light is whether the ethers will be tarred by the same brush as methyl tertiary butyl ether (MTBE), despite having different properties and water solubilities.

Reviewer 6:

The reviewer cautioned that continuing work on biodiesel ethers and heavy esters is valuable but it should be remembered that biodiesel continues to cost substantially more than petroleum diesel to produce so that its use as a neat fuel is probably limited; and there has been considerable work on heavy ethers as CI fuels for many years but essentially no use of the ethers in the marketplace. The reviewer pointed out that the PI confirmed that work on more conventional HC type CI fuels (and their blends with oxygenates), which can also be made from renewable feedstocks, is anticipated, but it was not part of the presentation, only in response to a question. The reviewer added that HC fuels may be more amenable to an adjustment of properties than oxygenates and the blends may be further amenable and such knowledge may have much more immediate application on wider scale.

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

Reviewer 1:

The reviewer noted that HECC can lead to improved efficiency and broaden the types of fuels used in transportation, both leading to reduced petroleum consumption. The reviewer acknowledged this effort is producing high impact results and has both great depth and long-term value.

Reviewer 2:

The reviewer thought that improved fundamental understanding of high efficiency, clean combustion engines and the understanding of fuel properties that can help enable them should ultimately result in improved engine efficiency and possible use of alternative fuels, both of which would reduce petroleum requirements.

Reviewer 3:

The reviewer stated that the objective of this project to develop a science base to enable high efficiency, clean combustion engines using fuels that improve energy security is definitely relevant.

Reviewer 4:
The reviewer remarked that, yes, this project could lead to soot mitigation without need for aftertreatment, which would substantially displace petroleum through greater efficiency. The reviewer also said that it could point to better strategies for utilization of renewable fuel alternatives.

Reviewer 5:
The reviewer noted that this project provides understanding which can be used to optimize engine performance based on fuel effects on mixing controlled combustion, leading to fuel saving in IC engines.

Reviewer 6:
The reviewer remarked that the project incorporates advanced fuels with constituents other than petroleum and incorporates the potential fuel savings from LLFC and reduced soot formation, requiring reduced soot burn off.

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

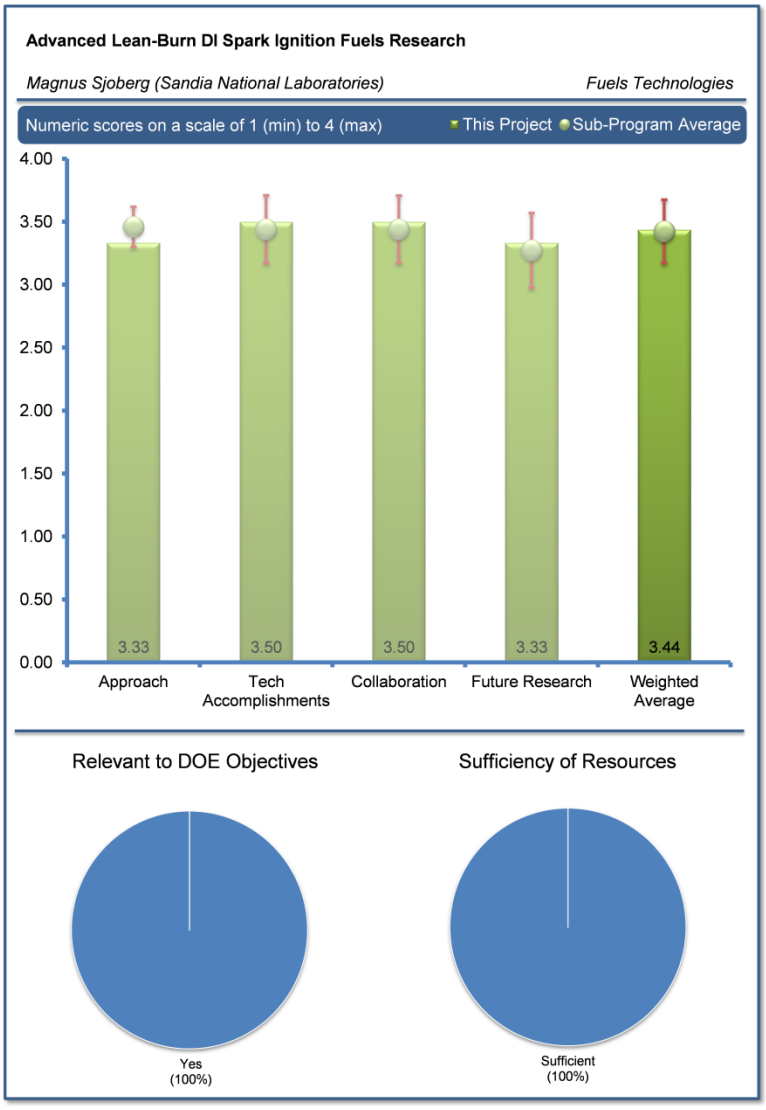
Reviewer 1:
The reviewer stated that funding seems sufficient and stable.

Reviewer 2:
The reviewer noted milestones are being met on timely basis, which suggests resources are sufficient.

Reviewer 3:
The reviewer indicated that for the work proposed, the resources seem adequate.

Reviewer 4:
The reviewer remarked that resources appear to be appropriate to the objectives and work plan.

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



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 described that the project is using a DISI spray guided engine system, which provides significant insights into combustion process optimization. The reviewer observed that the project is exploring limits of combustion stability under lean stratified conditions by blending ethanol and gasoline and doing experiments in optical and metal engines, and using the optical engine to probe specific conditions to further their understanding. The reviewer indicated that the project is developing the understanding to overcome barriers to higher efficiency engines. The reviewer commended the project, saying that overall, this is a strong technical approach and the tools being employed can provide transformative increases in understanding.

Reviewer 2:

The reviewer applauded the good approach of combining metal engine tests with optical engine tests and computational fluid dynamics (CFD) and kinetic modeling. The reviewer noted that the project had a strong mix of modeling and experiments (optical engine and metal engine) to understand the fuel effects on combustion for DISI engines.

Reviewer 3:

The reviewer described that the project's approach of using engines, then applying to CFD, extends the value of the data obtained into the modeling domain.

Reviewer 4:

The reviewer asserted that the approach of combining metal and optical engine experiments and modeling to develop a broad understanding of the impact of fuel properties on engines has proven to be a very good technique. The reviewer reinforced that this project addresses barriers to high efficiency and low emissions by increasing the knowledge base.

Reviewer 5:

This reviewer remarked that the PI has defined the project as providing a scientific basis for determining fuel characteristics to enable advanced combustion engines that would be as efficient as possible, and possibly reducing emissions to the point where aftertreatment may no longer be needed. The reviewer asserted that this scientific basis should be important for a range of future research. The reviewer remarked that the specific research performed to date could also be useful in future engine design to the extent that it shows

that gasoline combustion and E85/70% ethanol blend with gasoline (E70) combustion share characteristics to some degree that point to possible future design improvements.

The reviewer referred to the research that shows significant differences in combustion behavior between E85 and gasoline, with E85 being less sensitive to mixing irregularities, and the need for near top dead center (TDC) injection for E85 head ignition, etc. The reviewer then described the value of this part of the research as questionable and thought perhaps the value of it was never explained so that non-expert reviewers could see it readily. The reviewer explained that for many reasons, there is little chance of engines being purpose-built or even optimized to take advantage of the characteristics of E85/E70, particularly to the extent that they run contrary to the optimization for gasoline operation, which appears to be what this research shows (e.g., retarding spark timing to avoid head ignition, effects of temperature, etc.) unless future engines were to reincorporate fuel sensors that would adjust the spark timing, etc., according to the ethanol content or oxygen content of the fuel, which seems doubtful.

The reviewer elaborated that by defining the work's purpose as providing scientific understanding, the approach and accomplishments appear to be more favorable than if it was defined as overcoming actual barriers to specific technology developments. The reviewer expressed that the presentation does not make clear that it is actually providing such a broad scientific basis but focuses on differences and similarities between gasoline and E85/E70 rather than on development of analytical tools per se.

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

Reviewer 1:

The reviewer noted that the project examined E85 operation with near-TDC fuel injection and showed ultra-low nitric oxide (NO) and soot emissions. The reviewer remarked that the project performed particle image velocimetry (PIV) measurements of in-cylinder flows during compression and the role of air flow on well mixed and stratified operation, showing that mixing is needed to avoid soot formation for a gasoline type fuel, but that there is less sensitivity to mixing for ethanol. The reviewer acknowledged the further examination of the NO_x-PM trade-off using a spectrograph to show what species are present for operating conditions, and noted that one could see evidence of excessively rich conditions based on the spectra observed. The reviewer stated that the fact that late high pressure injection leads to rapid mixing and cooling of products, which reduces/circumvents NO formation, was a very interesting result. The reviewer complimented that the experimental approach and design are really outstanding, and the ability to interpret the observations to yield important insights is a great strength of this project.

Reviewer 2:

The reviewer acknowledged the good progress that was made on identifying the potential benefits and issues associated advanced lean burn DISI with high ethanol content fuels. The reviewer cautioned that work was still needed to determine whether this concept has enough benefits to pursue development.

Reviewer 3:

The reviewer offered that accomplishments and progress has been very good, especially the examination of E85 operation with near TDC fuel injection for ultra-low NO and soot and the comparison of E85 and gasoline showing NO emissions much lower with E85.

Reviewer 4:

The reviewer remarked that by defining the project in terms of gaining understanding, accomplishments seem to be significant even if the results are not encouraging in terms of overcoming actual barriers. The reviewer characterized that it is not clear how broad the applications of the analytical tools actually being developed are, since the focus of the presentation is on a specific application - gasoline versus E85 on DISI and focusing on a few combustion properties, which may be key to DISI more broadly, but that was not clear from the presentation.

The reviewer elaborated that the presentation did not clearly describe whether the results of this year's research point to ways in which both gasoline and E85/E70 combustion could be jointly made more efficient with lower emissions versus the extent to which the two require conflicting engine changes. That seems to be the key to coming to any practical conclusion from the research. As an example,

the reviewer explained that if the two are largely incompatible, that is an important lesson, which may suggest that future FFVs should work on optimizing at lower ethanol levels, although automakers seem to be coming to that conclusion independently of this research.

Reviewer 5:
The reviewer indicated insightful results for the impact of in-cylinder flow field on stratified-charge combustion. The project provides a very good understanding for the impacts of fuel on engine performance. However, the reviewer went on to say that given the large combustion control space parameter, the results still does not provide predictive tools or models for fuel property effects on engine efficiency optimization. Developing a proper model as a predictive tool will be very valuable for optimizing engine performance.

Reviewer 6:
The reviewer explained that understanding the effects of fuel ethanol blend on stratified injection and combustion is a key success since ultimately, un-throttled operation will remove one of the largest inhibitors to increased efficiency in the spark ignition (SI) engine.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer recounted that the project has active collaborations with different partners, including university partners, through direct collaborations and through involvement in the Advanced Combustion MOU.

Reviewer 2:
This reviewer described that the project's primary industry collaboration appears to be with GM on hardware issues/supply. The members of the AEC MOU are mentioned, but it is unclear how much collaboration actually exists outside of the information that is disseminated and questions that are asked at the semi-annual meetings. The reviewer wondered if perhaps the collaborations with AEC MOU members are outstanding, but had no information to make a determination. The reviewer also noted collaboration with USC on flame measurement and corona ignition.

Reviewer 3:
The reviewer mentioned that the collaborations with GM, University of Michigan and the 15 industry partners in the AEC MOU makes for a strong team to support this project.

Reviewer 4:
The reviewer remarked that the presentation identifies an adequate list of collaborators with appropriate technical roles identified for each, but does not appear to include any role for ongoing discussion of practical applications as related to future research directions.

Reviewer 5:
This reviewer characterized very strong collaboration among a team of 17 industry, university, and National Lab partners.

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

Reviewer 1:
The reviewer noted the continuation of ongoing work and the addition of an advanced ignition system. The reviewer indicated that the work to date is very informative, and expects that the continuing work will be equally significant.

Reviewer 2:
The reviewer expressed that plans to further pursue a fundamental understanding and evaluation of this concept are reasonable.

Reviewer 3:
The reviewer asserted that future work planned both of the continuation of projects, and the initiation of examining the use of advanced ignition for lean combustion, will continue to provide valuable results.

Reviewer 4:
The reviewer recounted that presentation indicated that effects of ethanol fuel blends will continue to be studied across the range of 0% ethanol blended with gasoline (E0)-100% ethanol (E100), which could include some blend levels that would be particularly relevant [e.g., 10% ethanol blended with gasoline (E10)-30% ethanol blended with gasoline (E30)], but is not more specific than that. The reviewer was concerned with the relevance the project believes the E100 range could have. While this research could continue to provide some scientific and theoretical understanding, this reviewer saw no reason why it should not focus on fuels that are likely to have practical results. E85 has already been shown to be too high a blend level for most applications and there is no question of E100 being a practical fuel for the United States. Moreover, gasoline-ethanol blends involve complex interactions between the ethanol and HC molecules so that merely studying straight gasoline and E100 does not necessarily express much about how the blends will behave. The reviewer suggested that it would make more sense to vary not only the ethanol concentration within a meaningful range, but also to vary the specific HC composition, particularly with those HC groups most prone to forming azeotropes with ethanol as well as those not so prone to do so.

Lastly, the reviewer stated that that the future research is proposed entirely of highly technical phenomena, whose relevance is not explained at all and is incomprehensible.

Reviewer 5:
The reviewer noted that the future approach is well planned with sufficient details.

Reviewer 6:
The reviewer offered that concentrating on mid-blends [20% ethanol blended with gasoline (E20)-50% ethanol blended with gasoline (E50)] in conjunction with stratified combustion, will provide a forward look at SI engines of the future. Combining prior research on this project with turbocharged induction (as MB has with their HOS homogeneous stratified lean burn combustion) will reveal even greater benefits.

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

Reviewer 1:
The reviewer explained that lean un-throttled SI spray guided engines can provide substantial improvements in FE and thereby displace petroleum. Efficiency gains can be 30-60% depending on the operating condition relative to conventional combustion.

Reviewer 2:
The reviewer observed that the objectives of determining fuel characteristics that enable current and emerging advanced combustion engines to be efficient is relevant to DOE goals of petroleum displacement.

Reviewer 3:
This reviewer stated that if this engine approach/concept is successful with fuels that contain high amounts of ethanol, then presumably fuel efficiency will be improved and lower amounts of petroleum derived gasoline components will be needed.

Reviewer 4:
The reviewer emphasized that this project provides understanding of, and a tool for, the optimization of engine performance based on fuel characteristics, which can lead to fuel savings in IC engines. The reviewer also recounted that it includes the study of bio-fuel blends, which reduces the dependency on petroleum fuels.

Reviewer 5:
The reviewer remarked that the project helps relate the effects of ethanol (EtOH) fuels on lean burn combustion, which has the potential to further reduce the gap to CI thermal efficiency.

Reviewer 6:
The reviewer expressed that improving the scientific understanding of DISI combustion to make it more efficient could indirectly lead to petroleum displacement. But in order for that to be true, the reviewer explained, the project either needs to focus much more on more relevant applications and/or needs to be explained much better, leaving out if necessary the hyper-technical minute details and explaining what has really been accomplished and what is planned for future work.

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

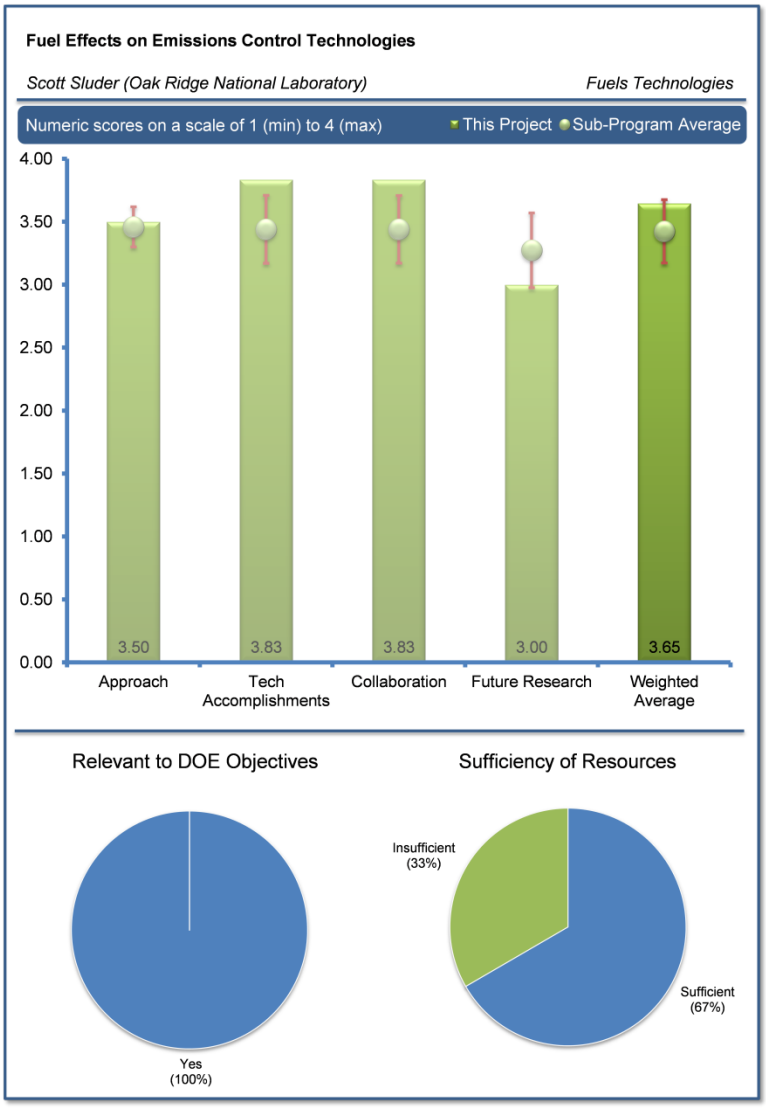
Reviewer 1:
This reviewer noted that funding seems sufficient and is stable.

Reviewer 2:
Reviewer stated that resources seem sufficient.

Reviewer 3:
The reviewer commented that the resources are sufficient for the projects identified.

Reviewer 4:
The reviewer felt that given the nature of this research, this level of resources is required. However, as described above, the relevance needs to be better defined or better explained in order to justify this commitment of resources.

Fuel Effects on Emissions Control Technologies: Scott Sluder (Oak Ridge National Laboratory) - ft007



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 recounted that the project is examining fuel impacts on exhaust gas recirculation (EGR) cooler fouling, which is an activity that is wrapping up. The reviewer also mentioned that the project is examining ways to make the most of alcohols in fuels to achieve lean-NO_x reduction, and examining biodiesel impacts on emissions control devices. These efforts rely on the high quality facilities and methodologies developed at ORNL, which permits significant new knowledge generation.

Reviewer 2:

The reviewer noted the project's approach of using engine tests coupled with micro- and bench reactors seems like a good approach.

Reviewer 3:

This reviewer remarked that the approaches used in the various tasks seem well thought out and executed. It was identified that high boiling point HC emissions have a strong influence on EGR plugging, but there seemed to be little information on how biodiesel effected these HC emissions. The reviewer pointed out that in this particular program, the question of whether biodiesel blends and other non-traditional fuel formulations worsen cooler fouling does not seem to have been answered; although it could be simply a lack of understanding of this reviewer or perhaps the data was not presented because of time constraints.

Reviewer 4:

The reviewer remarked that the approach involving engine data and modeling-based output provides greater leveraging of data.

Reviewer 5:

The reviewer thought that the project's approach directly addresses the challenge of inadequate data on the long-term impact of fuel on emissions control systems, but it is unclear how the results from this work will address the following barrier of inadequate predictive tools for fuel effects on emissions and emission control system.

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

Reviewer 1:
The reviewer acknowledged that the project showed that HC deposition in the fouled layer in the EGR cooler deposits lead to stabilization of the heat transfer effectiveness loss, even though deposition continues. The deposit does not need to be removed to achieve stabilization, and no fuel effect on stabilization was observed. The reviewer indicated that this is a significant result in that there have been concerns that biodiesel could worsen fouling effects. The project provided important observations on means of avoiding plugging.

The reviewer reported that silver-alumina catalysts can enable generation of ammonia (NH_3) using ethanol as a reductant. The project demonstrated on a flow reactor that NH_3 production can be very effective from ethanol. So, combination of lean burn with ethanol, combined with an ethanol selective catalytic reaction (SCR) (via the NH_3) could provide a much improved scenario for high ethanol fuel blends, overcoming the tank mileage penalty of E85 (for instance) and enabling high efficiency with higher ethanol blends.

The reviewer described how the project showed that among typical biodiesel contaminants [calcium (Ca), sodium (Na), potassium (K)], poisoning from Ca was much less severe than for Na and K. The reviewer mentioned that the project showed that out-of-specification biodiesel could lead to emissions system failure, although biodiesel within specifications did not impede meeting emissions at 150,000 miles. This gives the biodiesel industry guidance for ensuring compatibility with future vehicles systems that will need to meet more stringent emissions legislation.

Reviewer 2:
The reviewer commended the fact that accomplishments have been made in several areas, including better understanding of causes of EGR cooler fouling from biodiesel. The determination of effects of metals (Na, K) in biodiesel on the diesel oxidation catalyst (DOC) and SCR catalysts, and the discovery that ethanol can improve lean NO_x control over Ag/Al_2O_3 catalyst were also acknowledged by the reviewer.

Reviewer 3:
The reviewer observed that the researchers have made significant progress toward understanding fuel effects on various emissions control systems. The understanding of the role of Na and K in the substitution of copper (Cu) in the zeolite could lead to more effective, longer lasting diesel emission systems. The reviewer indicated that this will definitely be a benefit to OEMs, as well as their customers. The shift from fundamental investigations to bench-reactor based performance studies has demonstrated the ability to produce NH_3 without the normally required rich cycle or onboard urea. Lastly, the reviewer remarked that the role of high boiling point HC on the formation of EGR deposits should lead to a more sophisticated fuel or combustion based approach to reducing EGR deposits.

Reviewer 4:
The reviewer asserted that the project provides interesting and conclusive results on two topics: the effect of biodiesel blends on EGR cooler fouling; and biodiesel compatibility with catalytic converters.

Reviewer 5:
This reviewer stated that there were two key points. Fuel composition on EGR fouling and plugging is important because the reviewer's field data illustrates intake and EGR fouling is associated with polymeric deposits and with oxidized biodiesel. The reviewer also pointed out that the impact of EtOH blends on lean-NO_x reductant generation and particulate formation in conjunction with other studies (un-throttled lean burn) has the potential to further reduce the gap between diesel and gasoline efficiencies.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted the wide-ranging collaboration with industry, academia, and other labs.

Reviewer 2:
The reviewer thought the project appears to have very good collaboration that has been setup with the OEMs, for example, Cummins, Ford, GM, and Cross-Cut Lean Exhaust Emission Reduction Simulation (CLEERS) members. Other collaborations included NREL and NBB for biofuels issues, as well as several universities including University of Tennessee, University of Michigan, and Chalmers University.

Reviewer 3:
The reviewer reported that collaboration with universities and industry are strong and should lead to marketable solutions.

Reviewer 4:
The reviewer summarized the project's strong collaboration among a team from industry partners, universities, and National Labs.

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

Reviewer 1:
The reviewer said that the identified future research seems appropriate and builds on past work. The reviewer believed that lubricant effects such as phosphorus have been studied by both OEMs and the lubricant industry, and hoped that this proposed research has taken into account these earlier studies.

Reviewer 2:
The reviewer explained that the plans are to continue the work on ethanol lean NO_x and biodiesel impacts.

So far, the biodiesel used is conventional soy oil derived biodiesel. The reviewer suggested that given the amount of interest in algal biodiesel, it would be interesting to consider the peculiar FAME profile and trace contaminants composition for algal fuels and how that might impact EGR coolers, and aftertreatment devices.

Reviewer 3:
The reviewer affirmed plans to continue and complete the work in progress as well as ramping up work on phosphorus degradation of aftertreatment devices and the impacts of fuel and lubricant on PM formation.

Reviewer 4:
The reviewer stated that planned future activities are logical, and indicated more emphasis can be directed to the challenge of providing predictive tools for fuel effects on emission and emission control system (Barrier 2.4D).

Reviewer 5:
The reviewer suggested incorporating aged biodiesel starting at or near zero-hour induction period (IP) and increasing in acid number to potentially arrive at a similar failure mechanism to EGR and intake sludging when compared to warranty field returns.

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

Reviewer 1:
The reviewer pointed out that as mentioned at the outset of the project overview, ethanol and biodiesel are common alternatives to petroleum. Given these alternatives are generally more mature, and have penetrated the market, it seems logical to conduct research to optimize their use.

Reviewer 2:
This reviewer remarked that identification and successful resolution of issues associated with use of biofuels in engines would decrease dependence on petroleum.

Reviewer 3:
The reviewer mentioned that this project addresses the fuel technology barriers with regard to higher efficiency combustion and lower emissions as well as addressing the risks of fuel formulation impacts on engine aftertreatment systems.

Reviewer 4:
The reviewer remarked that this project centers on emission controls challenges for using biofuels. Understanding these challenges helps to overcome the barriers to viable biofueled powertrains, helping to reduce the dependency on petroleum fuels.

Reviewer 5:
The reviewer stated that EtOH and lean-burn is a powerful combination both for the fuel efficiency and renewability aspects and the specific power output.

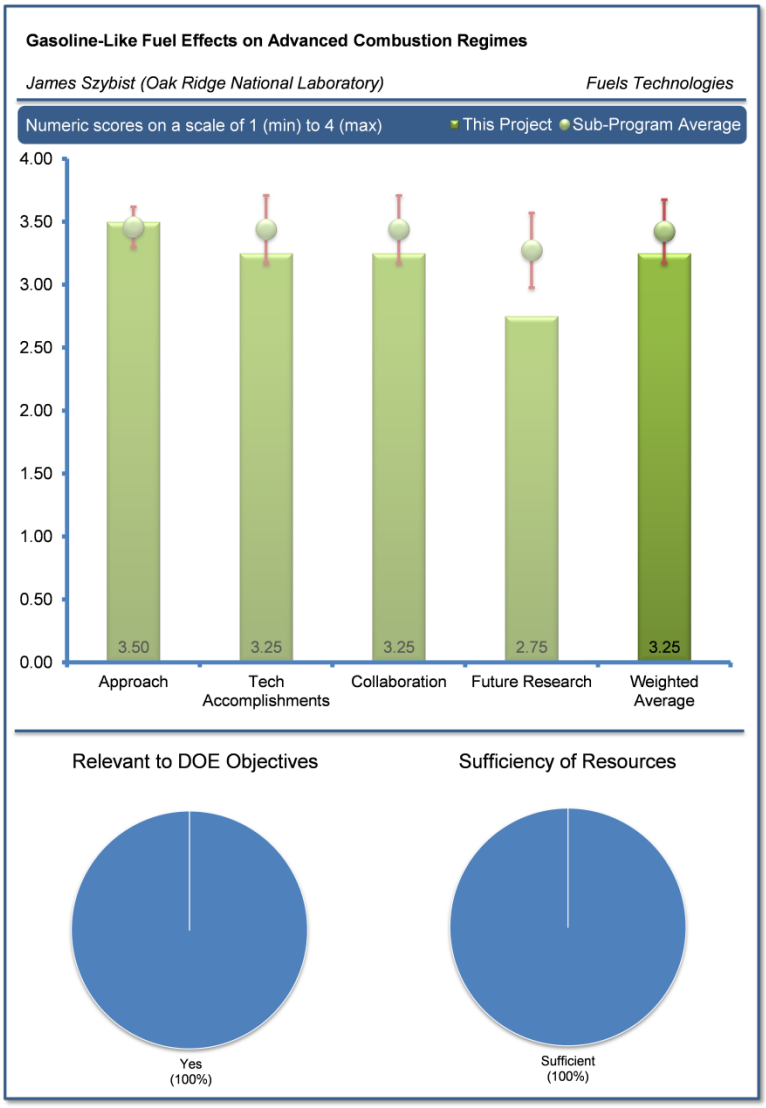
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the funding level has been dramatically cut and may not be permitting the project to overcome the barriers to improving emissions performance of high efficiency engines.

Reviewer 2:
The reviewer stated that given the importance of emission reduction, FE, and finding acceptable alternatives to petroleum, the resources appear to be insufficient. In addition, as fuel and lubricant research matures, there will likely be more need for engine testing, which requires significant resources.

Reviewer 3:
The reviewer said that resources seem sufficient.

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



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 the outstanding approach using fundamental understanding of the problem through CHEMKIN simulation to single cylinder engine testing, multi-cylinder engine testing and vehicle simulations. Excellent to see these integrated results in one project.

Reviewer 2:

The reviewer commended the nice experimental approach to a couple of good questions.

Reviewer 3:

The reviewer remarked that the project is a good combination of engine tests with Autonomie simulation. Engine platform has been designed to be flexible and permits a range of operating conditions and advanced combustion modes to be studied. The reviewer applauded that the RCCI concept was being tested in a multi-cylinder engine. Some tests were done with six-stroke engine operation and others with methanol (severe health issues). The reviewer was not certain if either are commercially viable, but felt they are okay for R&D. The reviewer also mentioned that some tests were done with renewable super premium, containing 30% ethanol. While this would increase use of ethanol and possibly have engine performance and emissions benefits, the reviewer wondered if those are paper benefits (i.e., for economic reasons, many owners of vehicles today that require or recommend the use of premium fuel use lower grades and those that have FFVs and access to E85 do not always use it). The reviewer wondered how many drivers would be willing to pay more for super-premium and actually fuel vehicles with it.

Reviewer 4:

The reviewer recounted that the project is characterizing the fuel chemistry in a single cylinder engine. The reviewer described the project's use of multimode RCCI combustion, multimode HCCI engine mapping. The reviewer pointed out that the multi-cylinder approach to RCCI is used by ORNL. The reviewer acknowledged that a different engine platform and multiple combustion strategies are used, along with three different fuels. Single zone CHEMKIN modeling is used to assist in analyzing negative valve overlap (NVO) chemistry.

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

Reviewer 1:
The reviewer acknowledged that two out of three of the high-level DOE milestones have been met with the third one on track for being met. The project demonstrated that use of a blend of 20% neat biodiesel (B20) in place of conventional diesel expands RCCI operating range by about 14%. The reviewer remarked that the drive cycle simulation work led to the claim that over 70% of the drive cycle can be covered by RCCI. The reviewer found the results on the NVO studies at lean conditions and use of oxygenates interesting.

Reviewer 2:
The reviewer reported interesting results on RCCI, and an interesting experiment on NVO, but thought it would be nice to see more of the intermediate and reforming products and their effect on combustion.

Reviewer 3:
The reviewer affirmed that biodiesel allows RCCI load expansion, and increased RCCI coverage improves FE. The project spanned a wide range of fuels in six-stroke engines. The reviewer mentioned that HCCI kinetics are impacted by fuels undergoing reforming, and that the project is on track for three fuels and a single cylinder engine.

Reviewer 4:
The reviewer commended the project's excellent progress, and wondered if the simulation results from Autonomie will be reliable for transients in a FTP cycle, given the project has only used steady-state maps.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that the collaboration list includes OEMs such as GM, Chrysler, Ford, MAHLE, the American Council of Engineering Companies (ACEC), CLEERS and several universities including University of Wisconsin and University of Michigan. As with most of the presentations, it is difficult to tell just from the list how frequent and extensive the level of collaboration is.

Reviewer 2:
The reviewer noted solid interaction with the combustion community.

Reviewer 3:
The reviewer mentioned collaboration with Sandia National Laboratories, ACEC, GM, and universities. The high-octane fuel symposium was a result of several investigations. The reviewer explained that the E20 optimum for efficiency advantages can overcome the energy density penalty when using E20 in an optimized engine.

Reviewer 4:
The reviewer commended strong collaboration among a team from industry, university, National Lab, and 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 plans seem reasonable.

Reviewer 2:
This reviewer commented to investigate alternative fuels.

Reviewer 3:
The reviewer thought that the future work does not clearly show how the barrier of creating predictive tools for fuel property effects on combustion and engine efficiency optimization will be tackled.

Reviewer 4:
The reviewer indicated that the RCCI work needs to address the real issues with RCCI. First, the cold start FTP. The reviewer noted that 90% of emissions are made in the first 60 seconds of running on the FTP. The reviewer pointed out that no one ever seems to try running cold, so the major emission issues are not addressed. Second, the reviewer thought the project should address real world FE. There are already complaints that downsized and boosted engines are not getting the expected FE improvement in the real world. RCCI does not fully cover the limited FTP and Highway Fuel Economy Test (HWFET) range; one needs to look at US06 Supplemental Federal Test Procedure (SFTP/US06) and real world conditions.

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

Reviewer 1:
The reviewer said the project is quite relevant.

Reviewer 2:
The reviewer stated that the focus of this program is the evaluation of bio-based fuel blending components to improve the efficiency and lower the emissions in engines operated in advanced combustion modes. If successful, this would directly displace some petroleum use in the vehicles fuels market.

Reviewer 3:
The reviewer mentioned the contribution to high fuel efficiency.

Reviewer 4:
The reviewer indicated that this project provides understanding for optimizing engine performance based on fuel characteristics and combustion mode, leading to fuel savings in IC engines. It also includes a study of biofuels which reduce the dependency on petroleum fuels.

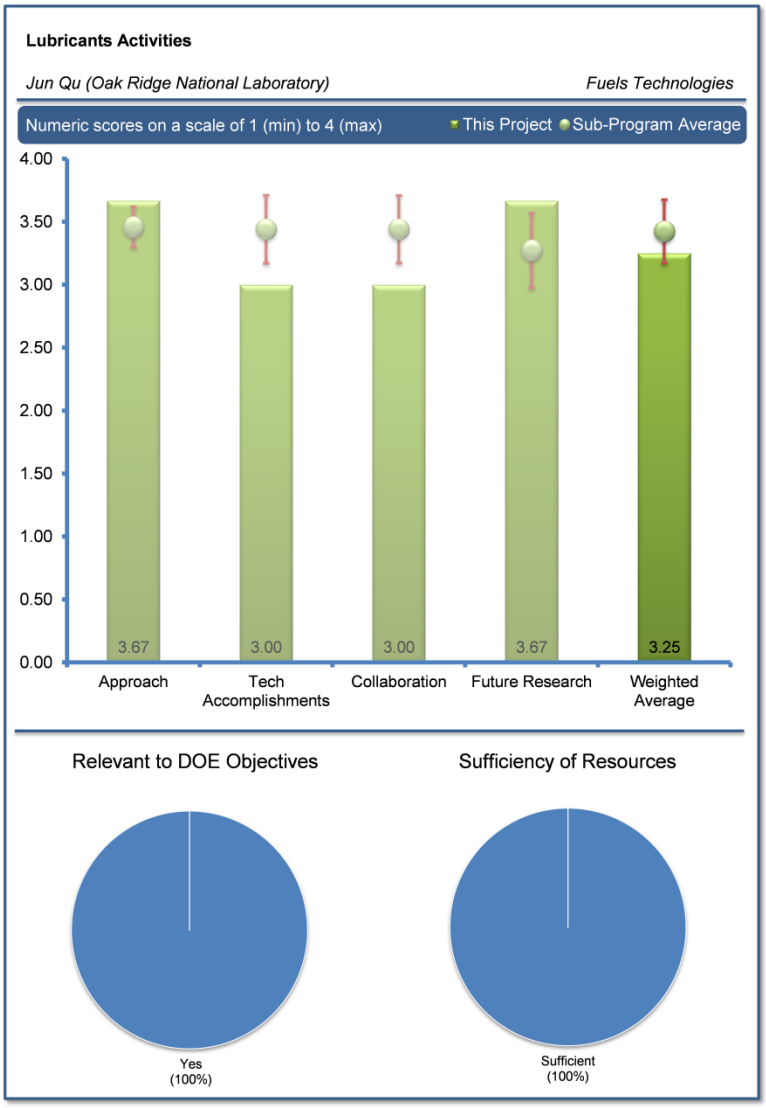
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer pointed out that milestones are being met, so resources seem sufficient.

Reviewer 2:
The reviewer stated resources are sufficient.

Reviewer 3:
The reviewer noted that there seems to be a close relation with some other projects, and was not completely clear what work was funded in which, but overall the effort seems appropriate.

Lubricants Activities: Jun Qu (Oak Ridge National Laboratory) - ft014



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 acknowledged that the technology barriers identified, for example, parasitic friction losses, emission catalyst poisoning, and wear protection in low viscosity oils, are well known and important challenges for which major innovations are long overdue. The use of ionic liquids (IL) to overcome these barriers is a novel and promising technology. The reviewer cautioned that one of the most basic challenges, the solubility of ILs, has been solved by the judicious employment of chemists and chemistry. The reviewer believed this is an extremely important step that this project has embraced and it has yielded excellent results. In addition, the overall project approach seems logically sequenced and feasible.

Reviewer 2:

The reviewer thought the approach would be more beneficial if it included global powertrain impacts, such as effects on combustion.

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

Reviewer 1:

The reviewer reported very promising results, and mentioned looking forward to seeing the results of testing on an engine dynomometer test cell for a broad engine speed-load operation.

Reviewer 2:

The reviewer noted that significant technical progress has been made, including the design and synthesis of oil soluble ILs, the demonstration of corrosion resistance, and storage stability. Additionally, anti-oxidation and significant friction and wear reductions in mixed and boundary lubrication regimes compared to oils formulated with zinc dialkyl-dithio-Phosphate (ZDDP) was highlighted.

Reviewer 3:

The reviewer stated that the accomplishments are in accordance with desired objectives.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that there is a strong potential for this project to expand collaboration, so that different aspects of ILs application for automotive will be elaborated.

Reviewer 2:
The reviewer commented that although collaboration has been restricted to ORNL and Shell Global Solutions, this seems appropriate at this stage of the project.

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

Reviewer 1:
The reviewer expressed that the proposed future research, including optimization of the ILs, further bench testing, modeling, and fired engine tests, are appropriate and a logical continuation of the current work. More detailed compatibility studies with other common additives such as dispersants, detergents, viscosity modifiers, etc., may be appropriate in future work.

The reviewer commented that future work should include the potential impact of IL on renegade or mega knock, as low viscosity lubricant migrates into combustion chamber. Future work should also include studies to assess sulfur corrosion on bearings and other materials.

Reviewer 2:
The reviewer suggested that understanding the link between molecular structures of ILs and lubricating performance and friction coefficients (i.e., the link between Slides 11 and 16) would be very valuable.

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

Reviewer 1:
The reviewer brought to light that the use of ILs is relatively novel and innovative and could lead to a class of oil additives that provide important efficiency benefits for a variety of applications, both automotive and industrial. Lubricant development over the years has been a very slow and deliberate process with few real game changing innovations. The reviewer concluded that the development of IL additives, although maybe not game-changing, has the potential to be a very significant improvement over conventional lubricants.

Reviewer 2:
The reviewer stated that this project helps to increase the mechanical efficiency of IC engines by reducing friction loss.

Reviewer 3:
The reviewer noted that friction is a major contributor to fuel consumption, and there is clearly room for improvement in the mechanical losses in an IC engine.

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

Reviewer 1:
The reviewer indicated that although funding up to this point has been sufficient, future work which includes fired engine testing will likely require a greater funding stream, especially during the phase when multi-cylinder-fired engine testing is planned.

Acronyms and Abbreviations

Acronym	Definition
ACEC	American Council of Engineering Companies
AEC	Advanced Engine Combustion
AMR	Annual Merit Review
ASTM	American Society for Testing and Materials
AVFL	Advanced Vehicle/Fuel/Lubricant Committee
AVFL-18	Project 18 under Advanced Vehicle/Fuel/Lubricants of the Coordinating Research Council
B100	Biodiesel blend of 100% neat biodiesel
B20	Biodiesel blend of 20% neat biodiesel
Ca	Calcium
CFD	Computational Fluid Dynamics
CI	Compression Ignition
CLEERS	Cross-Cut Lean Exhaust Emission Reduction Simulation
CRC	Coordinating Research Council
Cu	Copper
DI	Direct Injection
DISI	Direct Injection Spark Ignited
DME	Dimethyl Ether
DOC	Diesel Oxidation Catalyst
DOE	U.S. Department of Energy
E10	0% Ethanol blend with gasoline
E10	10% Ethanol blend with gasoline
E20	20% Ethanol blend with gasoline
E30	30% Ethanol blend with gasoline
E70	70% Ethanol blend with gasoline
E85	85% Ethanol blend with gasoline
E100	100% Ethanol
EGR	Exhaust Gas Recirculation
EISA	Energy Independence and Security Act of 2007
EMA	Engine Manufacturers Association
EtOH	Ethanol
FACE	Fuels for Advanced Combustion Engines
FAME	Fatty Acid Methyl Ester
FE	Fuel Economy
FFV	Flex-Fuel Vehicles
FTP	Federal Test Procedure
GDI	Gasoline Direct Injection
GM	General Motors Corporation

Acronym	Definition
GTDI	Gasoline Turbocharged Direct Injection
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression Ignition
HCFS	High-Pressure Common-Rail Fuel-Supply System
HECC	High Efficiency Clean Combustion
HWFET	Highway Fuel Economy Test
IC	Internal Combustion
IL	Ionic Liquids
IP	Induction Period
IQT	Ignition Quality Tester
K	Potassium
LII	Laser-Induced Incandescence
LLFC	Lean Lifted Flame Combustion
MB	Mercedes Benz
MOU	Memorandum of Understanding
MTBE	Methyl Tertiary Butyl Ether
NBB	National Biodiesel Board
NH_3	Ammonia
NO	Nitric Oxide
NO_x	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
NVO	Negative Valve Overlap
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
PI	Principal Investigator
PIV	Particle Image Velocimetry
PM	Particulate Matter
PN	Particulate Number
R&D	Research and Development
RCCI	Reactivity Controlled Compression Ignition
RFA	Renewable Fuels Association
RVP	Reid Vapor Pressure
SCR	Selective Catalytic Reduction
SFTP	Supplemental Federal Test Procedure
SI	Spark Ignition
TDC	Top Dead Center
VTO	Vehicle Technologies Office
ZDDP	Zinc Dialkyl-Dithio-Phosphate