4. Advanced Combustion Engine Technologies

Improving the efficiency of internal combustion engines is one of the most promising and cost-effective near- to mid-term approaches to increasing highway vehicles' fuel economy. The Vehicle Technologies Office's (VTO) research and development activities address critical barriers to commercializing higher efficiency, very low emissions advanced internal combustion engines for passenger and commercial vehicles. This technology has great potential to reduce U.S. petroleum consumption, resulting in greater economic, environmental, and energy security.

Already offering outstanding drivability and reliability to over 230 million passenger vehicles, internal combustion engines have the potential to become substantially more efficient. Initial results from laboratory engine tests indicate that passenger vehicle fuel economy can be improved by more than 50%, and some vehicle simulation models estimate potential improvements of up to 75%. Advanced combustion engines can utilize renewable fuels, and when combined with hybrid electric powertrains could yield further reductions in fuel consumption. The EIA reference case forecasts that by 2040, more than 99% of light- and heavy-duty vehicles sold will still have internal combustion engines, therefore the potential fuel savings are tremendous.

The VTO undertakes research and development activities to improve the efficiency of engines for both light and heavy-duty highway vehicles, whether they run on petroleum-based (gasoline and diesel) or alternative fuels. VTO supports every phase of research in these areas, from fundamental science to prototype demonstration. VTO's research focuses on improving engine efficiency while meeting future federal and state emissions regulations. It does this through three main approaches:

- Developing advanced combustion strategies that maximize energy efficiency while minimizing the formation of emissions within the engine.
- Developing cost-effective aftertreatment technologies that further reduce exhaust emissions at a minimum energy penalty.
- Recovering energy from engine waste heat normally lost through the cooling and exhaust systems.

Commercialization of these advanced combustion engine technologies could allow the United States to cut its transportation fuel use and corresponding greenhouse gas emissions by as much as 20 to 40%.

Research and development is done in collaboration with industry, national laboratories, other federal agencies (such as the National Science Foundation [NSF]) and universities, as well as through the following government/industry partnerships:

- U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability (U.S. DRIVE) Partnership focusing on light-duty vehicles
- 21st Century Truck Partnership, focusing on medium- and heavy-duty vehicles

The major goals of the Advanced Combustion Engine R&D subprogram are:

- By 2015, increase the efficiency of internal combustion engines for passenger vehicles resulting in fuel economy improvements of 25% for gasoline vehicles and 40% for diesel vehicles; and by 2020, improve the fuel economy of gasoline vehicles by 35% and diesel vehicles by 50%, compared to 2009 gasoline vehicles.
- By 2015, increase the efficiency of internal combustion engines for commercial vehicles to 50%, a 20% improvement from the 42% of the baseline 2009 heavy-duty engine. This goal is part of the overall SuperTruck initiative to increase Class 8 truck freight hauling efficiency by more than 50% by 2015. By 2020, further improve engine efficiency to 55% with demonstrations on commercial vehicle platforms.
- By 2015, increase the fuel economy of passenger vehicles by at least 5% using thermoelectric generators that convert energy from engine waste heat to electricity.

Subprogram Feedback

The U.S. Department of Energy (DOE) received feedback on the overall technical subprogram areas presented during the 2014 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 Vehicles Technologies Office (VTO) subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

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

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

Question 3: Were important issues and challenges identified?

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

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

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

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

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

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

Question 10: Has the program area engaged appropriate partners?

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

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

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

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

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

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

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

Subprogram Overview Comments: Gurpreet Singh (U.S. Department of Energy) – ace000

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

Reviewer 1:
The reviewer observed a well-presented overview on overall strategy and goals.

Reviewer 2:
The reviewer answered yes, and commented that it was a lot to cover in such a brief presentation but that it was well summarized.

Reviewer 3:
The reviewer commented yes, although technical success or progress should not be misinterpreted as retail success or social acceptance of the technology.

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

Reviewer 1:
The reviewer responded yes, and clarified that some of the projects are quite high risk/high potential and some closer to real world production implementation.

Reviewer 2:
The reviewer remarked generally well balanced, although long term could use some more definition.

Reviewer 3:
The reviewer opined that, looking at near-/mid-term research and development (R&D), current internal combustion engine (ICE) technology, including relatively untapped lean burn and ethanol/lean burn, have been fully exhausted in investigation, and new technology, such as homogeneous charge compression ignition (HCCI)/reactivity controlled compression ignition (RCCI) or any other technology that drives a paradigm change in customer behavior, is at best 15 years out or more.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer responded yes.

Reviewer 2:
The reviewer responded yes, the workshops with stakeholders are effective to identify the real issues and find ways to address the hard points.

Reviewer 3:
The reviewer said in a technical sense, yes, and in an implementation sense, no.

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

Reviewer 1:
The reviewer said yes, and commented nice job of working with stakeholders. The reviewer noted that some programs remain high risk, but these risks are properly stated, and successful completion of the tasks will reduce the risks.

Reviewer 2:
The reviewer commented not the implementation challenges.

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

Reviewer 1:
The reviewer commented yes.

Reviewer 2:
The reviewer responded moderately; good presentation of this year's status, not completely compared to last year's status.

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 commented yes, and observed a good match.

Reviewer 2:
As the reviewer indicated previously, technical barriers will be more easily overcome than social acceptance, retail and infrastructure challenges.

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

Reviewer 1:
The reviewer commented yes, nicely aligned and clearly focused with stakeholder agreement.

Reviewer 2:
The reviewer said yes.

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:
According to the reviewer, strengths include the coordination with academia and industry so that the funding directly addresses the real challenges in an effective way. The reviewer observed no major weakness, although more funding would always help.

Reviewer 2:
This reviewer commented on weaknesses. The reviewer believed additional focus on IC as we know it is still in the 0-15 year future for engines, perhaps longer, and advanced combustion is after that.

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

Reviewer 1:
The reviewer stated yes, observing many solid technologies under development that might not have received much attention without DOE encouragement.

Reviewer 2:
The reviewer commented yes.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer commented yes, very good collaboration.

Reviewer 2:

The reviewer noted that oil producers, retailers and other similar parties are part of the equation. According to the reviewer, it may not be appropriate to this discussion, but if the technical solution develops into an implementation nightmare, outside input from those affected parties will be valuable.

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

Reviewer 1:

The reviewer commented yes, a real strength.

Reviewer 2:

The reviewer commented not yet.

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

Reviewer 1:

The reviewer did not see major gaps.

Reviewer 2:

The reviewer identified infrastructure and implementation as gaps.

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

Reviewer 1:

The reviewer commented that off-road vehicles are not directly addressed. Test procedures and emission limits are evolving; there may be unique engine requirements.

Reviewer 2:

The reviewer remarked infrastructure and implementation.

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

Reviewer 1:

The reviewer observed a good portfolio now.

Reviewer 2:

The reviewer identified infrastructure, implementation, and lean burn/ethanol combustion as other areas to consider.

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

Reviewer 1:

The reviewer encouraged the program to keep doing more of the same.

Reviewer 2:

The reviewer suggested the program meet with original equipment manufacturers (OEMs) and oil producers on the business/program side to discuss potential technical solutions. If implementation is too painful or costly to customer, it will not happen.

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

Reviewer 1:

The reviewer commented none at this time.

Reviewer 2:

The reviewer said no.

Project Feedback

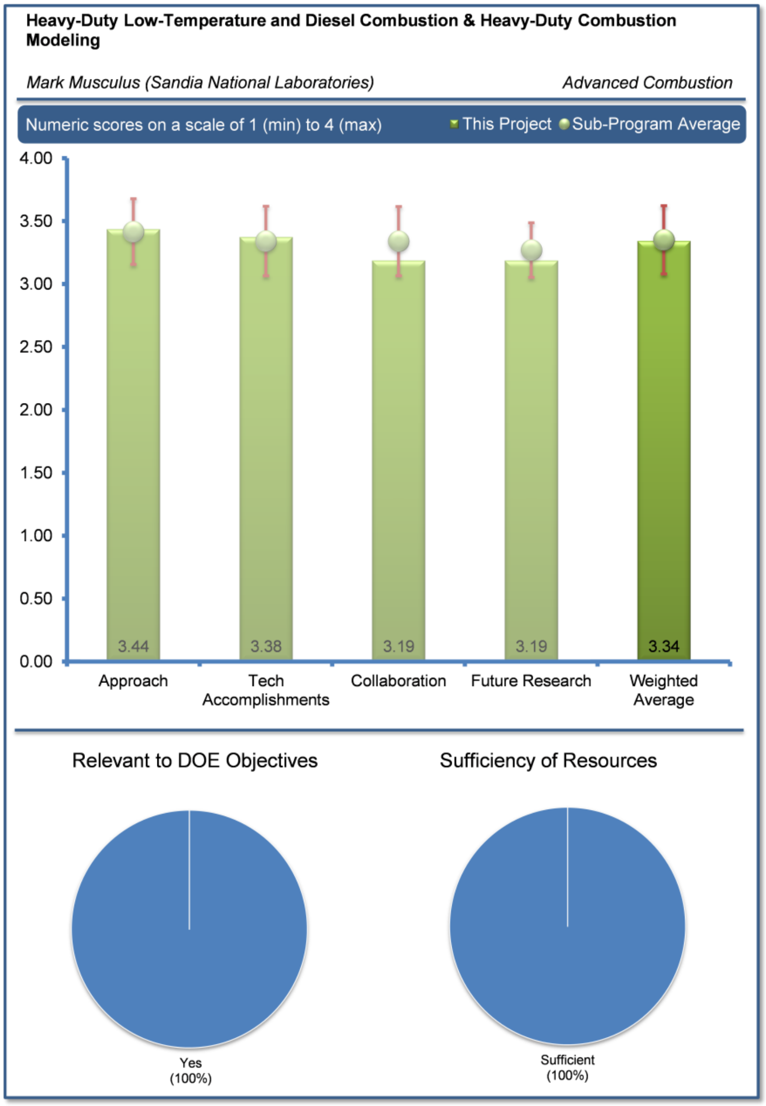
In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each 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
Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling	Mark Musculus (Sandia National Laboratories)	4-10	3.44	3.38	3.19	3.19	3.34
Light-Duty Diesel Combustion	Paul Miles (Sandia National Laboratories)	4-16	3.50	3.30	3.10	3.10	3.30
HCCI and Stratified-Charge CI Engine Combustion Research	John Dec (Sandia National Laboratories)	4-20	3.44	3.44	3.44	3.31	3.42
Spray Combustion Cross-Cut Engine Research	Lyle Pickett (Sandia National Laboratories)	4-25	3.57	3.50	3.86	3.21	3.53
Automotive Low Temperature Gasoline Combustion Engine Research	Isaac Ekoto (Sandia National Laboratories)	4-29	3.11	3.22	3.22	3.11	3.18
Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research	Joe Oefelein (Sandia National Laboratories)	4-34	3.50	3.29	3.07	3.43	3.33
Fuel Injection and Spray Research Using X-Ray Diagnostics	Christopher Powell (Argonne National Laboratory)	4-38	3.63	3.50	3.38	3.38	3.50
Use of Low Cetane Fuel to Enable Low Temperature Combustion	Steve Ciatti (Argonne National Laboratory)	4-40	2.58	2.58	2.92	2.75	2.65
Model Development and Analysis of Clean & Efficient Engine Combustion	Russell Whitesides (Lawrence Livermore National Laboratory)	4-44	3.33	3.25	3.25	3.17	3.26
Chemical Kinetic Models for Advanced Engine Combustion	Bill Pitz (Lawrence Livermore National Laboratory)	4-47	3.72	3.72	3.61	3.44	3.67
2014 KIVA Development	David Carrington (Los Alamos National Laboratory)	4-52	2.89	3.00	3.00	3.00	2.97
Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Stuart Daw (Oak Ridge National Laboratory)	4-57	3.50	3.25	3.00	3.33	3.29
High Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines	Scott Curran (Oak Ridge National Laboratory)	4-60	3.56	3.44	3.61	3.39	3.49
Accelerating Predictive Simulation of IC Engines with High Performance Computing	Kevin Edwards (Oak Ridge National Laboratory)	4-64	3.30	3.30	3.30	3.30	3.30
CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR	Stuart Daw (Oak Ridge National Laboratory)	4-67	3.67	3.50	4.00	3.17	3.56
CLEERS Aftertreatment Modeling and Analysis	George Muntean (Pacific Northwest National Laboratory)	4-72	3.50	3.30	3.40	3.10	3.34
Particulate Emissions Control by Advanced Filtration Systems for GDI Engines	Kyeong Lee (Argonne National Laboratory)	4-76	3.00	3.00	2.80	2.80	2.95
Enhanced High and Low Temperature Performance of NOx Reduction Materials	Chuck Peden (Pacific Northwest National Laboratory)	4-81	3.88	3.75	3.63	3.50	3.73

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Thermally Stable Ultra-Low Temperature Oxidation Catalysts	Chuck Peden (Pacific Northwest National Laboratory)	4-84	3.75	3.50	3.42	3.50	3.55
Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines	Bill Partridge (Oak Ridge National Laboratory)	4-88	3.50	3.07	3.50	3.21	3.25
Emissions Control for Lean Gasoline Engines	Jim Parks (Oak Ridge National Laboratory)	4-93	3.80	3.50	3.70	3.60	3.61
Neutron Imaging of Advanced Engine Technologies	Todd Toops (Oak Ridge National Laboratory)	4-97	3.50	3.00	3.20	3.30	3.19
Collaborative Combustion Research with BES	Scott Goldsborough (Argonne National Laboratory)	4-100	3.38	3.13	3.25	3.13	3.20
Fuel-Neutral Studies of Particulate Matter Transport Emissions	Mark Stewart (Pacific Northwest National Laboratory)	4-102	3.50	3.50	3.70	3.30	3.50
Cummins SuperTruck Program - Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks	David Koeberlein (Cummins)	4-106	3.90	4.00	3.50	3.80	3.89
SuperTruck Program: Engine Project Review	Sandeep Singh (Detroit Diesel)	4-109	3.80	3.90	3.60	3.60	3.80
Volvo SuperTruck - Powertrain Technologies for Efficiency Improvement	Pascal Amar (Volvo Trucks)	4-112	3.70	3.80	3.70	3.70	3.75
ATP-LD; Cummins Next Generation Tier 2 Bin 2 Diesel Engine	Michael Ruth (Cummins)	4-115	3.56	3.56	3.31	3.44	3.52
A MultiAir / MultiFuel Approach to Enhancing Engine System Efficiency	Ron Reese (Chrysler LLC)	4-120	3.30	2.90	3.20	3.30	3.09
Advanced Gasoline Turbocharged Direct Injection (GTDI) Engine Development	Corey Weaver (Ford Motor Company)	4-124	3.40	3.30	3.10	3.60	3.34
Advanced Combustion Concepts - Enabling Systems and Solutions (ACCESS) for High Efficiency Light Duty Vehicles	Hakan Yilmaz (Robert Bosch)	4-128	3.50	3.50	3.75	3.25	3.50
Advancement in Fuel Spray and Combustion Modeling for Compression Ignition Engine Applications	Sibendu Som (Argonne National Laboratory)	4-131	3.50	3.43	3.57	3.29	3.45
Improved Solvers for Advanced Engine Combustion Simulation	Matthew McNenly (Lawrence Livermore National Laboratory)	4-135	3.42	3.50	3.50	3.50	3.48
Cummins-ORNL\FEERC Combustion CRADA: Characterization & Reduction of Combustion Variations	Bill Partridge (Oak Ridge National Laboratory)	4-138	3.40	3.50	3.20	3.30	3.41
Investigation of Mixed Oxide Catalysts for NO Oxidation	Ayman Karim (Pacific Northwest National Laboratory)	4-142	3.50	3.50	3.42	3.00	3.43
Robust Nitrogen Oxide/Ammonia Sensors for Vehicle On-board Emissions Control	Rangachary Mukundan (Los Alamos National Laboratory)	4-146	3.17	3.08	3.33	3.17	3.15
Thermoelectric Waste Heat Recovery Program for Passenger Vehicles	Todd Barnhart (Gentherm)	4-150	3.25	3.42	3.33	3.17	3.33

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Cost-Competitive Advanced Thermoelectric Generators for Direct Conversion of Vehicle Waste Heat into Useful Electrical Power	Jim Salvador (General Motors LLC)	4-156	3.25	3.17	3.17	3.17	3.19
Nanostructured High-Temperature Bulk Thermoelectric Energy Conversion for Efficient Automotive Waste Heat Recovery	Martin Cleary (GMZ Energy Inc.)	4-162	3.33	3.25	3.17	3.17	3.25
High Efficiency GDI Engine Research, with Emphasis on Ignition Systems	Thomas Wallner (Argonne National Laboratory)	4-167	2.92	2.92	2.92	3.00	2.93
Low Temperature Emission Control	Todd Toops (Oak Ridge National Laboratory)	4-171	3.60	3.50	3.40	3.30	3.49
The Application of High Energy Ignition and Boosting/Mixing Technology to Increase Fuel Economy in Spark Ignition Gasoline Engines by Increasing EGR Dilution Capability	Edward Keating (General Motors LLC)	4-174	3.42	3.17	3.33	3.17	3.25
Next-generation Ultra-Lean Burn Powertrain	Hugh Blaxill (MAHLE Powertrain LLC)	4-179	3.25	3.42	3.42	3.17	3.34
Heavy Duty Roots Expander for Waste Heat Energy Recovery	Swami Nathan Subramanian (Eaton Corporation)	4-184	3.43	3.43	3.36	3.29	3.40
Development of Radio Frequency Diesel Particulate Filter Sensor and Controls for Advanced Low-Pressure Drop Systems to Reduce Engine Fuel Consumption	Alexander Sappok (Filter Sensing Technologies, Inc.)	4-189	3.30	3.50	3.70	3.40	3.46
High-Dilution Stoichiometric Gasoline Direct-Injection (SGDI) Combustion Control Development	Brian Kaul (Oak Ridge National Laboratory)	4-193	3.13	3.00	2.94	3.19	3.05
Intake Air Oxygen Sensor	Claus Schnabel (Robert Bosch)	4-197	3.50	3.50	3.20	3.50	3.46
Variable Compression Ratio Engine with Variable Valve Actuation and Supercharger	Charles Mendler (Envera LLC)	4-201	3.00	2.83	2.75	2.83	2.86
Overall Average			**3.42**	**3.34**	**3.34**	**3.27**	**3.35**

Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling: Mark Musculus (Sandia National Laboratories) - ace001



Reviewer Sample Size

A total of eight reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that this project continued to be an example of a great national laboratory program, noting a solid approach and good results.

Reviewer 2:

The reviewer felt this project had an outstanding approach in leveraging simulation results to define new experiments and identify new areas to investigate.

Reviewer 3:

The reviewer stated that the overall experimental approach to understanding species formation and fuel consumption was truly outstanding, adding that the hardware and test conditions were relevant, and the collaboration with modeling efforts was yielding valuable insight. The reviewer added that the laser-absorption characterization of polycyclic aromatic hydrocarbon (PAH) nanostructure and formation mechanisms was valuable in combination with modeling. The reviewer noted that this was less important in the context of low temperature combustion (LTC), since manufacturers were unlikely to adopt this to a significant degree. The reviewer also added that the companion work in gasoline direct injection (GDI)/spark ignition (SI) would be very useful.

Reviewer 4:

The reviewer remarked that using an optical engine in conjunction with computational fluid dynamics (CFD) modeling was a good approach to understanding in-cylinder combustion phenomena and processes in diesel combustion.

Reviewer 5:

The reviewer commented that the approach of coupling optical engine experiments with CFD modeling was very useful for understanding and elucidating the fundamentals of injection, combustion, and pollutant-formation processes. This reviewer added that it looked like some adjustments had been made in response to the reviewer comments from last year.

Reviewer 6:

The reviewer observed that the current approach combined both experimentation and modeling to derive physical insights. The goal was to develop a new conceptual model to accelerate the design of advanced low-temperature, heavy-duty (HD) engine applications. The project was investigating injection and spray effects, combustion chamber geometry effects, and soot precursors with a variety of toolsets. The reviewer added that, for example, the CFD modeling was driven to compliment the experimentation and provide additional insights that could not be measured.

Reviewer 7:

The reviewer said that the author provided a rather comprehensive approach. This person added that it was accompanied by a good team. There may be improvements possible regarding the connection between the work here at a fundamental level with more real-world operation. Specifically, this reviewer felt that there could have been more clarity with respect to overall engine and power-plant efficiency.

Reviewer 8:

The reviewer asserted that the general approach was good. The experiments were well thought-out and well executed. This reviewer would like to have seen a more rigorous overall approach to the work, adding that the work presented appeared to be more a random collection of topics. This reviewer would like to have seen one topic fully investigated (such as post injections), and the connection shown to how simulations were improved and validated, quantifying the opportunity/savings of the new approach (such as fuel efficiency and/or emissions). This does not preclude the side topics that appeared, but this reviewer would like to have seen a stronger connection of how findings from this project ultimately impacted the performance of the fleet.

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 the project team's excellent work in a critical area.

Reviewer 2:

The reviewer indicated very interesting results on viewing the growth of soot precursors from the laser-induced fluorescence (LIF) tests in the optical engine. The reviewer indicated that there were important observations on the occurrence of dribble after the end of injection showing that it occurred for all injectors (and thus was not just a symptom of "bad" injectors), and that dribble was greater for n-heptane than diesel fuel.

Reviewer 3:

The reviewer highlighted that significant progress had been made in a number of areas. This person added that it was important to quantify the impact of the dribble, and asked if it manifested itself as an unburned hydrocarbon (HC) issue in a full powertrain system or vehicle.

Reviewer 4:

The reviewer was impressed by the findings of how the post injection interacted with the soot formed by the main injection. This reviewer would like to hear a hypothesis as to why it was improved, then to see a test plan to prove (or disprove) it. This person added that it was similar with the PAH work. Results were shown but without a hypothesis as to why. This reviewer noted it was good to see that more representative bowl geometry was now being included.

Reviewer 5:

The reviewer specified that Slide 3 of the presentation showed a progression of conceptual models starting with conventional diesel and LTC diesel. The reviewer added that the current work was focusing on developing the multiple-injection LTC model. This person felt that it would have been helpful to show what the principal investigator (PI) believed was confidently known regarding the conceptual model and what needed further understanding (such as expanding on Slide 23). Additionally, this reviewer asked, of the seven objectives outlined in Slide 4, how these helped clarify areas of uncertainty.

This reviewer said that the project included CFD contributions in KIVA and CONVERGE from different institutions (University of Wisconsin (UW), Cummins) using different modeling approaches for combustion. This reviewer asked how the things learned from these approaches would be consolidated to develop the conceptual model. The reviewer wanted to know if a particular code was uniquely equipped to solve a particular aspect of the problem, and how much time was anticipated to be allocated toward the injector dribble effect. The reviewer added that there had been evidence that dribble could have negative effects on combustion for some engine concepts. The reviewer asked if this work would drive injector suppliers to reduce dribble effects.

Reviewer 6:

The reviewer voiced that the overall experimental approach to understanding species formation and fuel consumption was truly outstanding, but added that the recent work overemphasized the importance of dribble. (The body of work already existed on this effect from about 15 years ago, correlating the effects of fuel pressure and sac volume on dribble and associated emissions.) This reviewer felt that greater focus going forward on end-of-injection mixing should be valuable. This person added that achieving contoured bowl geometry and higher-flow injector was an important milestone, as it would lead to better correlation with metal engine results, as well as give relevant geometry for examining injection strategy and effects on particulate matter (PM) formation.

Reviewer 7:

The reviewer stated that LTC was associated with high efficiency by reduced after-treatment. This person added that the topic could have been treated with greater thoroughness, specifically as LTC had been associated with a large release of UHC. It would have been good to document dribble in modern fuel systems. This reviewer added that the images from Slide 11 were insightful, and inquired about the estimated volume of dribble and what the impact would have been of the nozzle design (mini- or micro-sac, valve covered orifice styles) to the dribble. The reviewer also inquired about the following: the entrainment coefficient and impact on the overall predictability (such as for emissions); some of the basic flow and performance characteristics of the proposed Delphi DFI 21; and the basic nozzle configuration. This reviewer felt the project team could have given additional information regarding the soot model (Slide 22). The reviewer also asked if the work was carried out at the Engine Research Center (ERC). This person lastly added that the presentation could have shown some planar images.

Reviewer 8:

The reviewer remarked that clear evidence of injector dribble being detrimental to engine efficiency and emissions should have been presented before too much more work was done on characterizing dribble. This person added that, if and when the evidence showed that the detrimental effect was significant, then the first action to be taken should have been to present the evidence to several injector manufacturers and then challenge them to modify injector design to eliminate or reduce dribble. The reviewer noted an analogy was made with regard to injector “bounce” from 20 years ago and added, after the above approach was followed, today one did not encounter injector bounce that was significant enough to be a cause of concern. This reviewer said that, in other words, there was no sense in spending more than a certain useful minimum of time and resources on “characterizing” something detrimental when it was to be eventually eliminated.

This reviewer added that soot was a key issue in conventional diesel combustion and asked if soot was the most important problem for low-temperature diesel combustion. This person added that the understanding of soot mass was vastly reduced with LTC combustion, and that meeting soot number density standards “may” still have been an issue. The reviewer noted that, as far as LTC diesel combustion went, perhaps more time should have been spent on understanding the sensitivity of this advanced combustion process (to control variables so that a multi-cylinder engine could find a way into production), and added that this was a very serious barrier to LTC combustion.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed excellent project team collaboration and indicated that the close collaboration with modeling was seeing a payoff.

Reviewer 2:

The reviewer remarked that the project’s collaboration was an example of how lab/industry collaboration should be done.

Reviewer 3:

The reviewer commented that there were a variety of partners mentioned contributing to this project. It was important for the PI to consolidate the lessons learned to achieve the desired objectives.

Reviewer 4:

The reviewer pointed out that the Advanced Engine Combustion (AEC) Working Group was mentioned as a key collaboration with industry. This person added that it looked like a closer collaboration was set up with one of the AEC Working Group members (Cummins). This reviewer was uncertain how close the collaborations with the other AEC members were.

Reviewer 5:

The reviewer said that collaboration with injection system suppliers could be significantly improved.

Reviewer 6:

The reviewer would have liked to see more collaboration with industry, and added that Cummins clearly had a vested interest, given that their hardware was being used. Delphi was similar, in that Delphi had hardware that they would have liked to have evaluated. This reviewer said the rest of the OEM interactions were summed up with “correspondence” and the “AEC,” but added that the work with UW and Convergent was good and should continue.

Reviewer 7:

The reviewer mentioned that the team assembled was very good, with the core team composed of UW, Delphi, Cummins, and Convergent Science; yet the work demonstrated here could have been enhanced by more direct information provided by these partners in their specific areas. The reviewer expressed that little information was given to the soot modeling from University of Wisconsin-Milwaukee (UWM), and that no injector specifications or targets were given that could help the technical community understand the capability of the hardware (such as the accuracy of the injection events).

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

Reviewer 1:

The reviewer asserted that the plans presented should continue the good progress that was being made.

Reviewer 2:

The reviewer indicated a solid project plan to attack significant issues.

Reviewer 3:

The reviewer said for the project team to continue building the conceptual model.

Reviewer 4:

The reviewer commented that upgrading fuel injection hardware was crucial. Also, the reviewer added that the effect of key operating variables on combustion sensitivity (such as combustion noise versus combustion stability), as well as understanding cause and effect, should have been explored as far as the optical engine went.

Reviewer 5:

The reviewer indicated that the PI had shown that post injections could reduce both emissions and fuel consumption. This person asked how many injection events were to be considered. The current approach appeared to focus on a main plus post injection strategy.

Reviewer 6:

The reviewer noted that the focus on gaining a greater understanding of injection strategies, injector characteristics, and state-of-the-art injector hardware was of primary importance, but added that being able to vary the characteristics of the injector may also be useful to understanding the sensitivity.

Reviewer 7:

The reviewer stated that new bowl geometry was a good direction and, as mentioned in the question-and-answer period, there was a need to be careful to not spend too much time on injector dribble. The reviewer said to quantify the impact. If it was significant, it should have been offered back to the fuel injector suppliers as a problem that needs to be solved.

Reviewer 8:

The reviewer noted the future work would focus on the testing with new piston geometry, an attempt to reconcile the work with geometries that were more in keeping with production hardware. This reviewer felt the project could have been more aggressive and innovative towards showing the correlation between this work and improved combustion and cycle efficiency. It gave the impression of staying focused on a narrow work scope.

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

Reviewer 1:

The reviewer commented that developing a fundamental understanding of injection, combustion, and emissions-formation processes should be the key to improving the design of future engines and enabling improvement of engine efficiencies, which supported the Department of Energy (DOE) objective of reducing petroleum consumption.

Reviewer 2:

The reviewer stated that fundamental understanding of in-cylinder processes, especially heat transfer and mixing, was critical to achieving low emissions with high efficiency.

Reviewer 3:

The reviewer said that the project was very relevant to efficient and low-emission combustion.

Reviewer 4:

The reviewer indicated that clearly this type of work was required, to better our understanding and our tools. This person added that it needed to be kept in mind, too, that the real proof of success was improving the product.

Reviewer 5:

The reviewer claimed that it was important to understand the contributors to soot, since future Low Emission Vehicle (LEV)III/Tier3 regulations would be applied to medium-duty (MD) vehicles as well as light-duty (LD) vehicles.

Reviewer 6:

The reviewer summarized that the project considered fundamental research towards improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 7:

The reviewer noted that the project provided a fundamental experimental understanding of conventional and low-temperature combustion and spray process interactions in an engine.

Reviewer 8:

The reviewer voiced that the current work was providing a solid contribution to understanding injector dynamics and soot, but added that there was little on fuel consumption improvements.

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

Reviewer 1:

The reviewer commented that this was a significant program and seemed to be properly funded.

Reviewer 2:

The reviewer asserted that the resources appeared to be adequate and that the funding level had been consistent.

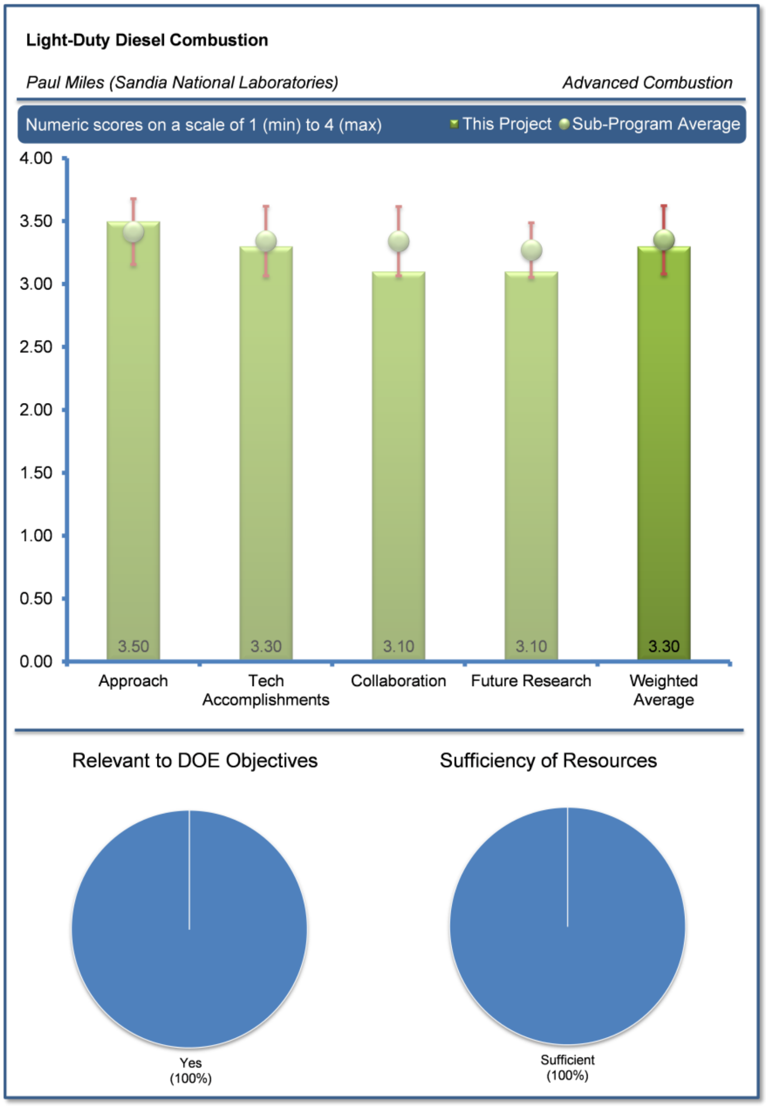
Reviewer 3:

The reviewer said very good progress was being made by the project, which suggested that the resources were sufficient.

Reviewer 4:

The reviewer suggested that the project team could involve more visibly industrial partners. These appeared to be involved (e.g., Cummins and Delphi), but there was no technical information shared. The reviewer felt this would have been beneficial and to some extent required for this project. The project could have provided selective metal engine data to compare with optical results/benchmark of the injector, while respecting confidentiality.

Light-Duty Diesel Combustion: Paul Miles (Sandia National Laboratories) - ace002



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that this was a remarkably well-rounded program looking at most of the key aspects of light-duty diesel, making effective use of optical diagnostics and combustion CFD to further understanding. This person added that the newly updated injection rate measurement facility allowed detailed study of single and multiple injections on low-temperature and conventional diesel combustion. At the same time, the effects of temperature, oxygen concentration, pilot diesel mass, and injection pressure on the ignition quality of the fuel/air mixture were accomplished, and key factors were also identified. The reviewer indicated that the results provided a better understanding for diesel combustion. Computational modeling had also been improved and notably included both university research and commercial CFD tools. The predicted swirl ratio and pilot ignitability results showed a reasonable match with experiments. This reviewer noted that the disadvantages of the current modeling methods, which gave useful information for code development, were also established. Overall, the work was both fundamentally sound and very comprehensive.

Reviewer 2:

The reviewer said that there was a good combination of experimental work feeding information into the models and using the models to help understand the experimental results.

Reviewer 3:

The reviewer noted that the approach of coupling optical engine studies using a production engine configuration (General Motors Corporation [GM] 1.9 liter) with simulations was very useful.

Reviewer 4:

The reviewer stated even more emphasis by the project team on squish interactions would be of interest.

Reviewer 5:

The reviewer commented that it became clear that the intent of this study was to explore mixing/ignition processes for a close-coupled, pilot-main injection event. Initial research showed on a test bench that a dwell of (roughly) less than 0.3 ms led to an impact on the initial rate of injection of the main event. The reviewer added that the PI did not quantify the approach for studying close-coupled pilot injection mixing-ignition characteristics based on the presentation. This person added that it would have been helpful to know the game plan for systematically addressing the impact of dwell both experimentally and computationally based on a design of experiments that included variance in dwell times. Maybe it was hidden in the presentation, but it was not clear to the reviewer if this was the case.

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 indicated the project had very good progress in the pilot injections studies, as well as interesting results regarding the optimal fuel/air ratio.

Reviewer 2:

The reviewer reported that injection rate dependency on fuel type when using a pilot injection was an interesting result. This person added that more investigation on this topic to understand the root cause might identify important issues that needed to be included in the injector spray models.

Reviewer 3:

The reviewer commented that excellent progress had been made against the objectives of the program, addressing key factors that affected pilot ignition and methods to improve the diesel ignition process with pilot injection. The planar (LIF) measurements provided more information on equivalence ratio distribution and diesel ignition at different pilot mass fractions. The improved three-dimensional (3D) CFD study showed the benefits of doing full 360-degree mesh simulation compared to sector mesh simulation. The reviewer added that the indicated development of cold-start strategies and cold, in-cylinder emission control deserved more discussion, as it was of keen interest. Further, as the pilot ignition study was based on the heat release rate from experiment, the engine cycle-to-cycle variation should be addressed more fully. The reviewer noted that, as the averaged pressure and temperature near top dead center (TDC) were very important for the ignition study, more information on how pressure and temperature were controlled near TDC was also warranted.

Reviewer 4:

The reviewer stated that some initial results were shown concerning the impact of mass injected (via injection pressure) on the pilot heat release rate, but it was not clear how this behavior could be quantified in a real-world engine. It was not clear if the definition of robust ignition correlated with what was acceptable in a real-world engine. It would have been helpful if the study could better quantify the impact of any pilot dwell time research on the overall behavior of an engine.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted the project team had widespread collaborations, including a memorandum of understanding (MOU).

Reviewer 2:

The reviewer noted excellent team collaboration with a university, code vendor, and industrial partners, adding that perhaps more details were desirable regarding how Convergent Science was integrated into the project.

Reviewer 3:

The reviewer asserted there looked to be close collaboration with UW on some aspects of the project, adding that, with regard to industry collaboration, it was claimed that there was collaboration/information sharing with the OEMs.

Reviewer 4:

The reviewer explained that just about the entire presentation focused on the experimental aspects of this project, and thus little was shown from the partners. It was clear that the UW-ERC was supporting the project with CFD analysis, and that Convergent was also supporting the project. This reviewer added that showing more contributions from the partners would have been helpful in evaluating collaboration.

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

Reviewer 1:
The reviewer confirmed that the project plans looked good and to continue the progress made.

Reviewer 2:
The reviewer indicated that the planned future work was a good extension of the research completed to date, adding that the planned study of close-coupled multi-injection (as well as piston geometry) would generate a greater impact on engine design applications. One suggestion this reviewer had was to also look at the effects of nozzle-geometry specifications (number of holes, spray angle, etc.) on mixture formation and ignition. This reviewer added that going to a full 360-degree simulation would enhance the ability to look at the jet-to-jet variations in this context.

Reviewer 3:
The reviewer stated that the future work needed more detail. It was not clear to this reviewer what close coupled meant or how the initial chosen pilot start of injection could affect both the low- and high-temperature heat release rates. This person asked if possibly varying start of injection would be helpful. The reviewer also asked how a close-coupled pilot strategy would compare to a more traditional pilot, long dwell, and then main injection strategy, where the latter could take place at lower injection pressure to compensate for over-mixing.

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

Reviewer 1:
The reviewer noted that elucidating the fundamentals of the combustion process should help to improve engine design, leading to higher efficiencies and lower fuel consumption, which in turn reduces petroleum-derived fuel consumption.

Reviewer 2:
The reviewer indicated that improved combustion understanding would help engine designers to develop improved, more efficient engines.

Reviewer 3:
The reviewer said, well, perhaps somewhat through the backdoor by increasing efficiency, and added that it might be interesting for the project team to expand the work in the future to include non-petroleum fuels to more directly address petroleum displacement.

Reviewer 4:
The reviewer commented that this research did support the further development of light load combustion strategies for direct-injection, compression-ignition engines that could reduce oxides of nitrogen (NO_x), PM, and carbon monoxide (CO)/HCs. This reviewer added that, nevertheless, future experiments should be more focused to address real-world engine applications as previously commented, such as better quantifying the experimental conditions and resulting conclusions versus other options.

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

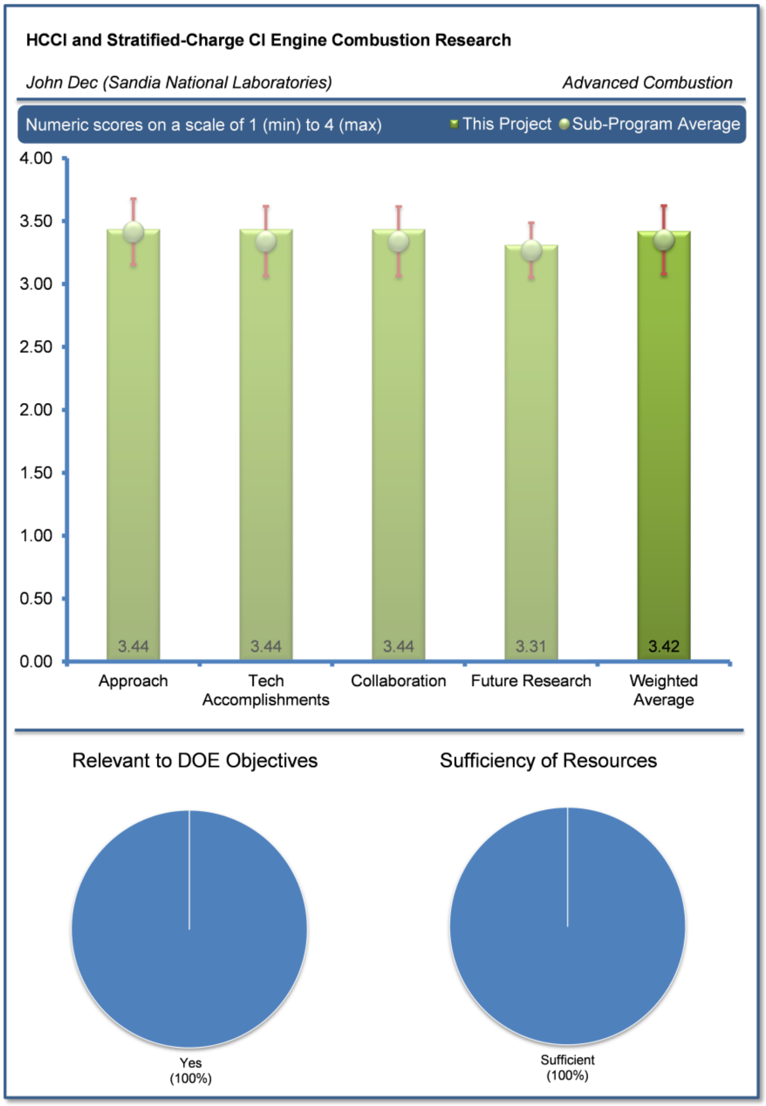
Reviewer 1:
The reviewer expressed that the resources seemed adequate, but added that the PI had scoped out quite a program, such that these resources would have to be used wisely and efficiently.

Reviewer 2:
The reviewer affirmed that good project progress was being made and that there were no indications that the resources were not sufficient.

Reviewer 3:

The reviewer observed a well-funded project for the work output.

HCCI and Stratified-Charge CI Engine Combustion Research: John Dec (Sandia National Laboratories) - ace004



Reviewer Sample Size

A total of eight reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that the approach was excellent in that all pertinent tools were brought to bear on low-temperature gasoline combustion. This included metal engine experiments (to find the limits and effects of variables) and optical engine experiments (to probe key issues in a fundamental manner), and further provided understanding and data to improve models of low-temperature combustion (so that more detailed analysis could be performed with the validated models).

Reviewer 2:

The reviewer noted that the project showed a comprehensive approach with the contributions of metal and optical engine hardware, which were accompanied by collaborations with partners contributing to the computational modeling. The reviewer added that milestones were clearly identified including the status at which the project team found themselves.

Reviewer 3:

The reviewer remarked that the proposed research sought to demonstrate efficiency improvements for a low-temperature gasoline combustion system. The approach provided a strong integration of full metal and planned optical measurements. This person added that the PI indicated that the CFD contribution was planned to grow in the future.

Reviewer 4:

This reviewer commented that the fundamental learning objectives of this project were basically the same as the work reported by Dr. Ekoto, and added that both were addressing low-temperature gasoline combustion (LTGC). Both projects were also planning to explore augmented ignition. It seemed to this reviewer that the two research activities should be able to identify synergies common between them and the information that was being generated. This reviewer added that the PLIF measurements of the fuel stratification and correlation with LTGC should be very insightful data.

Reviewer 5:

The reviewer observed extremely interesting work on this topic. While this reviewer may have had some concern about “LTC” versus “dilute” combustion, this program was a very good way to address those questions with fundamental data and analyses.

Reviewer 6:

The reviewer said it would have been helpful to include an estimate of brake thermal efficiency (BTE) from the project team's indicated efficiency numbers. This reviewer was glad to have seen inclusion of the combustion noise metric, but did not see how it was applied to constrain the high load limits portion of the research.

Reviewer 7:

The reviewer asserted that the approach had demonstrated the indicated efficiency potential over a reasonable load range, but added that, without considering the tradeoffs necessary for turbo-machinery and transient operation, this potential might not easily translate into a practical combustion solution.

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

Reviewer 1:

The reviewer affirmed good project progress this year.

Reviewer 2:

The reviewer noted encouraging technical progress in building upon past lessons learned with intermediate temperature heat release and expanding to look at partial fuel stratification (PFS). This reviewer asked if the PI would consider more injection events in the future. Additionally, this person felt the conclusions drawn regarding the interpretation of ringing intensity and combustion noise level were relevant and solid technical contributions.

Reviewer 3:

The reviewer stated that the overall accomplishments were useful toward demonstrating high gross indicated efficiency, and a better fundamental understanding of where HCCI/LTGC strategies might provide an efficiency advantage over other boosted GDI strategies (under the constraint of near-zero tailpipe emissions). This reviewer added that addressing exhaust gas availability transient control (i.e., achieving robust operation while controlling within a narrow range of phi and glomerular filtration rate [GFR]), as well as enabling boost and effective after-treatment, would help to speed the path to commercialization.

Reviewer 4:

The reviewer reported that a large amount of progress and technical accomplishments had been made, as shown in Slide 7. This reviewer was not sure if the analytical investigation of the Miller cycle had been taken to completion, in that a higher boost level needed to be investigated in conjunction with dropping the effective compression ratio to 14. This person noted that, because knock and combustion stability were challenging to analytically predict, Miller cycle investigations were sometimes best done experimentally.

This reviewer added that much more light had now been shed on the behavior and correlation between ringing intensity and combustion noise level, and how retarding CA50 affected it. Peak thermal efficiency numbers had been double checked after fixing some issues with fuel measurement and now there was increased confidence in the reported numbers. The reviewer noted that the increases in thermal efficiency observed with double injection were exciting, adding that the x-axis of the plots that showed injection timing should have indicated before (or after) TDC firing (or TDC breathing) so it was clearer.

Reviewer 5:

The reviewer reinforced that this was very nice work, adding that it would have been nice if the investigator could have framed the work and research plans in terms of how it would augment what had already been reported in the literature. For example, there was much literature on PFS and optimization efforts in terms of injection pressure, swirl, number and timing of injections, fuel splits between injections, etc. There was also literature on the ringing intensity index versus combustion noise measurements. This reviewer asked how this work was going to augment or overcome the deficiencies of what has already been done, adding that it would have been helpful to put the work in perspective with what else was going on in the field. This person also noted that the investigator responded well to last year's comments.

Reviewer 6:

The reviewer noted that the effort appeared to be a calibration optimization approach for a specific hardware set. The reviewer asked how the results could be generally applied.

Reviewer 7:

The reviewer voiced that the work extended the studies to the higher compression ratio of 16 from previous studies at 14. The latest results showed greater thermal efficiency but became limited at peak load. This reviewer added that it might have been helpful to assess what the targets were for the work (comparing these with the current state of technology). This person added that the latter results also required higher EGR, and asked what the implications of this would be in practice. The reviewer asked if the Miller cycle data were simulated. There was an extensive treatment of combustion noise and ringing. This reviewer added that the treatment is comprehensive, including its mitigation with factors such as combustion phasing.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted excellent project team collaboration with the relevant stakeholders.

Reviewer 2:

The reviewer felt that this project team was a good example of how collaboration should work.

Reviewer 3:

The reviewer remarked that collaboration with industry and other labs was very good; adding that closer connection with other LTGC efforts at Oak Ridge National Laboratory (ORNL) and Argonne National Laboratory (ANL) would also be useful.

Reviewer 4:

The reviewer commented that the team assembled was very good, with the core team composed of GM, Cummins, Lawrence Livermore National Laboratory (LLNL), University of California (UC)–Berkeley, University of Melbourne, and Chevron. The reviewer added that the specific contributions of each of these members could have been better highlighted, and that more detail could have been provided from the simulation work done by UC–Berkeley and GM.

Reviewer 5:

The reviewer pointed out that the PI should leverage industry collaborators to project these results from an indicated metric to brake numbers. The PI mentioned this point during the presentation. This reviewer additionally asked what specific technical challenges the PI required for the CFD modeling. The reviewer asked if there would be some correlation between the CFD predictions and the experimental fuel distribution images.

Reviewer 6:

The reviewer felt that it was hard to determine the extent of the project's collaborations from the presentation.

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

Reviewer 1:

The reviewer said that the project team was continuing a great series of research plans.

Reviewer 2:

The reviewer was glad to see the project team's effort to predict BTE.

Reviewer 3:

The reviewer remarked the proposal to add realistic friction and turbocharger models to the single cylinder work was sensible in that it would allow an assessment of thermal efficiency on a net and brake basis. This reviewer noted that the addition of a spark plug to conduct spark-assisted low-temperature combustion was also a step in the practical direction, and added that the use of 300-bar injection pressure had the potential to modify partial-fuel stratification favorably and result in an increase in thermal efficiency.

Reviewer 4:

The reviewer commented that the proposed optical imaging of in-cylinder mixing would provide excellent insight and provide a relevant dataset for CFD model validation. This person asked, furthermore, if the PI planned to investigate more than two injection events.

Reviewer 5:

The reviewer acknowledged that a strong consideration of the compromises necessary for robust transient operation, efficient turbocharging, and effective after-treatment was critical to moving LTGC closer to commercialization. This reviewer added that combustion optimization should be a secondary goal after these primary constraints were applied, with thoughtful assessment of the anticipated technology limits.

Reviewer 6:

The reviewer noted that the PI knew what the ideal phi distribution was, and, in turn, asked if the ideal phi distribution was known, why not just determine the best solution analytically. Given the larger number of degrees of freedom at play, it would seem to be the more sensible approach.

Reviewer 7:

The reviewer pointed out that, in light of the discussion of the sensitivity of the results to uncertainties, it seemed that an uncertainty/error-propagation analysis should have been shown in the figures. This would have shown the total impact of the uncertainty of all measurements used in the work and facilitate the comparison to other results (whose investigators should also do the same).

Reviewer 8:

The reviewer said that the future work would focus on multi-hole injections with guidance from CFD modeling, which may need to be better explained and outlined. The project could have been more aggressive and innovative in showing new paths towards higher efficiency. The reviewer added that the very detailed studies were good and welcome, but new ideas on how to break the load and efficiency barriers were lacking.

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

Reviewer 1:

The reviewer asserted that the project considered fundamental research towards improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 2:

The reviewer affirmed that the project developed a clear technical basis for future engine combustion regimes.

Reviewer 3:

The reviewer appreciated the comments on comparing the thermal efficiency of the LTGC technology with other combustion systems.

Reviewer 4:

The reviewer emphasized that very high indicated thermal efficiencies were being shown for LTGC on a single cylinder engine with somewhat ideal conditions. This person added that, while there was still a long way to go and many more barriers to be addressed, this work showed potential for OEMs to follow.

Reviewer 5:

The reviewer explained that LTGC was important as a long-term strategy for improving LD engine efficiency, but added that the project needed to move forward in a few critical areas to enhance the opportunity for commercial applications.

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

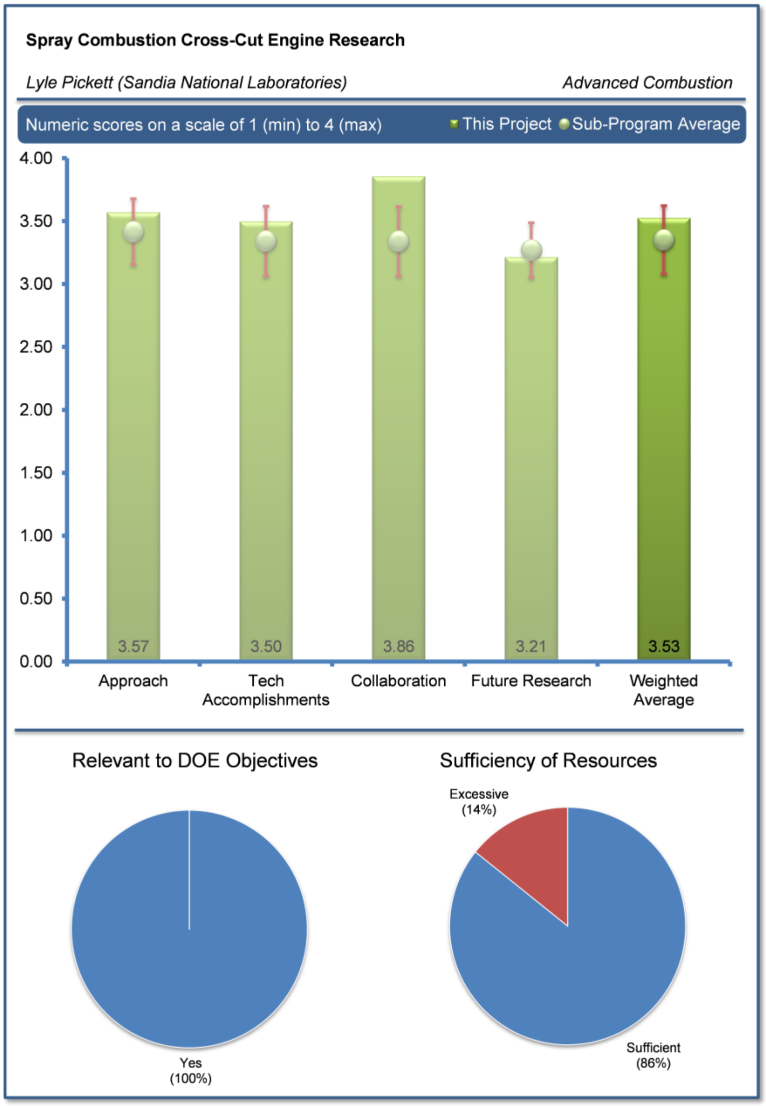
Reviewer 1:

The reviewer stated that the PI was using the supplied resources well.

Reviewer 2:

The reviewer said that there seemed to be an appropriate level of resource effort.

Spray Combustion Cross-Cut Engine Research: Lyle Pickett (Sandia National Laboratories) - ace005



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 indicated that outstanding methods were deployed to obtain experimental data to test and refine the CFD efforts.

Reviewer 2:

The reviewer highlighted that this was a well-organized project that encompassed many outside research organizations in a cohesive manner, as well as focused on maintaining experimental consistency among the various organizations. The reviewer exclaimed well done to the PI.

Reviewer 3:

The reviewer noted an excellent approach of establishing a network of national laboratory, university, and industry researchers studying fundamental injection and mixing phenomena using the same type of injectors and conditions, which enabled a basis for cross-comparison of results. This reviewer added that the project team also took advantage of the specialized equipment available at each lab.

Reviewer 4:

The reviewer remarked that the fundamental understanding of sprays was the key to advanced engine technologies, and added that the PI had undertaken a very collaboration-based effort in coordinating in-house measurements with experiments across the globe through the Engine Combustion Network (ECN). This person said it was good to see the study of gasoline sprays incorporated in the presentation and encouraged emphasis in this area.

Reviewer 5:

The reviewer commented that, overall, the technical barriers were well addressed and the experiments were well designed to investigate evaporating sprays in an engine-like environment, with most important factors from injection through combustion considered. The reviewer added that the experimental research efforts were directed to provide ample quantitative data on spray characteristics and combustion indicators, such that accurate numerical models could be developed and tested. Future work should consider addressing in more detail how applicable constant volume experimental results were to real engine conditions. This reviewer suggested that this could perhaps be done through comparative measurements in an optical bomb and optical engine.

Reviewer 6:
The reviewer said that it was very good to see inclusion of the gasoline injector, but would have liked more results. This person noted a novel approach to combining Schlieren and single-shot LIF to gain insight into spray/combustion behavior, and this reviewer looked forward to more results.

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

Reviewer 1:
The reviewer noted excellent progress, including extending the spray injection work to GDI ("Spray G"), the development of quantitative soot data sets, and the quantification of the near-field liquid volume fraction for diesel spray "A."

Reviewer 2:
The reviewer felt that it was good to see a focus on challenges associated with predicting spray behavior based on nozzle geometry. The models needed to be improved in this area.

Reviewer 3:
The reviewer remarked that the ECN continued to produce useful measurements. One suggestion this person had was to consider exploring spray angle measurements over various density ratios and temperatures for a variety of high-pressure nozzles.

Reviewer 4:
The reviewer commented that extensive experimental work had been conducted from near the nozzle region to far downstream, which hooked up with the measurement of ignition delays and transient soot contours. The project team provided a rich source of information for improving predictive modeling capabilities, with promising modeling results also shown. This reviewer added that the work should continue to identify the sensitive factors influencing spray characteristics such as spreading angle and liquid core height, which could then aid CFD model development to reduce dependence on arbitrary tuning parameters.

Reviewer 5:
The reviewer acknowledged the effort to correlate in-house optical measurements with x-ray measurements regarding the liquid core detection. The reviewer asked if this approach could be expanded to provide quantitative metrics that could be used for CFD modelers in the development of primary atomization models. For example, this reviewer noted that modelers are moving towards exercising Eulerian spray approaches that transition to Lagrangian droplets. These models generally required transition criteria. The reviewer asked if any unique experiments were available to help with the transition criteria.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated the ECN was an ideal model for collaboration among various partners.

Reviewer 2:
The reviewer pointed out the project team's huge collaborative effort deployed to speed up data acquisition.

Reviewer 3:
The reviewer noted the project's outstanding network of collaborators, composed of industry, national laboratories, and universities, which further enabled procurement of field-relevant injectors from the industry partners.

Reviewer 4:
The reviewer commented that the coordination of the ECN network had been excellent and extremely relevant to the advancement of clean engine technology.

Reviewer 5:

The reviewer emphasized the broad collaborative effort across industry and researchers, and added that it was good to see even more researchers joining ECN.

Reviewer 6:

The reviewer acknowledged the ECN was perhaps the poster child for industry-university-government-lab cooperative research, and added that what was even more remarkable was that the collaborative, open-forum concept had actually worked in practice. The PI was to be congratulated for his ability to effectively coordinate the various efforts. The only downside that this reviewer noted was that the range of different spray modeling approaches being compared was somewhat limited. This reviewer said that some comparisons (undoubtedly in the works) with Eulerian-Lagrangian, Eulerian-Eulerian, or even volume-of-fluid methods for handling dense sprays near the injector would be particularly enlightening. Of course, this was potentially limited by the volunteer nature of the network.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 project plans appeared to continue to build on the successes obtained to date.

Reviewer 2:

The reviewer stated that the project team's Spray G plan was good and would help gasoline spray models.

Reviewer 3:

The reviewer's only suggestion was to explore the possibility of correlating spray angle behavior for various high-pressure nozzles as a function of key parameters (such as density ratio, temperature, length-to-diameter ratios, etc.).

Reviewer 4:

The reviewer reported that the proposed work was fine, but that the project team should consider looking at internal injection flow coupling with downstream sprays (such as the effects of cavitation, hydro-machining, internal wave motion, needle motion on sprays, etc.). This might draw upon and build up collaboration with ANL and ORNL, given their diagnostics capabilities. This person added that, while it was good to see gasoline injection now being studied in addition to conventional diesel, it might have been useful to expand the family of fuels being considered to include biodiesels, E85, etc.

Reviewer 5:

The reviewer stated that the PI showed in the presentation slides the desire to visualize spray collapse for the gasoline spray. This person asked what separated this study from measurements already shown in the literature. The reviewer added that the PI was encouraged to consider different optical techniques, such as spray particle image velocimetry to quantify the entrainment field during spray collapse. Furthermore, this reviewer asked if there was any plan to study multiple injection events to compliment the PFS work of John Dec.

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

Reviewer 1:

The reviewer stated that spray characterization was a major pathway to efficient direct injection (DI) combustion systems and enabled improvements in fuel consumption.

Reviewer 2:

The reviewer commented that improving the understanding of fuel sprays was critically important to understanding and improving engine behavior, and noted that the experimental information provided by this project was crucial to improving fuel spray and engine models.

Reviewer 3:

The reviewer noted that the great fundamental spray research that would support various DI combustion approaches deemed necessary to reduce engine-out NO_x and soot in both compression and SI engines.

Reviewer 4:

The reviewer remarked that mixing analysis was critical to combustion simulation.

Reviewer 5:

The reviewer acknowledged that improved understanding of spray and mixing processes was important for improving the design of engines using direct fuel injection. This person added that this should lead to the development of more efficient engines, and thus lower fuel/petroleum consumption.

Reviewer 6:

The reviewer indicated that, as this research promoted improved tools and understanding that would ultimately improve engine efficiency, it generally supported the overall objectives. However, this reviewer added that the current program seemed limited by only considering conventional diesel and gasoline, and could more directly impact petroleum displacement through studies with non-petroleum fuels.

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

Reviewer 1:

The reviewer pointed out that, by utilizing collaborative assets under the ECN, this program had very effectively expanded its resources substantially for little expense other than the coordination needed to keep all the parts moving in the same general direction. The person added that this had to be one of the most cost-effective DOE projects out there.

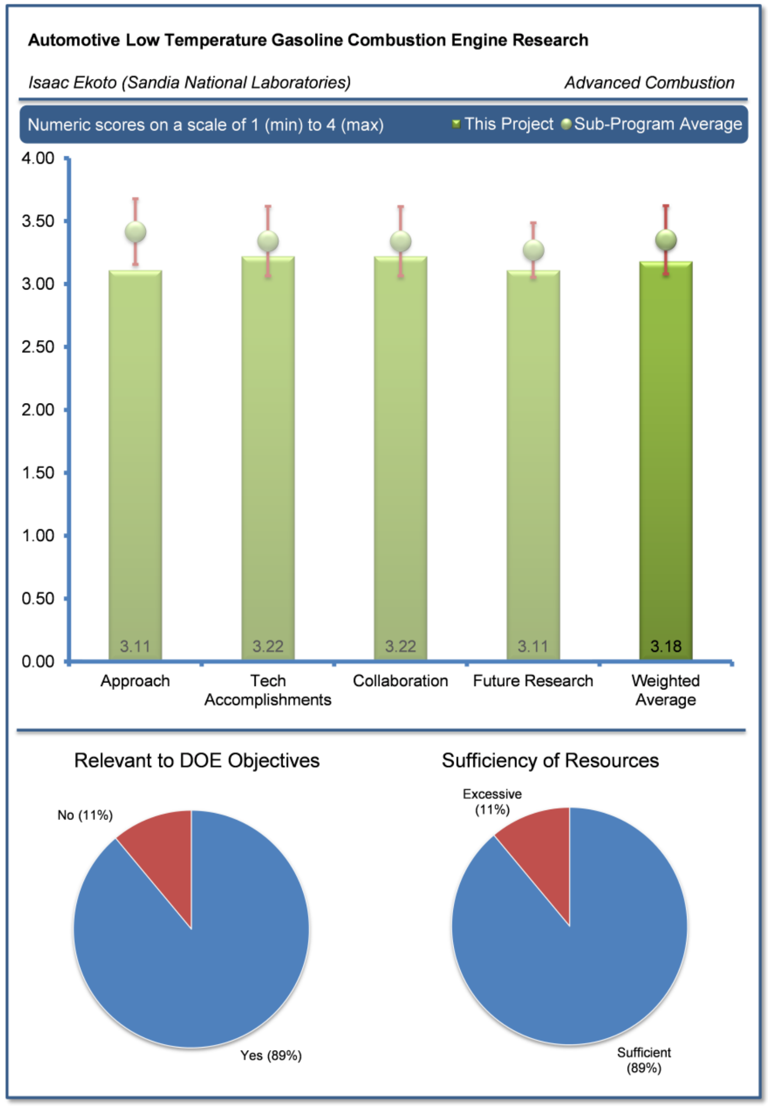
Reviewer 2:

The reviewer stated that the project's allocated resources appeared sufficient for this work.

Reviewer 3:

The reviewer suggested that the project was possibly overfunded, and added that it would have been nice to have seen a budget breakout for this project. This reviewer felt the project was well-funded for the work output.

Automotive Low Temperature Gasoline Combustion Engine Research: Isaac Ekoto (Sandia National Laboratories) - ace006



Reviewer Sample Size

A total of nine reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that the project showed a comprehensive approach with the contributions of optical engine hardware, in-cylinder measurements and diagnostics, and computational modeling. Milestones were identified to expand the fundamental understanding of LTGC, with specific focus on the negative valve overlap (NVO) fueling impact on the main combustion.

Reviewer 2:

The reviewer noted that the PI's approach to gas speciation was thoroughly undertaken, involving correlation of results across different test facilities. The PIs also used modeling tools to help explain their results, in addition to verifying their observed trends at ORNL.

Reviewer 3:

The reviewer acknowledged the project's good coupling of optical engine tests with computer models.

Reviewer 4:

The reviewer commented that the approach as listed by the PI was quite good, and was somewhat indicative of all projects at Sandia National Laboratories (SNL).

Reviewer 5:

The reviewer observed that this project used the unique capabilities at Sandia to study LTGC. This person added that fundamental questions regarding low temperature heat release were being studied, as well as the effects of temperature and/or species concentration.

Reviewer 6:

The reviewer observed that the approach offered unique insight into combustion species formation, but was not part of a critical path for commercialization of LTGC technology.

Reviewer 7:

To this reviewer, it seemed that the presentation concentrated more on what was being done, rather than why it was being done and what would be the benefit once the data was understood. It also seemed that the fundamental knowledge barriers being addressed in this work were the same as those being addressed in Dr. Dec's work. This reviewer added that, as such, and since the work was addressing fundamental knowledge gaps, this reviewer felt that there should be synergy between the two programs. The reviewer asked if there were synergisms and how what was learned in each program was helpful to the other. Alternatively, this reviewer inquired about whether results of this study could be presented so industry could do comparative analysis between the two approaches, so as to determine which approach held more promise technically, or what the tradeoffs of complexity of implementation versus benefits were that came into play.

Reviewer 8:

The reviewer mentioned that the presentation noted NVO was a promising approach for implementing LTC. This reviewer suggested that it would help to have some evidence for that.

Reviewer 9:

The reviewer noted a generally good approach, adding there seemed to be some fuzziness of what concept(s) were being researched. The reviewer wanted to know if this was compression ignition. The reviewer said to explain the logic of the ignition work, and added that it needed to be clear it was not just jerking from one thought to the next.

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 mentioned good progress versus milestones, including the following: hydrocarbon speciation during high-O_2 NVO; confirmation that acetylene is the species primarily responsible for results with high-O_2 NVO; and determination that low-O_2 NVO might be a more viable approach for production engines than high-O_2 NVO.

Reviewer 2:

The reviewer asserted that the study focused on high-O_2 NVO experiments (raising the temperature of the charge for low load stability), cylinder sampling experiments (demonstrating the capability to speciate NVO products via the dump-valve and gas chromatograph apparatus), speciation of low-O_2 NVO products (providing fuel reforming at these lower O_2 concentration levels), vacuum ultraviolet (VUV) mass spectrometer experiments, and the development of new opportunities for advanced gasoline ignition. The reviewer added that model results from the high-O_2 NVO experiments confirmed the main combustion phasing chemical effect was mostly due to the improved charge reactivity from increased NVO acetylene production. This reviewer said the work showed that low-O_2 NVO could be a more controllable pathway to optimal HC intermediate production. This was well coordinated with the work of ORNL, and the operating conditions of the tests were well documented.

Reviewer 3:

The reviewer affirmed project team’s nice work on a number of experiments.

Reviewer 4:

The reviewer emphasized that this year, an important accomplishment regarding the role of acetylene had been made, adding that it had been determined convincingly that acetylene production during the NVO heat release was the main reason for the enhancement of the main combustion heat release. This person added this conclusion came from the modeling part of the investigation, and low-O_2 NVO species sample measurements had also been performed and compared to ORNL data. This could potentially offer better control of the main combustion process, and the reviewer added that initial species measurements using the Lawrence Berkeley National Laboratory (LBNL) molecular beam mass spectrometer looked promising. These were compared to the gas chromatography measurements.

Reviewer 5:

The reviewer indicated the project team was doing a very nice job with the experiments and establishing nice leveraging with other groups. This person added that it seemed that a fundamental CFD analysis with comprehensive kinetics was needed, and that this could explain or verify the PI’s conjectures on the acetylene formation and its importance. The reviewer asked if this would then feed useful information to the PFS activities.

Reviewer 6:

The reviewer noted good progress in measuring the exhaust components and determining the role of acetylene in changing the reactivity of the NVO gas and driving the main combustion. The reviewer asked if the PI was able to determine if the source of acetylene was from wall wetting on the piston, and if there was any evidence from inspection of the piston top. This reviewer added that the work on advanced mass spectroscopy at LBNL should be continued.

Reviewer 7:

The reviewer highlighted that the work relative to NVO was good for improving our fundamental understanding. This person would have liked to see this understanding translated into a "controls" approach that would ensure robust combustion along with high efficiency and low emissions over a range of speeds, loads, and environmental conditions. Similarly, this reviewer added that an assessment could be made as to the accuracy required for the different control parameters (injection timing, injection amount, valve timing, etc.). The SI accomplishments were somewhat limited, given this work was just getting off the ground. This reviewer added that the project team was seeking feedback from industry, and the resulting report was a very good start.

Reviewer 8:

The reviewer claimed that the latest findings did not seem to be moving the project substantially closer to a "leap forward" in LTGC strategy. This reviewer added that the insight on the role of simple HC species and acetylene was now a few years old, but little progress had been shown on fuel effects (for example) that could move this insight forward.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the project team's collaboration appeared to be excellent.

Reviewer 2:

The reviewer noted that it looked like there were good collaborations with the auto companies, as well as with the other national laboratories.

Reviewer 3:

The reviewer noted that the project team was a part of the big group, and observed outstanding collaboration.

Reviewer 4:

The reviewer felt the team assembled was very good, with the core team composed of four national laboratories, two universities, and multiple OEMs. The reviewer added that the work such as the low-O_2 NVO was well coordinated with the work of ORNL, and suggested that there may be an opportunity for the OEM partners to provide more feedback and direction towards the viability of the concept here.

Reviewer 5:

The reviewer encouraged the collaboration with LBNL and ORNL in accurately characterizing exhaust components.

Reviewer 6:

The reviewer remarked that there was good collaboration with the other national laboratories on the NVO topic, and the ignition project was off to a good start as well. This reviewer would have challenged the PI to see if there were any other institutions doing ignition work that would add value and contribute to the project. The OEM involvement should continue as well.

Reviewer 7:

The reviewer stated that the pace of collaboration with the ignition system suppliers (e.g., USC) should be increased. If possible, suppliers of prototype Corona or Plasma ignition systems should be contacted to see if these suppliers would work with SNL.

Reviewer 8:

The reviewer observed very good collaboration to get the task done, but added that otherwise it was difficult to see cooperation with the other labs leading to a common objective.

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

Reviewer 1:
The reviewer stated that the work needed to be performed to demonstrate the effects of oxygenated species (as, for example, in Fuels for Advanced Combustion Engines [FACE] fuels) on the NVO mechanisms being examined.

Reviewer 2:
The reviewer supported the future focus on advanced ignition systems as a means to support dilute combustion.

Reviewer 3:
The reviewer asserted that the project's planned research seemed reasonable.

Reviewer 4:
The reviewer asked if there was sensitivity to fuel properties, and added that fuel, even in a conventional SI engine, was still a significant source of noise (in a statistical sense).

Reviewer 5:
The reviewer highlighted that the project planned to continue post-processing data to speciate low-O_2 and high-O_2 NVO engine samples. This person added that the project would also perform scoping studies for advanced ignition technologies, although the directions to be taken were not too clear (thermal plasmas/lasers, pre-chamber).

Reviewer 6:
The reviewer said generally strong, but added that the project needed a clearer thinking-through of the concept(s). Perhaps this would be the natural fallout of the experimental data, but this reviewer asked for the PI to please clarify the plans and research directions as part of the big picture.

Reviewer 7:
The reviewer would have liked to see more project details on the future ignition system plan.

Reviewer 8:
The reviewer claimed that it would be good if the future work could have been stated more in terms of specific technical goals/challenges, as opposed to the current rather general activities. This would have allowed the audience to get a sense of why these activities were planned and what would be learned when they were successfully completed.

Reviewer 9:
The reviewer commented that it was not clear exactly what kind of combustion concept was going to be investigated. It was also not clear exactly how the ignition studies were going to relate to the combustion concept. This reviewer asked if using Reynolds-averaged Navier-Stokes (RANS) modeling was a valid approach in trying to predict cyclic variability in the combustion process, and suggested using a Large Eddy Simulation (LES) model.

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

Reviewer 1:
The reviewer noted that the project considered fundamental research towards improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 2:

The reviewer highlighted that SI engines still dominated in the light duty fleet, and other researchers had shown that more capable ignition systems could lead to improved engine efficiency. So this area of research was relevant. This reviewer added that accurate and predictive simulation of the ignition event was equally important and relevant.

Reviewer 3:

The reviewer voiced that exploring approaches such as NVO to improve engine efficiency was consistent with DOE goals.

Reviewer 4:

The reviewer summarized that the project sought to extend dilute operation of gasoline combustion for increased fuel efficiency.

Reviewer 5:

The reviewer stated that the research was relevant to several engine combustion schemes that were being developed.

Reviewer 6:

The reviewer noted that the work was relevant in that it presented an approach to alter the reactivity of the charge mixture without the inclusion of an additional fuel.

Reviewer 7:

The reviewer felt that it was unclear that this work, especially the specific operating conditions that were being considered, would lead to a tangible reduction in petroleum consumption.

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

Reviewer 1:

The reviewer stated that there was no indication that the project's resources were not sufficient.

Reviewer 2:

The reviewer observed sufficient resources for the project.

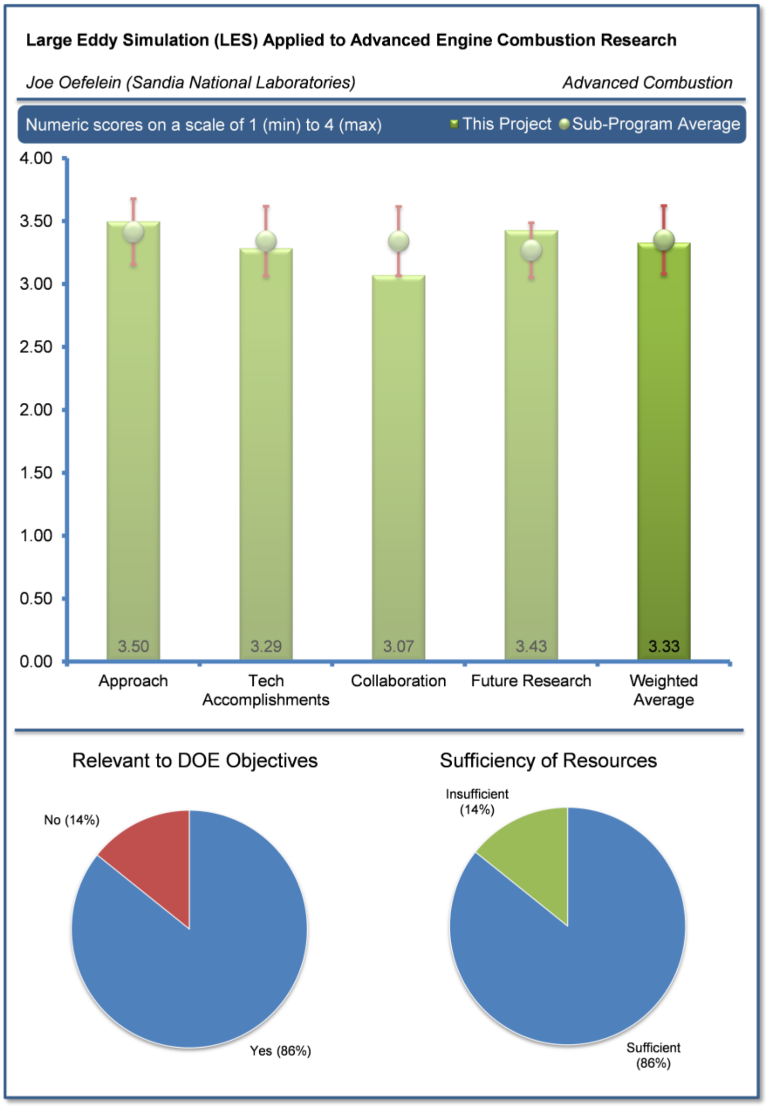
Reviewer 3:

The reviewer said the resources seemed to be at the appropriate funding level.

Reviewer 4:

The reviewer indicated that the resources appeared to be excessive for the perceived benefit.

Large Eddy Simulation (LES) Applied to Advanced Engine Combustion Research: Joe Oefelein (Sandia National Laboratories) - ace007



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 expressed that this is very important work to provide a benchmark to show the ultimate capability of simulations and models.

Reviewer 2:

The reviewer emphasized that the application of complex modeling tools such as LES is important for understanding and modeling fundamental fuel injection, mixing, and combustion processes. Also, the approach of first using complex techniques to get correct, accurate results and then determining how the computational approach can be simplified (thus reducing computational time/requirements) made a lot of sense.

Reviewer 3:

The reviewer explained that the project's approach sets to develop and exercise a high-fidelity simulation code to bridge the gap between basic science and applied research. This person felt that this was an endeavor that should be undertaken at the national laboratories, and added that the PI should clarify what the pathway was from this work to industry. This reviewer asked if industry would have access to the RAPTOR code.

Reviewer 4:

The reviewer indicated that the approach has been very methodological throughout the last few years, with the initial focus on more basic combustion applications such as simple flames. It appeared LES was slowly approaching a reasonable level of predictive simulation capability for direct injection engine combustion characteristics. This reviewer added that overall this project was making progress, though it would be great to see a real focus on assessing LES for practical engine applications (e.g., accelerating these latter efforts).

Reviewer 5:

The reviewer reported that, generally, the work on detailed turbulence modeling (and more recently, the addition of real fluids modeling) is great, but the project continues to struggle to show the direct connection to real-world engine modeling for the purposes of designing better engines. This person added that potential steps are seen in the plan, such as possible coordination with spray modeling work at ANL, but the real jump would be to coordinate and collaborate with commercial code vendors and industry to take this fundamental numerical analysis research and get it (obviously not directly, due to the computational costs, but in a derivative fashion) into commercial tools and into the hands of engine designers. This reviewer added that then the impact of this great research could be felt where it could do the most good—designing cleaner, more efficient IC engines.

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 indicated great results showing detailed simulations that match experimental results, and added that this would provide insight into engine behavior.

Reviewer 2:
The reviewer noted very good project progress versus the planned milestones.

Reviewer 3:
The reviewer asked how the property evaluation from the PI's real fluid model compared with other property calculation routines, such as REFPROP from NIST. The PI shows a comparison of Raptor simulations with the ECN Spray A. This reviewer asked if there was a plan to compare model predictions with x-ray measurements for a more quantitative comparison of mass distribution. The reviewer asked if the PI had performed any assessment on the added benefit of this modeling approach over engineering LES simulations available in commercial codes like CONVERGE. The reviewer added that CFD modeling of sprays has been focused on better predictions in the dense spray region, and asked if the current modeling approach provides help to assist in the development of engineering-based Eulerian-Lagrangian transition models.

Reviewer 4:
The reviewer stated that, to date, progress had been made assessing LES against basic combustion problems, and that the project was slowly working toward a useful tool for assessing advanced combustion strategies in future direct injection engines. This person added that progress had been reasonable, though it needed to be accelerated for application to practical combustion devices.

Reviewer 5:
The reviewer stated that, again, while the technical accomplishments, themselves, are excellent, the project loses points appreciably in addressing its contributions to overcoming barriers. (For this reviewer, those being the barriers to applying the technology to designing better IC engine combustion systems.)

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted, historically, this project has leveraged combustion data from other sources to assess and develop the LES methodology, and that the project team has collaborated well with various experimentalists and modelers from a number of research organizations. This reviewer added that collaboration has been strong throughout the years.

Reviewer 2:
The reviewer felt that there was good collaboration with experimental groups to compare to the simulations, and added that it was a good idea to compare the project team's LES results to CONVERGE, which is used in industry.

Reviewer 3:
The reviewer felt that the collaborations were mostly with other national laboratories, adding that no industry collaboration was evident. But there may not be much opportunity at this stage and this level of computer simulation. This reviewer noted that, ultimately to be the most useful, this work would need to be related to the type of simulations the OEMs can run.

Reviewer 4:
The reviewer remarked there should be a continued and stronger linkage with the ECN. Additionally, this person asked what the collaboration pathway was to link the lessons learned from this project with other code development work being done at Los Alamos National Laboratory (LANL) and LLNL. The PI mentioned that the code was being refactored for Graphics Processing Unit (GPU) acceleration. This reviewer asked if it was possible to incorporate to this work some of the learning from LLNL on combustion modeling with GPUs.

Reviewer 5:
The reviewer asked why there was no industry collaboration by the project team and if there was a lack of interest or failure to reach out to industry.

Reviewer 6:
The reviewer explained that there was a great deal of collaboration with academia and national laboratories (particularly in the high performance computing [HPC] area) and even some with the aerospace industry (although again on a very basic research level). What this reviewer felt to be missing was collaboration with commercial software vendors to take this basic research and apply it to engineering tools, as well as (of course) collaboration with IC engine designers. This reviewer felt there was a real, perhaps even dire, need for better turbulence and spray modeling capabilities in the trenches, but added that this project was cruising above the fray at 50,000 feet.

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

Reviewer 1:
The reviewer said the project plans seemed reasonable.

Reviewer 2:
The reviewer said that it was a good idea to compare the research to commercial codes.

Reviewer 3:
The reviewer mentioned that the proposed effort was excellent. This reviewer’s only suggestion was to focus more on ensuring the LES is truly capturing in-cylinder behavior that agrees with engine measurements and/or constant-volume combustion vessels.

Reviewer 4:
The reviewer asked if the modeling approach could simulate flash boiling and cavitation. The reviewer asked what the remaining technical challenges currently prohibiting engine simulations were. A priority should be put on demonstrating highly resolved, highly scalable in-cylinder flow calculations. This reviewer said to continue to demonstrate the comparison of the high-resolution codes with engineering models to show benefit (this will develop with increased involvement in the ECN). The reviewer then wanted to know if there was a plan to simulate the gasoline spray G test condition.

Reviewer 5:
The reviewer expressed that the project reviewers really did appreciate the work done here even though these reviewers had been grading it rather severely. What excited this reviewer most was the plan to perhaps take it to the next level and begin (if still somewhat tentatively, in this reviewer’s opinion) to address the more practical problems associated with IC engine analysis and design. The proposed collaboration with ANL was a start, but diving deeper into the engine-modeling world is even more highly encouraged.

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

Reviewer 1:
The reviewer stated that the application of complex modeling tools such as LES is important for understanding and modeling fundamental fuel injection, mixing, and combustion processes. This should enable the design of more efficient engines, leading to lower fuel consumption, which is consistent with DOE goals.

Reviewer 2:
The reviewer indicated that high-fidelity spray simulation is a pathway to model the cyclic variability commonly experienced in advanced combustion concepts.

Reviewer 3:

The reviewer asserted that the LES is still working in the potential phase of aiding in the development of future DI engines. This may eventually provide a tool for the development of advanced combustion strategies that could reduce engine-out NO_x and PM.

Reviewer 4:

The reviewer said the current and future work as described here is only tangentially applicable to meeting this objective. Down the road, as the program gets more engaged in real engine analysis and then starts looking at non-petroleum fuels (or even just starts getting directly applied to solve questions of increasing efficiency), it will have more direct relevance.

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

Reviewer 1:

The reviewer said that it was good to see that the team is growing, and indicated there is a need to add more resources to figure out how to reduce the cost of LES calculations so that these techniques can be incorporated into the engine design and development time scale.

Reviewer 2:

The reviewer observed a modest project budget for this work effort.

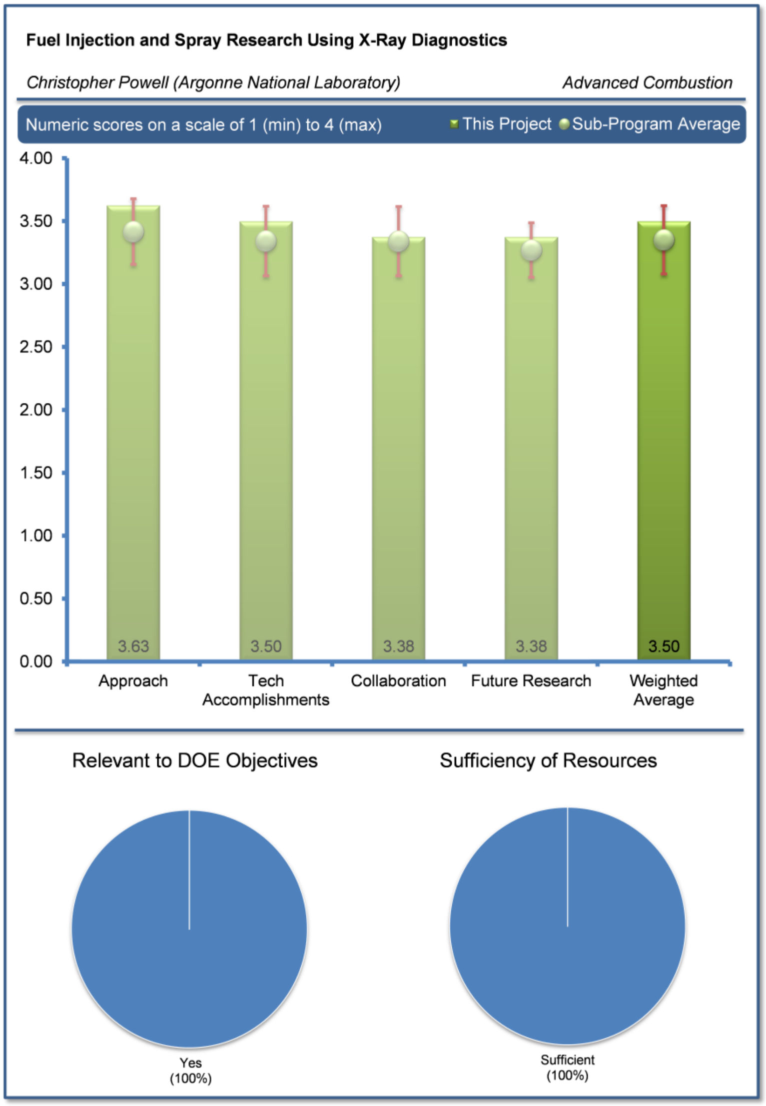
Reviewer 3:

The reviewer reported that the allocated resources were sufficient unless an additional head count is needed to accelerate engine simulations.

Reviewer 4:

The reviewer remarked that, for the stated milestones, the project's resources appeared adequate.

Fuel Injection and Spray Research Using X-Ray Diagnostics: Christopher Powell (Argonne National Laboratory) - ace010



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 great use of a variety of measurement tools to get at different aspects of spray characterization.

Reviewer 2:

The reviewer asserted that the approach proposed by the PI was sound. This project was providing fundamental, state-of-the-art data to accelerate model development.

Reviewer 3:

The reviewer explained that x-ray diagnostics appeared to be a useful tool for investigating spray phenomena.

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 very significant results from the project.

Reviewer 2:

The reviewer found the work visualizing needle dynamics and ingestion of gas into the nozzle hole very noteworthy.

Reviewer 3:

The reviewer indicated that it looked like good progress in measurements of multi-hole diesel nozzles for the ECN. This person added that the project team appeared to be trying to address previous reviewer concerns about this being an ensemble-average technique rather than enabling investigation of shot-to-shot variations.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commended the PI's participation in the ECN. In addition, the experiments were helping to improve CFD models, as shown through the collaboration with University of Massachusetts.

Reviewer 2:

The reviewer noted that the investigators appeared to have attempted to address previous reviewers' concerns about limited collaborations by increased interactions with the ECN and establishing private projects with Delphi Diesel and Caterpillar.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 voiced that the proposed work seemed reasonable for continuing progress and improving the capabilities of the technique.

Reviewer 2:

The reviewer said that the project team should focus on cause/effect leading to improvement opportunities.

Reviewer 3:

The reviewer stated that the x-ray measurements provide a quantitative metric that can be directly compared with CFD computations. Many CFD modelers are now investigating the using of Eulerian-to-Lagrangian transition formulations to predict primary atomization. The reviewer encouraged the PI to work with the ANL team of Som to potentially, through measurement, determine a proper transition between both approaches. This reviewer also encouraged the PI to migrate towards gasoline sprays as indicated in the presentation.

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

Reviewer 1:

The reviewer noted that fuel injection was critical to combustion efficiency and control.

Reviewer 2:

The reviewer remarked that a better fundamental understanding of spray phenomena should aid development of improved fuel injection systems, leading to higher-efficiency, lower-emissions engines.

Reviewer 3:

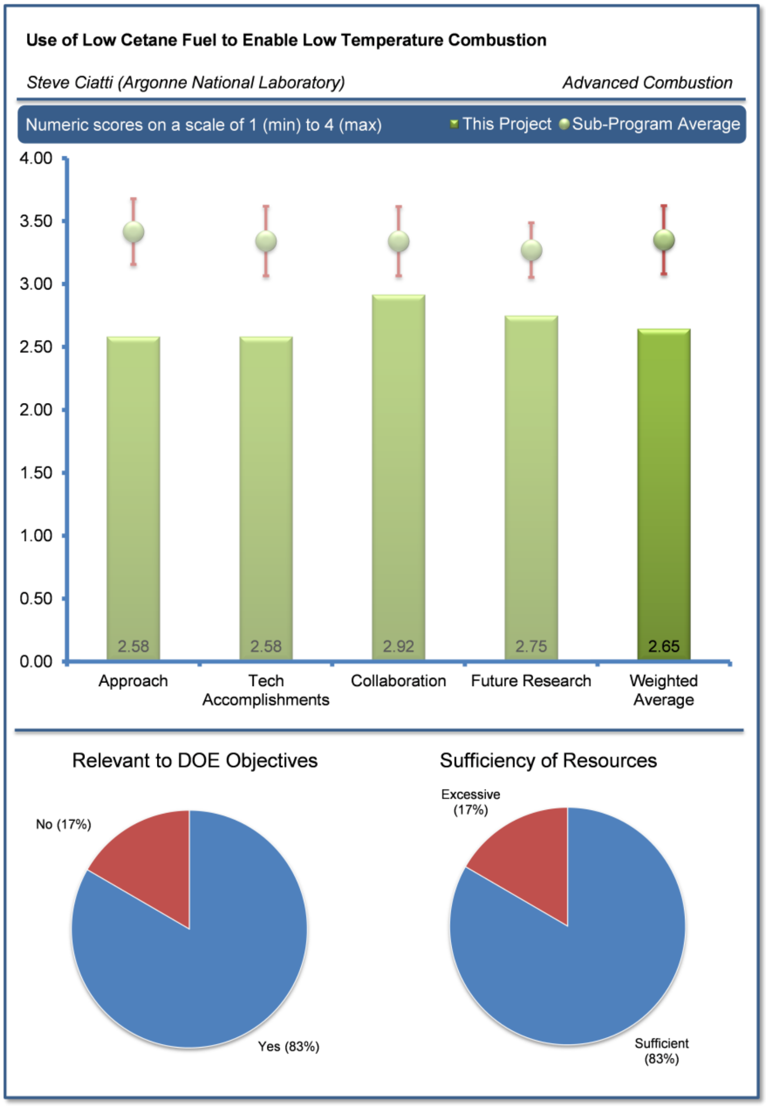
The reviewer indicated that the measurements offered quantitative information in the dense spray region, which was a problem for the CFD modeling community.

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

Reviewer 1:

The reviewer supported the project team's proposed upgrades to the x-ray beamline.

Use of Low Cetane Fuel to Enable Low Temperature Combustion: Steve Ciatti (Argonne National Laboratory) - ace011



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 pointed out that the approach uses a diesel-type engine with a compression ratio of 17.8 to study various gasoline low-temperature combustion phenomena of interest. This approach provides a relevant physical platform, but because of the high compression ratio, a concern is the management of high-load combustion noise and pressure-rise rate issues. This reviewer added that the approach of using regular pump gasoline increased the chances of the concept making it into production.

Reviewer 2:

The reviewer said it still appears to be a "process of discovery" or calibration optimization approach, rather than seeking to understand the fundamentals or mechanisms behind the responses seen in the experiments.

Reviewer 3:

The reviewer pointed out that the use of 2-ethylhexyl nitrate (EHN) to alter the reactivity (and thus expand the speed-load range of 87 Anti Knock Index [AKI] gasoline) was relevant. It will be interesting to compare the results to those of others who have also been working with cetane improvers to expand speed-load range. This reviewer added that a key driver for trying to improve the feasibility of using 87 AKI gasoline is to enable the use of "pump gasoline." However, the 87 AKI gasoline used in the current work is E0 (i.e., contains no ethanol). This is not representative of the majority of gasoline in the United States, which contains about 10% ethanol (i.e., E10). This reviewer concluded that it was not clear whether the results and trends found for E0 would apply to E10.

Reviewer 4:

The reviewer indicated the project seems to expand the operating range of a multi-cylinder gasoline LTC engine to lower loads on 87 AKI gasoline (expanding from previous results at 5 bar brake mean effective pressure [BMEP]). The work used 0.4% EHN cetane enhancer. The project seeks to reduce PM and NO_x emissions compared to conventional diesel combustion. This reviewer added that the project also seeks to better understand the effects of fuel/air mixture preparation, fuel reactivity, and intake conditions on low load ignition propensity and combustion stability. The authors use 3D CFD to simulate the changes in fuel/air mixture conditions and combustion. This reviewer added that the roadmap, including targets and specific milestones, might be better organized. There is a sense that the project is improvising as it moves ahead. Examples of this may be the proposed use and this year's testing of low-pressure exhaust gas recirculation (EGR), narrow spray angle, hot EGR, and so forth.

Reviewer 5:

The reviewer commented that this was interesting work, but some of the program assumptions created serious limits. The diesel engine geometry and single injection limit the range of mixing that can be generated, and the mixing is shown to be critical. Perhaps there are opportunities if spark ignition could be used at some conditions. This reviewer added that this program needed to spend more time thinking about the approach (e.g., what the knowledge of kinetics and in-cylinder flow developed by other DOE projects indicates about the ideal approach to in-cylinder processes, and how can that relate to this program). In addition, the reviewer asked if there is still a possible system (adding ignition, cetane additive controls, etc.) if one is not fully successful at low speed load. This reviewer noted that cold-start was a very big issue for emissions, and asked if this engine could even start on gasoline without a spark plug. While the totality of these issues may be beyond the scope of the project, the project team has to address how these issues can be contained to avoid the risk of doing a lot of work on a system that fundamentally cannot work.

Reviewer 6:

The reviewer cautioned that the project has relatively little general applicability for achieving success with LTGC in a practical, commercial application. The person added that the work had relatively little coordination with other LTGC efforts, and that the metrics for combustion performance did not appear to be well defined or consistent with other works.

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 said progress was being made on the extension of low-temperature combustion to lighter loads. It had been determined that richening the combustion zone with a combination of a narrower spray angle and lower rail pressure extends the minimum load to lower levels. This reviewer noted that the addition of EHN, a cetane enhancer, had also helped in lowering the load limit. This had been achieved at soot and NO_x levels lower than a comparable conventional diesel combustion engine.

Reviewer 2:

The reviewer said basically good results, but needed more on how calibrations and strategies were developed. This reviewer asked if important opportunities had been missed by using single injection.

Reviewer 3:

The reviewer noted some interesting results, but, as previously mentioned, it was not clear whether results obtained from E0 would be applicable to E10, which is the “pump gasoline” across the majority of the United States.

Reviewer 4:

The reviewer explained that the project was able to attain stable Low Load/Speed Operation Investigations with 87 AKI gasoline. This person added that the accomplishment counted on a brief experiment using EHN to study low-load operation using a single injection, uncooled EGR (this latter effort did not give the expected results), and narrow angle injector. The brake-specific fuel consumption (BSFC) results are better than typical port fuel injection (PFI) SI engines but are 10% worse than the diesel benchmark for this engine (an older calibration).

Reviewer 5:

The reviewer indicated that there was a need to address the UHC emissions during a cold start scenario, and the NO_x and PM emissions during steady state operation. The barriers here should be identified and quantified as soon as possible. The reviewer added that this may direct a change in the research focus, and noted that LEVIII/Tier3 emissions standards by 2025 will be at 30 mg/mile HC+NO_x and 3 mg/mile PM emissions for ALL light-duty vehicles. This reviewer emphasized that this was a significant challenge.

Reviewer 6:

The reviewer warned that the accomplishments seemed to be measured against ill-defined performance baselines. The comparison against Euro IV emissions and efficiency was really disappointing, as it had no relevance to North America. This person added that the test points and objectives are poorly defined, and even the constraints on performance (e.g., combustion noise) seem to have no foundation in general principles.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated the team is very capable, including GM for engine hardware, technical guidance, and engineering support; University of Wisconsin for KIVA 3D simulation support; British Petroleum for fuel sourcing; Driven for engine controller and algorithm support/modification; and UC–Berkeley for E10 HCCI ignition information.

Reviewer 2:
The reviewer noted that good CFD modeling support from UW (KIVA) and ANL (Converge) existed. Links to other relevant work like SNL are being explored. This reviewer added that the support for hardware came from GM.

Reviewer 3:
The reviewer highlighted that the introduction of simulations to help understand the results is very important and being done. This person added that it might be necessary to modify the engine hardware (e.g., bowl geometry, injector, and etc.).

Reviewer 4:
The reviewer said some collaborators were mentioned, while some seemed to just be providing supplies.

Reviewer 5:
The reviewer summarized that collaboration seemed to exist, but stronger engagement with industry was needed to focus the test program and establish realistic objectives and bring the project into relevance.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 specified that the project proposes to continue to expand the engine operating map (low load at idle speed), pursuing an injection strategy of lower injection pressure (similar to GDI). The project will continue to reduce NO_x and PM emissions to achieve LTC behavior across the entire map. This reviewer added the authors propose to migrate to low-pressure EGR to provide reduced O_2 concentration and additional premixing at higher loads.

Reviewer 2:
The reviewer stated that the planned future work was right on track to address the remaining barriers of conflicting requirements between combustion and ignition control over the load range. Low-pressure EGR, the use of a supercharger, and the continued push to reduce engine-out NO_x and PM were good measures for pursuing these goals. This reviewer added that, going forward, HC emissions would also need to be lowered compared to the baseline diesel combustion engine.

Reviewer 3:
The reviewer noted that the project plans seemed reasonable, provided that the fuel focus is shifted to E10 instead of E0.

Reviewer 4:
The reviewer felt that the future work appeared to incorporate important features of advanced LTGC engines, but that the test program objectives were unclear. This reviewer inquired about the efficiency and emissions objectives and how the modeling efforts would enhance the probability of success of the experimental work. Conversely, the reviewer queried how the experimental work would contribute to improved modeling of LTGC.

Reviewer 5:

The reviewer remarked that it would help to have a more organized plan of optimizing the combustion system. This reviewer suggested using simulations and logic to decide what needed to be done, and to move in that direction.

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

Reviewer 1:

The reviewer said that this project seeks to advance the limits and controllability of LTGC, which has the potential for significant fuel consumption savings.

Reviewer 2:

The reviewer noted that finding feasible ways to expand the speed-load range of advanced low-temperature combustion strategies was important to improving the commercial viability of those engines.

Reviewer 3:

The reviewer observed that the project promoted improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 4:

The reviewer noted some relevance, although the general area of HCCI seemed to be reducing in industrial interest and the likelihood of a future all-HCCI seemed low.

Reviewer 5:

The reviewer mentioned that LTGC was an important combustion technology for reducing petroleum consumption, but that the present work was not of sufficient relevance to commercial development of this technology.

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

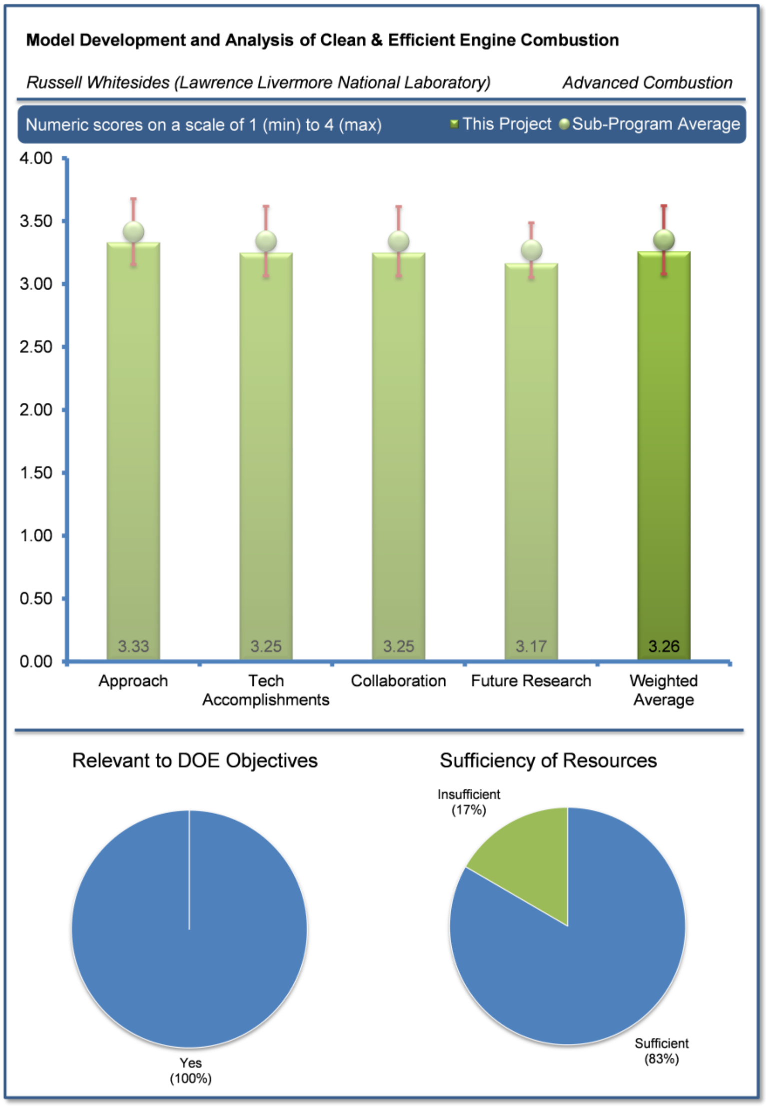
Reviewer 1:

The reviewer said the project scope should be reduced to focus on the experimental work alone until it can be better defined.

Reviewer 2:

The reviewer felt the resources seemed sufficient, assuming there was suitable collaboration with other computational programs to support the CFD, etc.

Model Development and Analysis of Clean & Efficient Engine Combustion: Russell Whitesides (Lawrence Livermore National Laboratory) - ace012



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 voiced that the approach of using numerical simulations and experiments to gain more insight into high efficiency clean combustion (HECC) regimes, and developing tools for desktop computers that combine fluid dynamics with chemical kinetics, was very good.

Reviewer 2:

The reviewer stated that the work of the PI was striving to improve the computational efficiency of combustion calculations to support predictions over a variety of combustion regimes.

Reviewer 3:

The reviewer felt that this project had been well designed throughout the years, though it was disappointing that there still existed little validation of developed tools for combustion predictive capabilities in real-world environments.

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 significant speedup in computation time was achieved, and added that it was good to see the efforts with SNL to validate models against experimental work.

Reviewer 2:

The reviewer noted impressive gains in computational speed by the project.

Reviewer 3:

The reviewer commented that implementation of the GPU solver was a key accomplishment, and that integration into CONVERGE would make it available in a timely manner to engine developers.

Reviewer 4:

The reviewer indicated that the key accomplishment during the past year appeared to be the computational speedup time using GPUs versus central processing units (CPUs). To the reviewer, although the summary side stated that the project was providing industry and researchers with accurate and efficient combustion modeling tools, there was still a lack of validation in real-world engine environments, such as matching the heat release rate over a reasonable operating range or in predicting certain species. This reviewer added it was recognized that this project developed tools for others and that validation was also a community issue, but more effort should be spent addressing validation given the claim of "accurate" combustion modeling tools.

Reviewer 5:

The reviewer stated that the PIs were developing algorithms for faster chemistry. However, this reviewer added that the sub-grid scale was still assumed to be compositionally well mixed. The reviewer asked if the PIs planned to investigate turbulence chemistry interaction. The reviewer would like to see stronger application of the combustion approach to engine validation cases in the future. For example, the reviewer wanted to know if the current approach could capture the intermediate temperature heat release that is key for Dec's engine to achieve higher loads.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated the collaborations mentioned included one OEM, two hardware/software developers, several universities, and one other national laboratory. This reviewer felt it was good to see efforts with SNL to validate models against experimental work.

Reviewer 2:

The reviewer commented that it was great to get NVIDIA involved to better implement the GPU solver.

Reviewer 3:

The reviewer reflected that the project has definitely included partners from various organizations throughout the years. One complaint that this reviewer had is that this collaboration has not led to a better validation process.

Reviewer 4:

The reviewer said that working with a software supplier is a very direct way to impact the industry. The PI referenced a new licensing framework with Convergent Science (Slide 7). However, this reviewer noted that the PI also showed a chart in Slide 12 showing the linkage of the advanced chemistry algorithms with commercial and open-source codes. The reviewer asked if the PI could explain the following: how the license agreement works; how this interplays with linking the combustion algorithms with other codes; if this capability was being shared with ANL because they investigate high mesh resolutions for their applications; if plans exist to validate test cases from the ECN database; and the contributions from the partner universities towards the project accomplishments.

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

Reviewer 1:

The reviewer indicated that the plans for future work seemed reasonable and should continue the progress in this project.

Reviewer 2:

The reviewer stated that continuing with the engine validation cases shown in the presentation was encouraged. One of the current trends in the industry is the proliferation of downsized boosted gasoline engines that rely heavily on flame propagation within a highly dilute environment. Additionally, this reviewer added that spark assisted compression ignition had been studied as a low temperature combustion mode. The reviewer asked if the PI was planning to validate these types of combustion systems with the advanced kinetics.

Reviewer 3:

The reviewer commented that the proposed research was reasonable, though it really needed to include some level of sufficient validation of the combustion predictive capability in a real-world scenario. This reviewer asked if a partner could possibly help with this task.

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

Reviewer 1:

The reviewer indicated that improving chemistry solvers was very useful to industry where CFD and chemistry calculations were used in the engine design process. This person added that speeding up the solvers and improving accuracy were important tools to design more efficient engines. This work had a direct impact on industry by improving the simulation tools that were used to develop new, efficient engines.

Reviewer 2:

The reviewer mentioned that development of better fluid mechanics/kinetic model solvers that can be used on personal computers should greatly enhance the ability to design advanced combustion engine systems.

Reviewer 3:

The reviewer observed that combustion CFD remained expensive and inaccurate for low-temperature combustion, and that this project was showing good progress in addressing this.

Reviewer 4:

The reviewer stated that the project provided a pathway to studying advanced combustion, particularly low-temperature combustion concepts.

Reviewer 5:

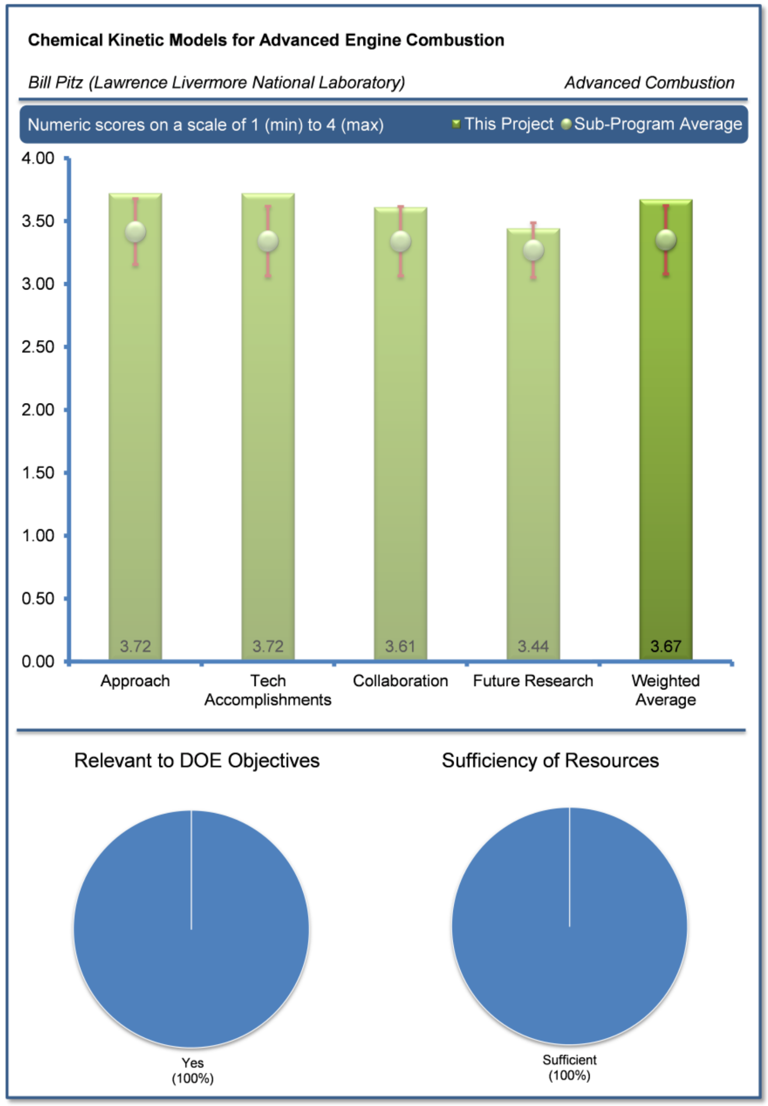
The reviewer affirmed that this work provides tools to researchers exploring advanced combustion strategies for meeting future engine fuel economy and emission standards. This person added it is relevant though currently upstream of other concurrent projects.

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

Reviewer 1:

The reviewer commented additional resources should be applied to the project in order to accelerate the progress toward the goal of reducing computation time.

Chemical Kinetic Models for Advanced Engine Combustion: Bill Pitz (Lawrence Livermore National Laboratory) - ace013



Reviewer Sample Size

A total of nine reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that this is very good fundamental work of the sort that really moves technology forward over time. The fundamentals of chemical kinetics underlie all combustion.

Reviewer 2:

The reviewer said great and necessary work, and continues to build on past foundation.

Reviewer 3:

The reviewer indicated development of chemical kinetic mechanisms for fuel components by the PI and co-workers was critical to advancing engine simulation/modeling.

Reviewer 4:

The reviewer stated that the work in developing FACE fuels and the associated kinetic models was critical toward unifying research in this area.

Reviewer 5:

The reviewer noted that the objectives and approach were well aligned to industry needs.

Reviewer 6:

The reviewer commented that the validation of highly resolved kinetics schemes was extremely challenging. The PI and his team were doing a thorough job with the available measured data.

Reviewer 7:

The reviewer stated that the approach has a strong fundamental basis and an outstanding team of investigators. Having an understanding and modeling capability for the complex chemistry occurring during combustion is a critical component of the advanced modeling efforts that are necessary to the realization of the highest possible efficiency and lowest possible emissions. This reviewer added that the work on surrogates is a good basis for establishing the base kinetic models for real fuels from which more simplified kinetic routines can be derived.

Reviewer 8:

The reviewer remarked that the approach was sound in that fundamental chemical kinetic models were generated for surrogate fuels for gasoline and diesel. The reviewer added these models were validated by comparison to fundamental experimental data. Such models have become more important in recent years with the growing interest in LTC.

Reviewer 9:

The reviewer said that the project seeks to develop predictive chemical kinetic models for gasoline, diesel, and next-generation fuels to facilitate simulations and overcome technical barriers for improved engine efficiency and reductions in pollutant emissions. The chemical kinetic reaction models for individual fuel components are important to accurately model fuel surrogates for gasoline, diesel, and next-generation fuels. This reviewer added that the work was accompanied by reduced mechanisms for use in CFD software tools.

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

Reviewer 1:

The reviewer said that the progress with gasoline fuels had been remarkable. Continued work in defining mechanisms for fuels containing higher aromatics concentrations of C12–C14 will be critical for understanding PM formation mechanisms.

Reviewer 2:

The reviewer noted good progress in adding to the diesel and gasoline palette and exceptional work in the validation models by comparing to experiments. This reviewer was impressed that the prediction for Dec's engine correlated to experiment to the degree it did.

Reviewer 3:

The reviewer mentioned excellent progress with application to real-world challenges, like engine auto-ignition and flame lift-off lengths, with varying fuel composition.

Reviewer 4:

The reviewer indicated excellent progress in meeting milestones. The accomplishments include the development of kinetic models for three out of four of the remaining components in Coordinating Research Council (CRC) FACE diesel fuels (n-butylcyclohexane, trimethylbenzene, and tetralin), development of chemical kinetic models for surrogates of the CRC FACE gasolines, and modeling of Sandia HCCI engine tests of gasolines with and without ethanol (including the intermediate heat release).

Reviewer 5:

The reviewer stated that the project keeps whittling away at the need for high-quality simulation of realistic fuels. This person also noted nice progress in the last year.

Reviewer 6:

The reviewer reflected that the project selected components from the CRC Advanced Vehicle/Fuel/Lubricants (AVFL)-18 Diesel Surrogate palette. The team developed models for n-butyl-cyclohexane, tri-methyl benzene, and tetralin. The project members modeled gasoline fuels by a 10-component surrogate palette to match properties of FACE gasoline fuels. Finally, this reviewer noted that the investigators modeled Sandia HCCI engine experiments with gasoline surrogate models, including ethanol. The authors had made a very disciplined effort to have the models validated with experimental data across a range of facilities. This reviewer concluded that the effort had also begun work on a preliminary model for large PAH as soot precursor.

Reviewer 7:

The reviewer mentioned that several worthy accomplishments were presented (Slides 6–17).

Reviewer 8:

The reviewer observed progressing towards completion of diesel surrogate palette.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent collaborations, and added that the kinetic models developed were being rapidly disseminated to the combustion community at large. The project team's work was serving as the basis for much of the kinetic routine development and subsequent predictions that were taking place in many combustion laboratories worldwide. New kinetic routines were made available on the web in a very timely manner. This reviewer added that the project team was responding well to last year's comments.

Reviewer 2:
The reviewer stated that the project was well connected to leading researchers in the fuels area from around the world. This reviewer added that there was a good balance of simulation, bench, and engine experiments.

Reviewer 3:
The reviewer indicated that this project was very well connected with contributors and potential users—the way it should be done.

Reviewer 4:
The reviewer mentioned a significant amount of collaboration with industry (through CRC projects and the AEC), other national laboratories, and universities. In addition, the reviewer noted that the developed chemical kinetic mechanisms were posted on the LLNL website for others to use.

Reviewer 5:
The reviewer remarked the collaborations appeared to be keeping the research aligned with experimentation and simulation requirements.

Reviewer 6:
The reviewer noted that the main PI collaborated to model the two-component diesel surrogate model developed for CFD engine applications, n-dodecane, and m-xylene, in collaboration with ANL and the University of Connecticut (UConn). UConn collaborated further with the reduced models of the surrogate models. This reviewer added that the ranges of temperatures and pressures were very applicable to engine conditions. ANL performed CFD simulations under engine conditions to reproduce the experimental data taken at SNL. This reviewer stated this included ignition delay and lift-off length measurements. The modeling of gasoline fuels was performed in collaboration with KAUST, UConn, and Rensselaer Polytechnic Institute (RPI).

Reviewer 7:
The reviewer said that the mechanism development at LLNL was world-class and is referenced by researchers around the globe. A plan to strengthen the link to industry is encouraged, especially in a pathway to reduce the mechanisms schemes for engine CFD simulations.

Reviewer 8:
The reviewer suggested greater coordination with industry would be useful to broaden the reach of this work.

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

Reviewer 1:
The reviewer indicated the future research is spot-on relevant with future technology trends and anticipated fuel effects.

Reviewer 2:
The reviewer observed well designed plans to build on the accomplishments made to date.

Reviewer 3:
The reviewer noted a well laid out program for meeting future objectives.

Reviewer 4:

The reviewer stated that the project team would continue to finish the nine-component surrogate mechanism for diesel. The project will continue to develop surrogates models for three remaining FACE gasoline fuels and new gasoline certification. This reviewer added that the models would continue to be benchmarked with experimental tests.

Reviewer 5:

The reviewer observed that the plan for the next year is excellent, and added that it may be time to start thinking about how much more depth is needed once reasonable diesel and gasoline surrogates have been modeled. The reviewer asked at what point was more detail no longer needed for the level of simulation needed to do tasks of engineering and research, and if it was getting near to that point. The reviewer concluded that this should perhaps be addressed in the next year.

Reviewer 6:

The reviewer stated that the work of gasoline should continue to be accelerated, including the effect of EGR and more equivalence ratios, pressures, and temperatures.

Reviewer 7:

The reviewer remarked that it is understood the full mechanism needed to exist before it could be reduced; however, to be practical to industry, accurate and fast (e.g., reduced) mechanisms were required. This reviewer added that it would be good to see experimental validation, at the engine level, to evaluate the accuracy of the reduced mechanisms. This person agreed with the direction to improve the capability in predicting soot; it is needed, for both diesel and gasoline.

Reviewer 8:

The reviewer asked if there were any plans to work on the chemistry for advanced ignition systems (such as plasma). This work would align with the projects undertaken at ANL and SNL. The reviewer wanted to know if the kinetics schemes currently available to capture the effect of acetylene on NVO combustion that Ekoto and Steeper at SNL were measuring, and if there was a plan to develop models for soot particle size distributions in the future. This reviewer further asked if the PI was confident that the mechanisms developed were able to capture both flame and auto-ignition in spark assisted HCCI (spark assisted compression ignition [SACI]) downsized boosted gasoline engines. Slides 3 and 4 showed a focus on soot modeling; however, this reviewer noted it was unclear where this work was planned in Slide 22.

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

Reviewer 1:

The reviewer stated that this is extremely relevant, and that engine simulation and optimization cannot occur without it.

Reviewer 2:

The reviewer observed directly relevance to DOE's combustion and fuel tasks.

Reviewer 3:

The reviewer voiced that the development of chemical kinetic mechanisms is critical to the development of models and simulators for advanced high-efficiency, clean-combustion engines.

Reviewer 4:

The reviewer reflected that the project promoted improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 5:

The reviewer noted very important chemical kinetic mechanisms, which are needed for LTC development, result from this project.

Reviewer 6:

The reviewer mentioned detailed kinetics modeling was a pathway for predicting advanced combustion concepts.

Reviewer 7:

The reviewer indicated that the work related indirectly to DOE's objectives for greater fuel efficiency, but was critical to achieving higher efficiency with low pollutant emissions.

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

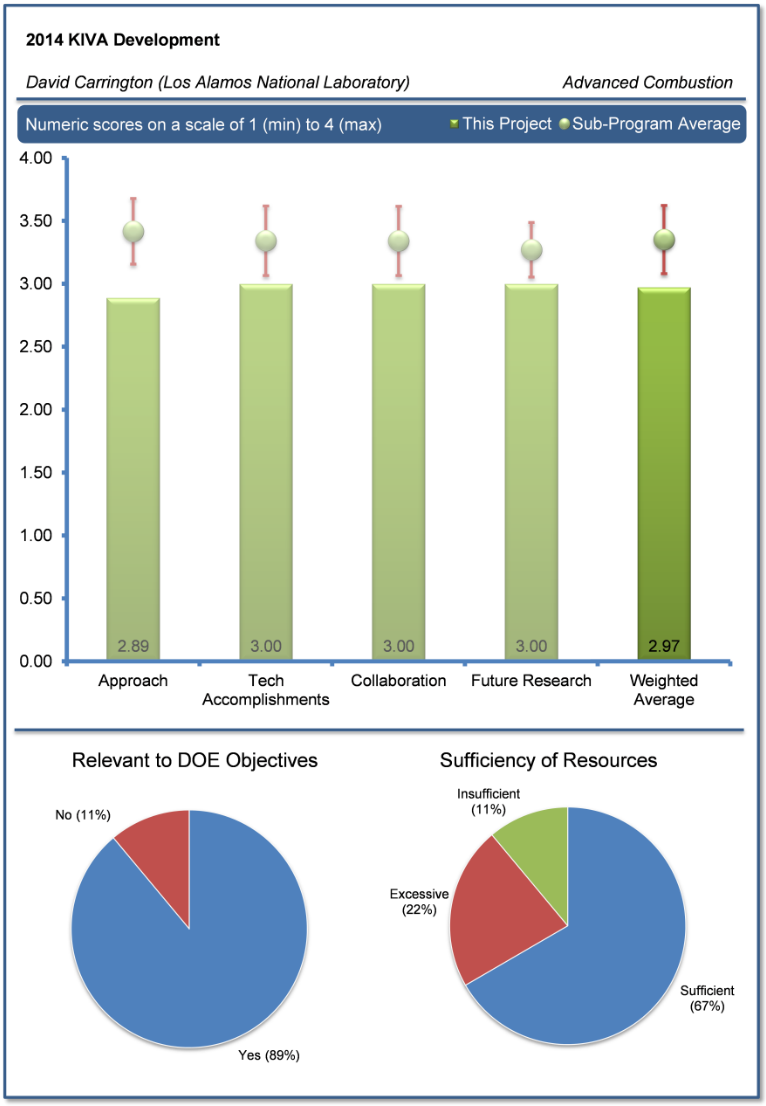
Reviewer 1:

The reviewer noted no express request was made for more funding. This reviewer asked what additional work more funding would allow if it were available.

Reviewer 2:

The reviewer said the resources seemed sufficient to do the high-quality work shown here.

2014 KIVA Development: David Carrington (Los Alamos National Laboratory) - ace014



Reviewer Sample Size

A total of nine 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 keeping KIVA relevant was critical for academic institutions performing fundamental work on internal combustion engines.

Reviewer 2:

The reviewer rated this as good to excellent. This person added that this was very important work and, if successfully completed, it would facilitate the independent work of many researchers developing more sophisticated aspects of combustion and spray modeling, with the net result being more robust and accurate CFD predictions. This reviewer was not sufficiently knowledgeable to critically evaluate the details of the work, thus the reason for the moderate rating of the project.

Reviewer 3:

The reviewer indicated the project seemed like a very solid continuation of a long-time program that was very valuable.

Reviewer 4:

The reviewer remarked that continuing to improve KIVA is worthwhile.

Reviewer 5:

The reviewer noted that the project seeks to provide improved tools for more accurate prediction of engine processes, including fuel injection, fuel-air mixing, and emissions prediction. The effort targeted a wide range of combustion regimes. This reviewer also mentioned that the project focused on new, more efficient algorithms and grid generation.

Reviewer 6:

The reviewer asked if this code competed or complemented commercially available code.

Reviewer 7:

The reviewer felt that the approach was not clearly articulated in the presentation.

Reviewer 8:

The reviewer mentioned that the current approach seeks to improve the backbone numerical algorithms and structure of the KIVA code to address many of its current shortcomings. Based on the current milestones (Slide 4) and timeline (Slide 2), it is a bit unclear to the reviewer how the current improvements to KIVA will compare to capabilities in popular commercial codes. This reviewer asked if KIVA would hold a strategic advantage. Additionally, many academic institutions are beginning to evaluate OpenFOAM as CFD software. This person noted that OpenFOAM has modularity and parallelization that is an objective of this project, and asked what the reason was to not begin with OpenFOAM as the base platform and focus on updating the physical submodels.

Reviewer 9:

The reviewer voiced that KIVA-3 and KIVA-4 are seeing less and less use within industry. KIVA has become more of a free resource to universities that want an open-source type format so they can do physical modeling. But even there, this reviewer added, other competitors like OpenFOAM are taking over the market share. A serious evaluation of the business model needed to be made. This reviewer added that it would really be healthy to continue to have KIVA as a competitor to other commercial codes, and asked what could be done to hasten the development and deployment of KIVA within industry.

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

Reviewer 1:

The reviewer emphasized that the addition of spray and advanced turbulence models were critically important, as were pre-processing and solver improvements.

Reviewer 2:

The reviewer noted good progress on meeting milestones.

Reviewer 3:

The reviewer was not an expert in this area, but the results seemed solid.

Reviewer 4:

The reviewer stated the emphasis of focusing on a sound numeric approach in KIVA is a good direction and should be pursued. Several test cases were presented to demonstrate the new capabilities of KIVA. This reviewer asked if there is a reason the PI did not invest in using newer databases, such as ECN spray measurements and engine data currently being taken at other national labs. This reviewer noted the project timeline ends in September 2015, and asked if the code would be mature and capable enough to simulate many of the low-temperature DI combustion problems being studied by other AEC projects.

Reviewer 5:

The reviewer mentioned that the accomplishments seek to update the original KIVA model, and span a range of methods and models, including spray models (with evaporation, breakup, and droplet transport), easier and quicker grid development, and parallel solution schemes. It appeared that the project made good progress, though it was hard to evaluate this. This person added that it would be most optimum it would be optimal to have the authors make a proof-of-concept when applied to a real engine scenario and compare this with other modeling tools and experimental data. Some of this was done with simple examples (such as in the grid generation).

Reviewer 6:

The reviewer felt that it was difficult to resolve what accomplishments were completed in the last calendar year.

Reviewer 7:

The reviewer indicated that it was not clear how all of the improvements made in KIVA compared to features currently available in commercial codes. This reviewer asked if KIVA was leading or lagging the commercial codes, and added that, as KIVA is maintained by a national laboratory, it should be leading.

Reviewer 8:

The reviewer emphasized the technical accomplishment appears to be excellent. However, it is a concern to this reviewer to not see the broad-based user community, universities, other national laboratories, and industry showing much excitement about this program.

Reviewer 9:

The reviewer noted plenty of work had been done and numerous test cases were shown. However, overall technical progress over the last few years on KIVA-4 has been very slow. The reviewer added that the key issue now was whether industry was really interested in KIVA-4, and asked why it was not. It is a free code, yet industry prefers to use other commercial codes. The reviewer opined that there was something wrong with this picture. This reviewer asked what could be done to make the usefulness and deployment of KIVA-4 within industry faster.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted collaboration was mostly with academic institutions, which seemed to be appropriate for KIVA.

Reviewer 2:

The reviewer said KIVA is a widely used tool with many collaborators actively involved.

Reviewer 3:

The reviewer noted that the team assembled includes the University of New Mexico, Purdue University Calumet, and University of Nevada–Las Vegas. This reviewer added that the presentation showed how the work was being split.

Reviewer 4:

The reviewer emphasized the collaborations cited were mostly with universities.

Reviewer 5:

The reviewer felt the collaborations that exist appear to be good, but added there was no mention of interface with “heavy” academic, research laboratory, or industry users to get feedback or their impressions of the program or to exercise it.

Reviewer 6:

The reviewer commented that the development goals of the project appeared very aggressive, with the logical progression of new models being somewhat fragmented. The reviewer encouraged the PI to solicit industry input as beta testers to provide feedback during the development process. It appeared that other national laboratories were entrenched into using their own in-house or commercial codes like CONVERGE and OpenFOAM. This reviewer asked what the business model was to proliferate KIVA to the wider technical community outside of the academic partners involved in the project.

Reviewer 7:

The reviewer remarked it was good to see a few universities involved, but felt it was interesting to see that Wisconsin was not among the project team. This reviewer stated that an additional collaborator should be SNL’s ECN. It is a chance to simulate and compare simulation to measurement. This person asked if the spray model could be “tuned” to one experimental condition, then be accurate (and predictive) for other conditions. If KIVA was leading the industry, this would be a way to showcase it—by showing how good the KIVA prediction was compared to commercial codes. This reviewer would like to see this in next year’s review.

Reviewer 8:

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

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

Reviewer 1:

The reviewer said the plan to complete the remaining objectives is good.

Reviewer 2:
The reviewer indicated that this seemed to be the correct direction. This reviewer looked forward to a tool that could handle turbulence and wall interactions more directly.

Reviewer 3:
The reviewer commented that the future work was appropriate, but should consider flame kernel models in the context of dilute combustion.

Reviewer 4:
The reviewer noted that, with the validation being done on numerical schemes, it would be good if this group could suggest good, fundamental test cases that others in the community could use to benchmark the numerical accuracy of their own codes or commercial codes. One could envision a distribution of tutorial test cases within the KIVA package. The reviewer noted that this group is in a unique position to help industry understand the limitations of using lower-order treatments on boundaries (such as cut-call, as mentioned in the presentation) and drive the larger engine CFD community to more numerical accuracy.

Reviewer 5:
The reviewer said the project would continue to pursue spray and combustion systems modeling, solvers, and grid generation, but added that the closure of the effort was not too clear.

Reviewer 6:
The reviewer felt that there needed to be faster progress on getting the remaining work done.

Reviewer 7:
The reviewer indicated, similar to previous comments on accomplishments, it was hard to judge if the proposed work was on target or not. There was no justification for any of the improvements. This person asked if the improvements were driven by gaps in current commercial codes that KIVA could fill. The reviewer further asked if they are general improvements, where they came from, and how they were prioritized. The reviewer noted Convergent Science's CONVERGE code was quite prevalent in many of the other presentations, while KIVA got little (or no) mention. The reviewer continued to ask if the KIVA resources would be better utilized by using the national laboratory capability to develop open “sub-models” that can be incorporated into commercial codes. If this is not doable today, the reviewer wanted to know what enablers were required to make this happen. This reviewer suggested this might be the better use of the resources.

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

Reviewer 1:
The reviewer stated that the project promotes improved modeling tools that will help in the overall fuel efficiency roadmap.

Reviewer 2:
The reviewer felt that KIVA modeling is invaluable to the academic research in the field of advanced ICEs.

Reviewer 3:
The reviewer indicated that KIVA is a basic tool for many levels of simulation necessary to DOE’s mission.

Reviewer 4:
The reviewer summarized that improved modeling/simulation of fluid injection, mixing, combustion, and emissions formation is important to the design of higher-efficiency, lower-emissions engines—which is consistent with DOE goals.

Reviewer 5:
The reviewer noted that accurate CFD codes were a pathway to predictive simulations for advanced engine concepts, and added that demonstration of this code to compute these concepts needed to be faster.

Reviewer 6:

The reviewer said it was clear that an open-source 3D CFD code had a place. This reviewer added that, given the current direction shown, it is not clear that KIVA is relevant—but it can and should be. This reviewer asked what the unique strength is of LANL and KIVA, and how it can best be leveraged to lead the industry. Similarly, the reviewer asked what the gaps/needs in current commercial codes were, and how KIVA could address them. This reviewer noted there needs to be time and thought put into this, and a plan clearly communicated.

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

Reviewer 1:

To this reviewer, having an open-source advanced CFD program that allows the technical community to work on sub-model development for higher precision and fidelity in the modeling of the various phenomena occurring in the engines—and then evaluating these sub-models in a predictive program and presenting results for peer evaluation—has been key to the rapid advancement that has occurred in CFD analysis over the past several decades. This reviewer added that providing such a program is an appropriate role for DOE, and DOE should be proud of the progress in engine understanding and development that has occurred though the KIVA program. However, this reviewer noted that KIVA-3 seems to approaching the end of its useful life and that an upgrade is needed. That is the objective of this program. The reviewer concluded that, to this end and relative to the importance of having a timely update introduced (which is of use to the CFD community), the program seems underfunded.

Reviewer 2:

The reviewer asked if, to get work done faster, the funding needed to increase or if the funding model needed to change.

Reviewer 3:

The reviewer said that the funding level seemed to be appropriate, and added that it sounded like much of the funding went to universities under subcontracts. This reviewer asked if there were enough core personnel at the laboratory.

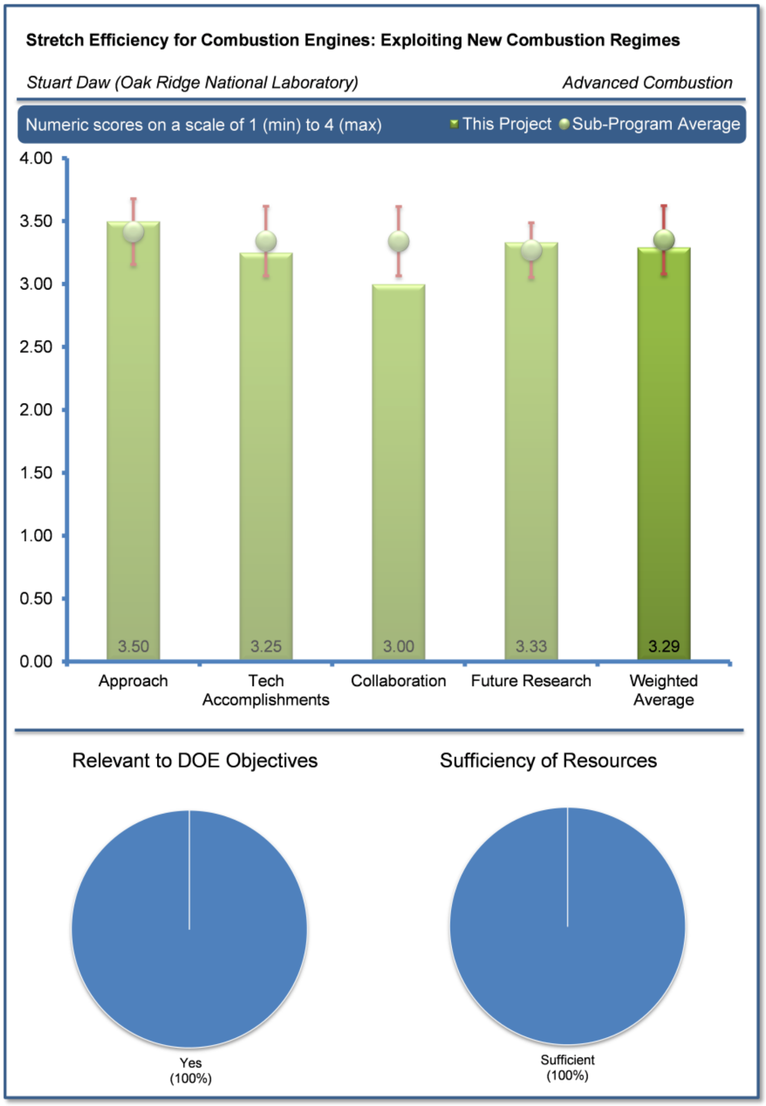
Reviewer 4:

The reviewer remarked that, in the future, the PI should more clearly credit in the presentation material on what contributions/sub-models were being made by LANL and the universities.

Reviewer 5:

The reviewer observed excessive funding for the current direction.

Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes: Stuart Daw (Oak Ridge National Laboratory) - ace015



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer said that this work was an excellent look at the fundamental thermodynamics of efficiency improvement in SI engines, with a very innovative approach to improving efficiency through thermochemical recuperation (TCR). This reviewer added that building a flexible engine platform to look at competing concepts was a great idea for both providing a common basis of comparison and reducing costs of duplicate hardware, etc.

Reviewer 2:

The reviewer noted that the project included some creative and unique ideas, as well as adaptations of other's ideas to improve engine efficiency. This reviewer looked forward to the results of in-cylinder reforming to see the net benefit considering the friction penalty of a non-firing cylinder. The reviewer summarized that this was a high-risk project with a potentially high reward.

Reviewer 3:

The reviewer believed that this type of study should be conducted through DOE funding. The reviewer agreed with the PI's concept of 'evolutionary versus revolutionary' technology investigation.

Reviewer 4:

The reviewer remarked that clearly this was high risk but may be promising. This reviewer added such programs were needed if we are to achieve breakthrough engine efficiencies.

Reviewer 5:

The reviewer stated that this proposed approach of reformate-assisted dilute combustion through thermochemical recuperation is high-risk, high-potential work that merits scoping funding from DOE. This person added that it was unclear how beneficial it would be to dedicate one of the four cylinders to reforming.

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 indicated great work on showing what could be accomplished and what barriers must be overcome.

Reviewer 2:

The reviewer emphasized good progress on assembling the engine system and starting to evaluate the two approaches of in-cylinder reforming and catalytic EGR loop reformer.

Reviewer 3:

The reviewer noted that results were shown at one operating condition, and added that it would be interesting to see a sensitivity study on operating conditions to see what conditions are best to do reforming to maximize efficiency (as exhaust temperature and gas compositions vary depending upon operating condition).

Reviewer 4:

The reviewer stated that ORNL is uniquely able to study the catalytic EGR reformer chemistry. This person asked if the PIs had knocking issues with the introduction of 'reformed' EGR in the power cylinders, and if the PIs believed this technology to be synergistic with lean-burn engine concepts.

Reviewer 5:

The reviewer observed good progress in getting the engine put together, but was hoping to see some engine test results this year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted excellent collaboration with universities, other government laboratories, and industry.

Reviewer 2:

The reviewer asked if there was any plan to incorporate CFD modeling of the in-cylinder reforming/combustion process. This person indicated this data could provide a good benchmark to drive future kinetics development.

Reviewer 3:

The reviewer mentioned some collaboration with other national laboratories and universities, and added that there appeared to be limited collaboration with industry.

Reviewer 4:

The reviewer felt that it appeared there could be more collaboration opportunities.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 asked if the PI would show comparisons between different EGR reforming approaches in the future.

Reviewer 2:

The reviewer suggested that it would be good to estimate the improvement in efficiency (possibly via numerical/analytical modeling) before proceeding too much on the experimental side of choosing which catalyst and approach to use. This reviewer was not sure if there were better catalysts than rhodium.

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

Reviewer 1:

The reviewer emphasized that this work could provide breakthrough results to improve engine efficiency and reduce petroleum usage.

Reviewer 2:

The reviewer noted that improving efficiency would aid petroleum displacement, and added that presumably this technology would work just as well with non-petroleum fuels.

Reviewer 3:

The reviewer summarized that the project focuses on a concept that has the potential for higher engine efficiency.

Reviewer 4:

The reviewer commented that this technology provided a pathway for dilute SI combustion to improve fuel economy with standard after-treatment technology.

Reviewer 5:

The reviewer stated that TCR is one avenue for exceeding the limits imposed by the Carnot cycle.

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

Reviewer 1:

The reviewer felt that this project needed additional resources to accelerate progress.

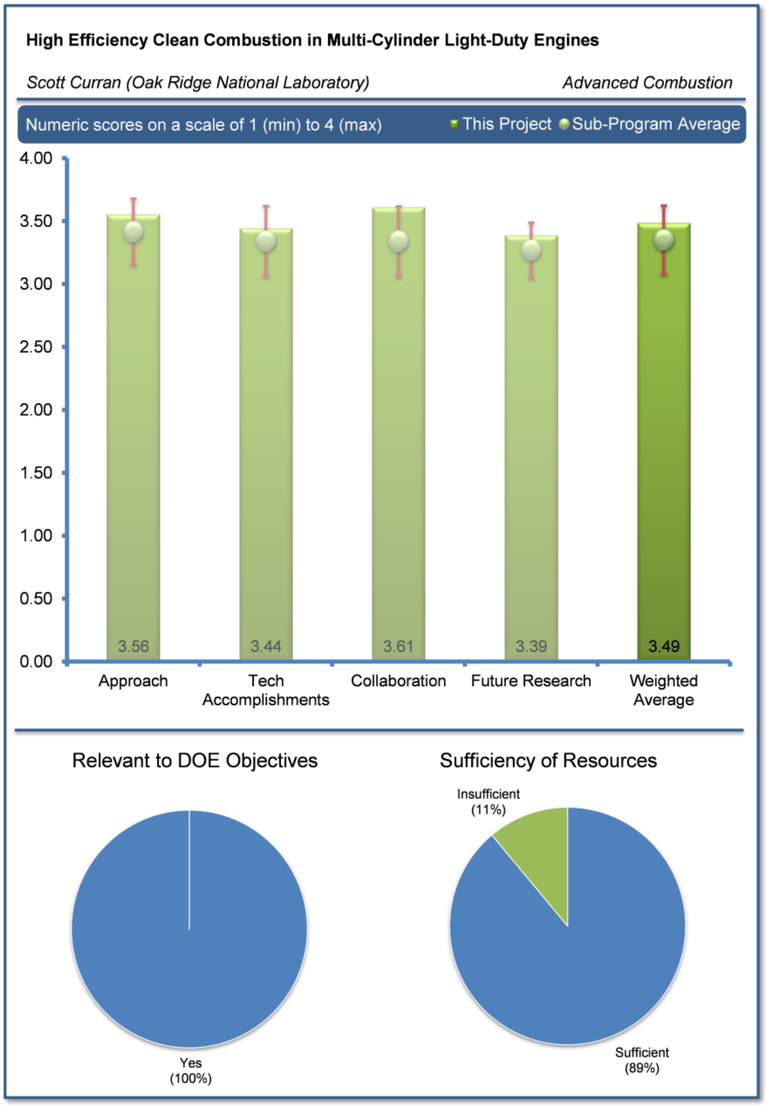
Reviewer 2:

The reviewer noted good use of resources and expertise.

Reviewer 3:

The reviewer indicated that the resources appeared to be adequate for the planned program.

High Efficiency Clean Combustion in Multi-Cylinder Light-Duty Engines: Scott Curran (Oak Ridge National Laboratory) - ace016



Reviewer Sample Size

A total of nine reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that the approach was excellent in that it seeks to be as relevant to real-world application as possible, using multi-cylinder engines, calibrating it over the test cycle, and using the map in vehicle simulations to assess benefits.

Reviewer 2:

The reviewer emphasized that the PI has a solid approach that combines experimentation and modeling, including characterization of emissions.

Reviewer 3:

The reviewer felt that it was very useful to see RCCI tested in real conditions, and added that the approach seemed solid.

Reviewer 4:

The reviewer indicated that the development of the technology is considered in the proper context for demonstrating its commercialization potential. This person noted efficiency is considered in the context of the application to conventional and hybrid powertrains, with realistic fuels, and with due consideration of the exhaust-aftertreatment challenges.

Reviewer 5:

The reviewer mentioned that a system-level approach was needed for evaluating vehicle-level emissions and efficiency benefits.

Reviewer 6:

The reviewer explained that the project seeks to overcome the lack of fundamental knowledge about advanced combustion regimes, the lack of effective engine controls for LTC, and the lack of actual emissions data on future engines. The effort seeks to assess the potential of advanced combustion concepts, such as RCCI, on multi-cylinder engines for improved efficiency and emissions along with advanced emission-control technologies. This person added that the approach includes the characterization of emissions from advanced combustion modes, and it defines synergies and incompatibilities with aftertreatment systems. The reviewer noted that the study also considers the operation in both conventional and advanced combustion modes, including mode switching.

Reviewer 7:

The reviewer mentioned this was a good approach, but should include the fuel economy impact of after-treatment in the vehicle simulation.

Reviewer 8:

The reviewer asserted that the effort to expand the assessment of the advanced combustion strategies to vehicle system and transient operation was an important component of performing realistic evaluation of the potential for these combustion technologies to move toward production. This reviewer added that the work should also identify important areas of system control, as well as emission challenges that would need to be addressed for these advanced combustion strategies to make the next step towards implementation.

Reviewer 9:

The reviewer said that the assessment of the RCCI concept in multi-cylinder light-duty, hybrid light-duty, and heavy-duty engines is extremely important to assessing the potential of this approach. This person's only criticism of the work is that E30 was used instead of E10, and added that, since E10 is commercially available, it is important to assess the RCCI capabilities with this 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 toward DOE goals.

Reviewer 1:

The reviewer said that the project was demonstrating excellent progress toward meeting realistic, well-defined objectives for the technology. This person added that extending the load range would be an important next step, so that the efficiency gains may be realized with equivalent acceleration performance.

Reviewer 2:

The reviewer noted excellent progress in assessing the performance of RCCI in various engine/vehicle platforms.

Reviewer 3:

The reviewer noted very nice work. This reviewer viewed what has been accomplished as setting the stage for the really important work that lies ahead, namely, the evaluation of the actual transient performance for both fuel consumption and emissions.

Reviewer 4:

The reviewer stated lots of good data, but added that data with E10 would be important.

Reviewer 5:

The reviewer asked how the RCCI fuel economy targets compared with a modern DI baseline engine (such as GM's LNF or Ford's EcoBoost).

Reviewer 6:

The reviewer remarked the accomplishments included demonstration of cylinder balancing control for RCCI operation, and establishing control authority on an HD engine for future RCCI operation. The RCCI mapping focused on efficiency and load extension. This person noted that the limited load range required mode switching to cover full drive cycles, and that the present work appeared to be limited to modeling; therefore, the implementation to actual hardware should be the focus now. This reviewer felt that this would be the high value added by the project, as steady state data was available from other programs and platforms. Also, this person felt that the use and reason for selecting E30 with diesel might need to be explained.

Reviewer 7:

The reviewer voiced that the benefits of RCCI combustion over various drive cycles were now better understood, and added that the fuel economy benefits of RCCI have now been compared to relevant PFI gasoline and diesel baseline engines. The RCCI region of the drive cycle needed to be expanded further to get more benefits. This reviewer added that the character of particulate matter from RCCI combustion was being better understood.

Reviewer 8:

The reviewer noted good progress towards vehicle-level estimates of emissions, but noted a need to consider cold start and catalyst light-off periods.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer emphasized excellent collaboration with industry, universities, and other national laboratories. This reviewer especially wanted to compliment the PI on Slide 16 regarding the project's collaborations, which clearly elucidates their types of collaboration with the various organizations—distinguishing between info exchange, equipment supply, and robust collaboration. This was the only presentation this reviewer had seen where those distinctions were made. In presentations by others, this reviewer often wondered whether what is characterized as collaboration consists only of a presentation once or twice a year.

Reviewer 2:
The reviewer noted excellent interaction with the relevant groups, and stated that a good level of collaboration had been achieved.

Reviewer 3:
The reviewer indicated that the PI has leveraged an extensive network of collaborators, providing good synergy and feedback towards the project.

Reviewer 4:
The reviewer said that the collaboration was well designed for progress on multiple fronts in the technology (e.g., efficiency, emissions, and technology demonstration).

Reviewer 5:
The reviewer noted that the team leveraged resources and expertise across industry, national laboratories, and universities.

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

Reviewer 1:
The reviewer observed that the plans were well designed to build on the progress to date and met program objectives.

Reviewer 2:
The reviewer encouraged the future work that focuses on engine transients.

Reviewer 3:
The reviewer stated that it was good to see the after-treatment integration into the vehicle simulation is planned for next year. This reviewer noted the transient work is also critical, to make sure the vehicle results predicted from modeling will be realizable in the vehicle.

Reviewer 4:
The reviewer commented that the future work was well laid out for the closing of fiscal year (FY) 2014 and for 2015. The program will continue to develop experimental RCCI maps suitable for standard drive cycles, and it will continue to try to demonstrate a 25% increase in the modeled fuel economy with RCCI over LD drive cycles. This reviewer added the selection of a low-temperature catalyst will be pursued, and that the project will also seek to demonstrate heavy-duty RCCI on a multi-cylinder engine.

Reviewer 5:
The reviewer said that the challenge is to not let the size of the RCCI regime diminish when relevant transient controls and transient calibration are done. This reviewer added that the after-treatment challenges with regards to CO and HC emissions, as well as low exhaust temperature, were also critical remaining barriers.

Reviewer 6:

The reviewer noted a solid plan to get the data, and added that it may be useful to collaborate with Bosch, which had done a lot of work and analyses on HCCI multimode controls. This reviewer added that much of what the project team had found might inform this work, and reminded the project team to be sure to use properly aged catalysts in this work.

Reviewer 7:

The reviewer indicated that the proposed future research had realistic yet ambitious goals, and was extremely relevant to efforts to commercialize the technology. However, this reviewer noted further transient performance objectives should also include more aggressive US06 cycles, or that the application should be restricted to hybrids or perhaps even medium-duty trucks (with higher displacement). The reviewer added that finding a means for reducing the ethanol requirements by addressing octane sensitivity might be useful.

Reviewer 8:

The reviewer emphasized that it would be critical to incorporate appropriate systems-level controls (model-based controllers would be ideal) to control RCCI through transient operation. Otherwise, this reviewer thought it was likely that the advantages of this mode of combustion would be lost in practical application.

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

Reviewer 1:

The reviewer offered that bridging the gap from single-cylinder engine studies—and determining the capabilities/feasibilities of advanced combustion concepts, such as RCCI in multi-cylinder engines—greatly advanced the assessment and development of the most promising of the high-efficiency, clean-combustion technologies.

Reviewer 2:

The reviewer indicated HECC was an important high-risk, high-reward technology for LDVs, and that this project was addressing all the appropriate areas.

Reviewer 3:

The reviewer noted that low-temperature combustion technologies are a means to improve engine fuel economy.

Reviewer 4:

The reviewer said the work was very relevant to the research on future systems.

Reviewer 5:

The reviewer voiced that RCCI has demonstrated high brake thermal efficiencies with ultra-low NO_x and soot emissions in steady state. However, this reviewer noted that the benefits and challenges of RCCI over federal driving cycles were still not well understood. The reviewer added that this effort would bridge this gap, and that the project promoted improved tools that would help in the overall fuel efficiency roadmap.

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

Reviewer 1:

The reviewer noted that the presenter did not complain of insufficient funds.

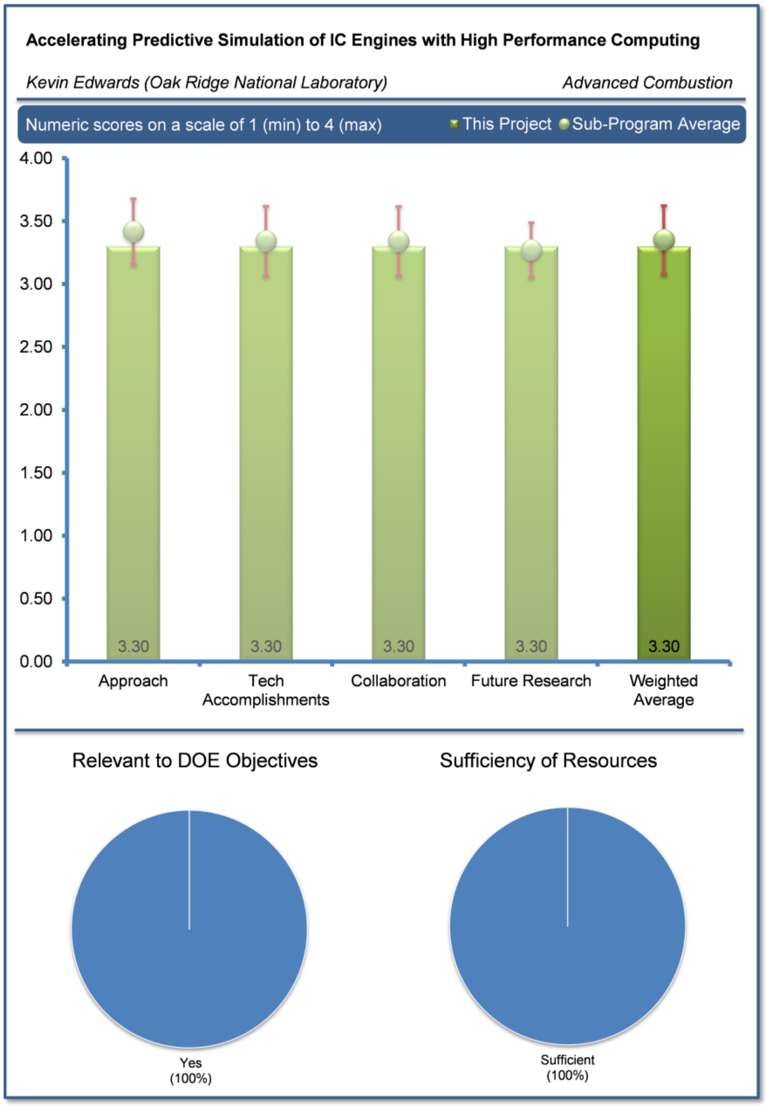
Reviewer 2:

The reviewer suggested that expanding the collaboration to address some of the critical challenges of the technology would be useful to making progress toward the needed LD efficiency improvements.

Reviewer 3:

The reviewer felt that the funding level seemed appropriate.

Accelerating Predictive Simulation of IC Engines with High Performance Computing: Kevin Edwards (Oak Ridge National Laboratory) - ace017



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that this was important work to help industry leverage the capabilities of large-scale computing.

Reviewer 2:

The reviewer felt it was good to see a complete, iterative design/model/optimization scheme.

Reviewer 3:

The reviewer indicated the approach of developing and applying innovative uses of HPC and predictive simulation to accelerating internal combustion engine (ICE) development was of value.

Reviewer 4:

The reviewer stated that the project provided a "package deal" of HPC computing and support for industrial partners to tackle specific large-scale engineering problems relating to IC engine design. While this can be a very useful way of promoting and conducting basic research, the "open" nature of the research limits its ability to impact the actual design process, or to even tackle very specific technical issues faced by industry. This reviewer said a better balance is needed between the project's "openness" criteria for maximum engagement of these resources (of course, this is just a reflection of higher-level policy) with the needs of industry to keep at least some aspects of the work proprietary. This reviewer's organization has formed partnerships with other laboratories and universities, which better meet these needs while also meeting their needs for publications, and etc. So, while one could argue the "technical barriers" are being addressed, the issue is with the "integration" of these resources within the needs of industry. The reviewer added that if the latter could be given more flexibility, then this would be an excellent or even outstanding effort.

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 had completed the development and deployment of the computer framework for launching parallel ICE simulations on ORNL's HPC resources. This person added that most of the other work for 2014 seemed to be still in progress but on track to meet milestones.

Reviewer 2:
The reviewer observed very interesting simulation results and suggested continuing to pursue experimental verification whenever feasible.

Reviewer 3:
The reviewer felt that the progress on the reported collaborations appears to be excellent, and added that it might have been interesting to include some comments and feedback from the customers on these three projects in terms of the timelines and utility of results, key assistance provided by ORNL, etc. The reviewer added that, as this appears to be a very customer-driven project, having the customers' feedback on the highs and lows of the interaction would be useful and perhaps (assuming things are being done right) lead other potential collaborators to step up to be included.

Reviewer 4:
The reviewer remarked that the techniques and solutions developed to run CONVERGE on the Titan supercomputer will help other projects that could use large-scale computing.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted good collaboration with a software supplier and industrial partners.

Reviewer 2:
The reviewer mentioned that collaborations were established with several industry partners (including Ford, General Electric, GM, and Convergent Science).

Reviewer 3:
The reviewer commented that the project appears to have three main collaborators to date, and added that, if the goal is true outreach and facilitation with industry, there is a long way to go to impact the industry as a whole. This person stated the question of balance between "openness" on the laboratory side and the proprietary aspects of potential projects from possible industrial partners needs to be more effectively resolved.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 plans seem reasonable.

Reviewer 2:
The reviewer indicated that the concept of a low-order "meta-model," which greatly reduces the computational cost, is a very interesting idea. Besides the meta-model mentioned, phase-invariant proper orthogonal decomposition (POD) also provides a good basis (modes) to construct low-dimensional turbulence/combustion models. The reviewer added that these POD modes offer the potential for rapid analysis and prediction of in-cylinder flows/combustion that might eventually be used for real-time control. Also, these base functions (modes) for the low-order models could be derived either from experiments or simulation. This person suggested that the authors could refer to the following references for more details: Holmes P, Lumley J L and Berkooz G, 1996, Turbulence, Coherent Structures, Dynamical Systems and Symmetry (New York: Cambridge University Press); and K. Liu, D. C. Haworth, X. Yang and V. Gopalakrishnan, "Large-eddy simulation of motored flow in a two-valve piston engine: POD analysis and cycle-to-cycle variations," Flow, Turbulence & Combustion. Vol. 91, pp. 373-403, 2013.

Also, this reviewer noted that to study the combustion stability, the SI ignition model development is very important. The flame kernel initialization and early development are essential stages for the cycle-to-cycle variations. This reviewer concluded that this subject could be an interesting topic.

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

Reviewer 1:

The reviewer said accelerating the development of high-efficiency, low-emissions engines by applying innovative uses of HPC and predictive simulation supports DOE goals.

Reviewer 2:

The reviewer commented that leveraging supercomputer resources to address engine combustion problems could help design more efficient engines.

Reviewer 3:

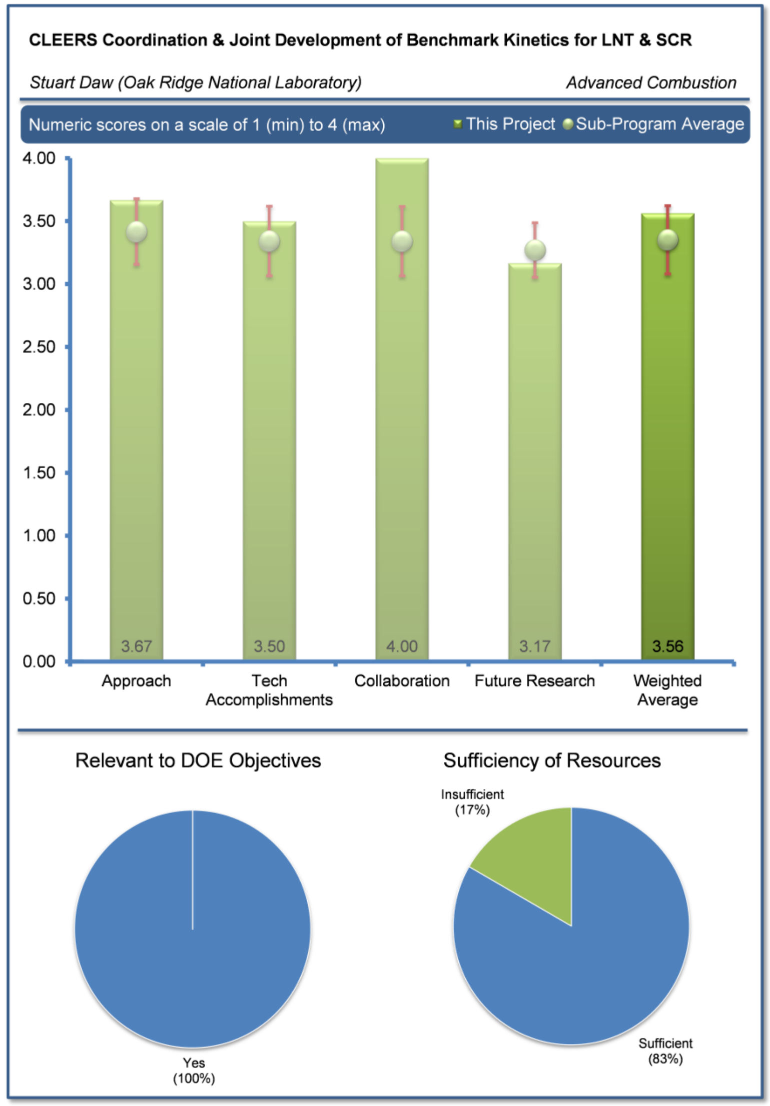
The reviewer indicated that, of course, this point is highly dependent on the projects that the collaborators want to bring in and which the project then chooses to support. This person added that the basic assisted HPC approach is neutral, but, by seeking out the right projects, it can then indeed promote the larger 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 did not think one could ever have too many computing resources, and added that better capitalizing on the GPU capabilities of Titan would add even more capability.

CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR: Stuart Daw (Oak Ridge National Laboratory) - ace022



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 commented that the overall approach of the CLEERS program reaches out very well to the appropriate people.

Reviewer 2:

The reviewer indicated that expanded and enhanced database activities for kinetics and modeling activities within the catalysis community are very important to continue and support. This material can be used by OEMs to tune and improve their control strategies for aftertreatment development without expending internal resources and funds. This reviewer added the inclusion of the industry OEMs, universities, and suppliers through the Cross-Cut Lean Exhaust Emission Reduction Simulation (CLEERS) conference, telecoms, public database, and feedback surveys is important for the development and characterization of future aftertreatment systems.

Reviewer 3:

The reviewer mentioned that CLEERS provides a valuable coordination of pre-competitive aftertreatment efforts by different companies, universities, and labs that are shared with the CLEERS participants. This person added the regular CLEERS audios and the annual workshop are extremely valuable.

Reviewer 4:

The reviewer noted CLEERS uses a good approach in dealing with experts, issues, challenges, modeling, coordination, and dissemination of proper, relevant information. The project team is using the right tools, such as a website, an annual workshop, and monthly teleconferences, as well as the best experts, a nearly all-inclusive policy, and a focus on developing strong relationships. CLEERS' charter has grown from a mere after-treatment modeling circle to one now including engines as well (gasoline, diesel, and natural gas), plus testing, and has stayed reasonably well connected with industry needs and outlook.

Reviewer 5:

The reviewer stated CLEERS coordination has been the main hub for connecting all the activities and communications among the after-treatment community, and noted it is so important to keep up with industry needs and the trend of state-of-the-art emission control strategies. This reviewer added that, overall, ORNL's effort has been very well focused in that regard. However, this reviewer saw there still are some opportunities of improvement. For example, this person would encourage the project to coordinate communications with the Environmental Protection Agency (EPA) or California Air Resources Board (CARB). In the area of model development, it is not clear how ORNL will approach competing with or implementing homegrown models with other models being used in industry.

Reviewer 6:

The reviewer felt that the experimental work is great, and added that the one weakness in this project is the need to leverage outside partners who are working on the project under their own funding. This reviewer indicated that, consequently, the ability of the project to reach their stated goals is dependent on the willingness of the partners. This reviewer believed the majority of the kinetic analysis comes from the Institute of Chemical Technology, Prague (ICT) and Politecnico di Milano and uses neither Chemkin nor Autonomie. The reviewer asked if this is a significant crack that has the capacity to severely limit the goals of the project. The person further asked if there is a well-defined mechanism and parameter transfer from ICT and Politecnico di Milano. The reviewer noted that Slide 13 showed the modeling to be custom codes, Chemkin and Autonomie. This reviewer further thought that most of the component modeling at ORNL is Matlab-/Simulink-based, which are included as add-ons to Autonomie. Although Automomie is supported, this reviewer did not believe the add-ons in Matlab are supported or generally disseminated.

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 highly valued activities within CLEERS to support aftertreatment characterization, including the following: enhanced and accessible databases; telecommunications; Advanced Combustion and Emissions Control (ACEC) low temperature aftertreatment support for protocol development; and the CLEERS annual conference. This reviewer further said lean NO_x trap (LNT)–N_2O generation is important for LNT technologies and lean systems (thereby very appropriate), and the project is looking to reduce N_2O generation using modeling and reaction characterization at low temperature. Emerging LNT/NO_x storage catalyst (NSC) technologies would argue against diminishing the effort to understand these materials. This reviewer added NH_3 storage is a strongly supported activity. Characterizing NH_3 storage as a function of temperature and aging is required for proper NH_3 dosing and conservation. This reviewer mentioned using isotherms to determine the number of NH_3 storage sites is an easy, effective way to demonstrate this.

Reviewer 2:

The reviewer commented on the very good progress on NH_3 storage capacities in selective catalytic reduction (SCR) catalysts, which will be useful for maximizing NO_x conversions and minimizing NH_3 slip. The results on N2O production from LNTs during regeneration were interesting.

Reviewer 3:

The reviewer emphasized that CLEERS is a government-sponsored program with its own benchmark, and added that it has grown from a small circle to one having industry-wide impact, even outside the United States. CLEERS' monthly teleconferences are highly educational and stimulating, and its annual workshops have become one of the best interaction opportunities in the 'development' circles. This reviewer noted CLEERS' focus has expanded to include discussions on various combustion and emission types. Its topics diversity (relevance) is adequate. This person said congratulations to ORNL (the PI and his team) for having created such a stimulating circle of open information exchange. This reviewer noted that in one area, however, CLEERS has been somewhat slow in shifting its focus from LNT to SCR, to accommodate the diesel industry needs and trends. It did, however, integrate properly and timely modern gasoline engine developments in its focal discussion areas.

Reviewer 4:

This reviewer described technical accomplishments and progress as excellent, and suggested that even more modeling results available to researchers would be better.

Reviewer 5:

The reviewer indicated that the adsorption isotherms were quite interesting, and added that the Temkin isotherm was used for the adsorption mechanism for a commercial modeling code. This work that shows the two-site Langmuir was very interesting. It validated the more commonly used two-site kinetic codes. This reviewer was disturbed at the conclusion that previous approaches could be wrong or chaotic (Slide 17). Differences in zeolite and metal ion exchange can cause significant differences in the kinetic description. Much of this could just be substrate differences. FY 2013 ORNL showed that NO–NO_2 oxidation was not important, and then indicated a new mechanism for NO oxidation—a bit mysterious. This reviewer felt perhaps a bit more clarity for the Annual Merit Review (AMR) would have been helpful.

Reviewer 6:

The reviewer saw that the project team had clearly made big efforts in improving existing models, with additional features in both LNT and SCR technologies. However, this person felt the deliverables and timing for each year were not well-defined.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that CLEERS had done an outstanding job in helping develop proper collaborations with industry, academia, and national laboratories. This person added that it had indeed gone above and beyond its initial charter, brought added value to the industry, and had made a positive, irreversible impact.

Reviewer 2:

The reviewer observed that collaboration is inherent in this project and is handled well.

Reviewer 3:

The reviewer noted that the project had broad inclusion of the catalyst community as well as highly respected research teams throughout the country.

Reviewer 4:

The reviewer indicated good collaborations with ICT on N2O generation from LNTs, as well as with Politecnico di Milano and Pacific Northwest National Laboratory (PNNL) on SCR mechanisms.

Reviewer 5:

The reviewer mentioned that the collaborations with ICT and Politecnico di Milano were outstanding and provided substantial value-added benefit to the project. This reviewer also noted that the collaboration with PNNL was good, but a bit disconnected due to the personnel changes at PNNL. This reviewer further added the regular visits of students from ICT and Politecnico di Milano was a great collaboration tool.

Reviewer 6:

The reviewer stated this project has demonstrated excellent collaborations for many years. However, the collaboration or interaction with combustion groups working on the advanced combustion area is relatively low. This reviewer recommended the project team update their engine-out emissions more frequently for harmonizing activities.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 increasing the focus on low temperature after-treatment activities is important to align with the advanced combustion strategies investigated by U.S. Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability (U.S. DRIVE). This reviewer added that the integrity of the data present in the database must be policed better and standardized to better utilize the information.

Reviewer 2:

The reviewer remarked that the coordination of the planning, focus group, workshop, and website is great, and added that low temperature after-treatment and kinetics model improvements are important. However, this reviewer recommended providing more specific and measurable deliverables for next year in the future plan.

Reviewer 3:

The reviewer stated that the project needed more specific action plans for low temperature catalyst work and support.

Reviewer 4:

The reviewer felt that in general cross-cut lean exhaust emissions reduction simulations (CLEERS) research work in after-treatment had done a fair job staying in sync with industry activities, although some of the other key industry challenges had not been regarded. This reviewer's examples included relatively high failure (warranty) rate in HD diesel emission systems and algorithm development (such as urea injection).

Reviewer 5:

The reviewer noted that N_2O formation during LNT regeneration was getting a lot of attention, and asked if it was certain this deserved this much attention, given that there was not yet a regulation and Tier 3 was already out. This reviewer wondered if the oxygen storage and NO_x reduction synergy in LNTs might need more attention, especially under highly transient conditions. This reviewer added more work on the ammonia formation over the LNT might be helpful, and that enhancing platinum-group metals (PGM) dispersion and aging resistance has a lot of utility for LNT devices. The isotherm work on SCR systems was quite interesting, but some information on the dynamics of return to equilibrium during transients might be very important.

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

Reviewer 1:

The reviewer reiterated that this project was one of most important programs funded by DOE in the emission control area. This reviewer added the focal point of this research portfolio was to develop enabling technologies for improving fuel efficiencies in cost-effective future powertrains.

Reviewer 2:

The reviewer noted the models that CLEERS develops will help maximize the fuel economy and minimize the emissions from future engines.

Reviewer 3:

This person asserted that research strongly supports this goal.

Reviewer 4:

The reviewer commented that CLEERS has properly integrated industry discussions on GDI and other high-efficiency gasoline engines—and many varied discussions on diesel combustion and emission control—assisting DOE's goal.

Reviewer 5:

The reviewer felt the work was well coupled with combustion strategies that would be used to meet future fuel economy and emissions standards. This reviewer noted modeling of after-treatment components enabled these strategies, and accurate models were needed.

Reviewer 6:

The reviewer acknowledged that there seems to be steady and perhaps growing resistance to LNT in larger displacement vehicles, and asked if there should be a strong continuation of LNT mechanism research. Both active and passive SCR are getting a significant amount of industrial attention. This person suggested perhaps a higher fraction of this activity should focus on the mechanisms for those systems, especially the dynamic response of the passive SCR system.

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

Reviewer 1:
The reviewer stated overall progress was not as expected probably because of the diluted effort on both modeling and experiments. This person added that more resources for this project would help facilitate all the existing activities in this direction.

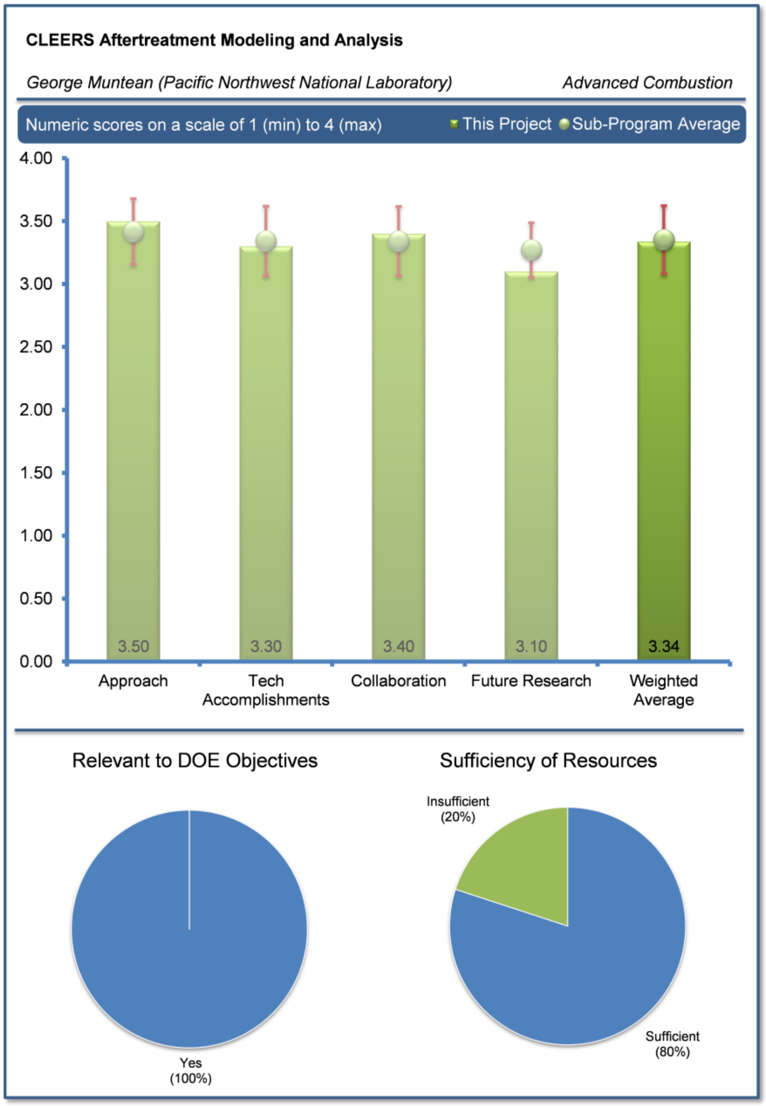
Reviewer 2:
The reviewer said sufficient, but just barely. As previously noted, if either of the international modeling partners terminates the collaboration, then there does not seem to be sufficient funding to take up the slack. This person believed a backup plan needed to be considered.

Reviewer 3:
The reviewer commented that CLEERS had integrated all it could to maximize its impact, and specified the following: the website; teleconferences; workshops; collaborative tasks; continuous communication (email); and a citation reference archive. This reviewer added it had also expanded its focus from mere modeling (its initial charter) into wider types of emission activities.

Reviewer 4:
The reviewer observed appropriate funding.

Reviewer 5:
The reviewer noted that the funding allowed for CLEERS coordination and for kinetic development was consistent with the progress that was shown.

CLEERS Aftertreatment Modeling and Analysis: George Muntean (Pacific Northwest National Laboratory) - ace023



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted that inter-laboratory and industry relationships have been properly integrated into its mission to achieve objectives.

Reviewer 2:

The reviewer noted PNNL applied a very scientific approach to analyzing SCR and LNT and diesel particular filter (DPF) catalysts.

Reviewer 3:

The reviewer felt PNNL was well structured to execute fundamental approaches for solutions to real-world problems. This person indicated their combined efforts via the Cooperative Research and Development Agreement (CRADA) would have provided more specific challenges from industries in understanding as well as implementing new technologies. This reviewer added that it would be interesting to see how their contribution under the DOE/National Science Foundation (NSF) joint program would turn out in the broad aspect.

Reviewer 4:

The reviewer remarked there continued to be a good approach, and base funding provides consistency, strategic direction, and repository. This person added that, for excellence, the project could add an industry survey (such as from the United States Council for Automotive Research [USCAR] or 21st Century Truck Partnership partners) to confirm/identify needs and interests.

Reviewer 5:

The reviewer mentioned that phasing out research in the area of LNT/NSC might be premature. This person noted that focusing on the low-temperature activity of catalysts that are durable to high temperatures is very appropriate and consistent with the ACEC roadmaps. This reviewer also indicated switching to NO_x adsorption (passive) from LNT catalysts.

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 explained CLEERS had developed strong relationships with proper outlets (such as the University of Milan, ICT, Chalmers, and etc.) and alike to develop proper kinetics models for LNT and SCR. This reviewer added that the work on various SCR performance attributes was noteworthy.

Reviewer 2:

The reviewer noted great progress in understanding the dip in activity at 350° C from SAPO SCR catalysts (the seagull effect). This person also said interesting analysis on the filters, particularly with the modeled flow results.

Reviewer 3:

The reviewer saw good progress on many relevant topics, which could be excellent if the project directly addressed industry and expert assessments of open-domain needs. This reviewer added the project presents and confirms challenges in the "open" domain.

Reviewer 4:

The reviewer felt that there was in general a very good foundation for this direction of research activities. With respect to SCR, identifying the source of the seagull profile of NO_x conversion is crucial to developing an understanding of reactions occurring in the zeolite, but this reviewer asked if Cu loading has been investigated as a possible source of this behavior. With regard to NSR, looking at low-temperature NO_x adsorbers as the primary focus is appropriate. However, this reviewer added that investigating deactivation pathways earlier in the project (to minimize effort spent on materials that will not perform) is recommended.

This reviewer asked where the catalyst material is deposited with respect to DPFs. Results showed that catalyst material appears fairly uniform through the wall, but this reviewer asked what the effect was on back pressure and flow velocity dynamics. Novel washcoat application may be a good solution for minimizing diffusion restrictions as well as soot-cake formation on the front face. The reviewer also noted that SPLAT was used successfully to characterize particle size for soot from a lean GDI engine.

Reviewer 5:

The reviewer stated that this project had made very good progress in SCR, and added that PNNL pioneered in exploring many features of new Cu-based zeolite catalysts. However, the high temperature NO_x storage/reduction (NSR) tasks did not seem to be well focused. Although the micro computed tomography (CT) capability was fascinating, without a doubt it will be a very unique and strong tool for particulate filter technology. However, this reviewer felt it was not clear how the information from the CT results could be utilized for the filter technology, and added that the scope needed to be a little clearer.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer highlighted that overall PNNL has good coordination in partnering with industries and other national laboratories. Also, the addition of academic partners such as Purdue University, Notre Dame, and Washington State University (WSU) will provide even further positive outcomes.

Reviewer 2:

The reviewer indicated the project work with the ACEC Low Temperature After-treatment team on test protocols for material discovery and characterization is a high priority within the after-treatment community and very appropriate.

Reviewer 3:

The reviewer confirmed that the project team has developed proper relationships with other national laboratories as well as with USCAR, 21st Century Truck Partnership, WSU, Cummins, and Notre Dame.

Reviewer 4:

The reviewer explained that the university, national laboratory, and (to some extent) industry collaboration is very good, but added that stronger industry presence from Tier 1 and OEM carmakers could improve. This reviewer also mentioned to possibly embellish "tech team" approach for common issues.

Reviewer 5:

It was not clear to this reviewer how PNNL interacted with its partner organizations (e.g., CLEERS, cross-cut team, ACEC, and ORNL). The reviewer had the impression that CLEERS, cross-cut, and ACEC are more like "customers" rather than collaborators, in that they receive the results of the work, but do not contribute to the actual work or accomplishments. This reviewer added that some collaborative work with ORNL, ANL, Purdue, and Notre Dame was mentioned.

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

Reviewer 1:

The reviewer said the project team was continuing on a successful path.

Reviewer 2:

The reviewer mentioned that the plan to assess low-temperature NO_x adsorbers is good, and added that it is good the work on the high-temperature NO_x adsorbers is being curtailed.

Reviewer 3:

The reviewer asserted that standard deactivation pathways should be investigated on new materials early in the discovery process to expedite the process of new material discovery. This person said the work in the other areas is quite substantial and important to continue.

Reviewer 4:

The reviewer explained the future activities on SCR were pretty clear, although it would be nice to add more efforts on the mechanistic approach on aged or deactivated SCR. Also, for low-temperature LNT (or NSR, or cold start concept (CSC)) it is recommended the project team interact with suppliers to understand what the level of performance is from the state-of-the-art low-temperature NOx trap technology.

Reviewer 5:

The reviewer noted PNNL's key strength is in catalysis fundamentals. As such, the project team has done a good job capitalizing on this strength properly. This reviewer added that the project team has focused on DPF, SCR, and NSR, but not on diesel oxidation catalysts (DOCs). DOC is, however, the most important diesel after-treatment device, and a poor performing DOC will render the entire system dysfunctional. This reviewer felt it was therefore somewhat surprising that DOC is not represented in CLEERS' catalysis-related investigative work.

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

Reviewer 1:

The reviewer reported that the scope of work presented was very relevant research. This work supported an industry/government effort to uncover novel materials that would enable low-temperature after-treatment to meet future emission-control requirements.

Reviewer 2:

The reviewer indicated that, with the existing, proper focus on diesel emission efficiency, the relevance of the CLEERS project to DOE's goal was properly demonstrated.

Reviewer 3:

The reviewer felt that the effort on the fundamental understanding of the after-treatment catalysis would ultimately help develop new advanced catalysts that will enable the emission-compliant, fuel-efficient vehicle technology.

Reviewer 4:

The reviewer affirmed that the insights into catalyst performance and deactivation will allow researchers to design better after-treatment systems for lean-burn vehicles, which will help decrease fuel usage relative to stoichiometric applications.

Reviewer 5:

The reviewer remarked that after-treatment would always be a significant cost and challenge for combustion-powered vehicles. Lean after-treatment is an enabler for significant gains in fuel economy, and the current systems are prohibitively expensive. This reviewer said modeling and collaboration were the foundational basis for breakthroughs.

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

Reviewer 1:

It did not appear to the reviewer that there were enough resources to answer many of the different questions related to mechanistic studies and characterization of both LNT and SCR catalysts.

Reviewer 2:

The reviewer said PNNL–CLEERS had made good use of PNNL's great catalysis research resources (in expertise and instrumentations).

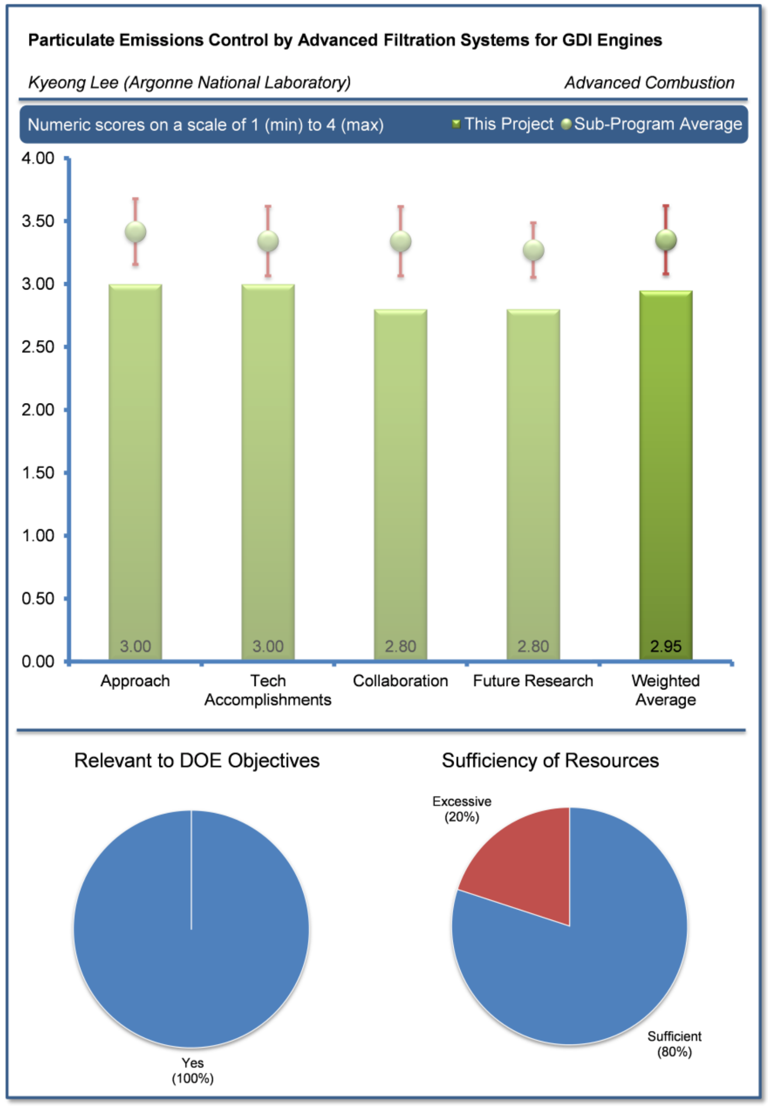
Reviewer 3:

The reviewer felt that the resources seemed to be sufficient. It was hard to make a judgment, as how much of the work being done under CLEERS or CRADA needed more clarification.

Reviewer 4:

The reviewer asserted that the funding level seemed appropriate for the large amount of work being performed at PNNL.

Particulate Emissions Control by Advanced Filtration Systems for GDI Engines: Kyeong Lee (Argonne National Laboratory) - ace024



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted a good approach to studying gasoline particulate filter (GPF) performance using a GDI engine, and added that measuring both PM and particulate number (PN) is important.

Reviewer 2:

The reviewer indicated this ANL team has a very unique capability and approach in particulate research. The approach includes filtration and regeneration via particle measurement, bench-scale imaging, microscopy, and bulk x-ray analysis on both particulate and filter substrates. Their environmental scanning electron microscope (SEM) provided some in-situ observation of soot-cake morphology during the regeneration.

Reviewer 3:

The reviewer mentioned the excellent approach to addressing key issues and quantifying particle size, count, and composition of engine-out and tailpipe emissions on a vehicle. This person said the approach addressed industry acknowledgement of the insufficient information about the properties of GDI PM emissions, the need for understanding filtration and regeneration mechanisms to support meeting the upcoming PM regulations (U.S. Tier3, Euro6), and the sensitivity of gasoline engines to increased back pressures associated with GPF.

Reviewer 4:

The reviewer had just one comment on Slide 3. The general belief at present was that the majority of the particulate emissions from GDI engines occurred during transients, not primarily on cold start (the reviewer highlighted the following two references). This reviewer added that most of the literature data is on the NEDC cycle, not U.S. test procedures and referenced the following: Happonen M, Matilainen P, Kanniainen K, Kinnunen T, Karjalainen P, Heikkilä J, Ronkko T, Keskinen J, Lähde T, and Malinen A. 2013. The Effect of a Particle Oxidation Catalyst (POC< sup>®) on Particle Emissions of a GDI Car during Transient Engine Operation. SAE Technical Paper; Liang B, Ge Y, Tan J, Han X, Gao L, Hao L, Ye W, and Dai P. 2013. Comparison of PM emissions from a gasoline direct injected (GDI) vehicle and a port fuel injected (PFI) vehicle measured by electrical low pressure impactor (ELPI) with two fuels: Gasoline and M15 methanol gasoline. Journal of Aerosol Science 57:22-31.

This reviewer also might object to the statement “no extreme heat release” in the GPF. Once light-off occurs there seems to be appreciable heat release. This person referenced the Emissions 2014 presentation by Corning. In this reviewer’s view, the background in this project is a bit weak, but the reviewer agreed with the approach for the GPF work.

Reviewer 5:

The reviewer said that the approach and methodology were too empirical, and that the work and conclusions were not adequately backed up by fundamentals. This reviewer added that there was room for a more scrutinizing approach to the nature of the problem at hand.

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 a thorough characterization of GDI PM source, quantity, and chemistry was identified. The research clearly and credibly quantified particulate count, size, and chemistry to dial in the level of the problem and the possible root causes. Also identified in the work were engine and operational mechanisms (cold operation and spray impingement), which generate particles and help to understand the characteristics of GDI particulate matter engine-out (Ca, Na, P, and Zn) and tailpipe (Mg, Al, and Cu), including a material analysis for source tracing to engine and engine oil, and, at the tailpipe, some catalyst materials. This reviewer added that, in addition to the particle formation methods and probable sources, the project team modeled behavior with good experimental fit in GDI oxidation mechanisms and kinetic correlations.

Reviewer 2:

The reviewer said good job in assessing the effects of various parameters such as injection timing and space velocity on the performance of the GPF. The reviewer also noted good characterization of the particulate, including the analysis of the ash. This reviewer recommended that the project team might want to obtain more data before claiming that the ash doubles the rate of soot oxidation.

Reviewer 3:

The reviewer was glad to see that this project had finally come to the right track. This person added that, compared to the previous year's progress, there were lots of interesting observations via a number of characterization results. This reviewer noted some of their results were still very vague, and was a little concerned about the conclusions given the limited information; some were not convincing.

Reviewer 4:

The reviewer indicated the project had produced good results, and added that it appeared to follow the literature properly. The relationship to ash was noteworthy, but some of the claims were too big and not sufficiently backed up using fundamentals.

Reviewer 5:

The reviewer made comments on individual slides. For Slide 8, this result seemed to be at odds with the literature, with no explanation given. This reviewer did agree with the conclusion of more particulates with transient versus steady state. This reviewer wished that the authors would reference the literature and explain the differences. For Slide 9, this had been discussed in detail in the literature (the reviewer noted previously supplied references), and asked what was new here. This reviewer really liked Slide 10, indicating that this was useful information. For Slide 11, this person was not sure about the result, but it was extremely interesting if consistent over a range of filters. For Slide 12, having the three-way catalyst (TWC) ahead of the filter probably eliminated the possibility that the soluble organic fraction enhanced soot oxidation. This reviewer asked if all the experiments had this configuration, as that answer makes a HUGE difference in the results. For Slide 13, the authors are going to have to work way harder to convince this reviewer that there is causality in this result. This reviewer was just not yet convinced that ash caused soot oxidation. For Slide 14, the reviewer asked why there were no precious metals, especially if the ash was based on a decomposition of the TWC coating. For Slide 15, this reviewer was really upset about the scales of the micrographs. It was hard to convince this reviewer of the crystallinity if the authors were playing with the micrograph scale. This reviewer was not impressed by Slides 16–18. The soot had already gone through a TWC. The reviewer asked how much of the organics had been oxidized there, and how much of the soot had changed morphology in the TWC. For Slide 19, the reviewer wanted to know how much of this was the TWC flaking, and where the TWC came from. Additionally, this reviewer did not see the relevance of Slide 20.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer indicated that the PI leveraged prior work and activities from universities, as well as suppliers of GPF and particle-measurement equipment. This reviewer added the PI had published several papers on this topic in 2014 (and 2013), including at the CLEERS workshop, the Society of Automotive Engineers (SAE), and the Fiesta World automotive conference.

Reviewer 2:
The reviewer noted good collaboration with Corning and Hyundai.

Reviewer 3:
The reviewer felt that the collaboration with Tokyo seemed pretty superficial, but added that the UW collaboration did seem fairly strong. This reviewer noted that hosting a workshop was not really a research collaboration; basically, it was just information sharing.

Reviewer 4:
The reviewer said the project team listed a number of collaboration partners; however, all the results shown in the presentation seemed to be from ANL. Also, this reviewer added that it was still not clear who did what on this project. This person noted the contribution from the industry partners (Corning and Hyundai) was well described.

Reviewer 5:
The reviewer remarked that gasoline PM control was a new area, and as such it included many new questions that required investigation to find proper answers. The coordination in this project included exchanges only with the Tokyo Institute of Technology and some PM investigation work with UW. This reviewer added that, to quantify the measured data (which is all about soot properties, filtration, oxidation, and kinetics), the project should have included integration of kinetics expertise. This appeared to be a major gap in the project, currently also resulting in the simplistic models and lack of proper explanation for some of the observations.

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

Reviewer 1:
The reviewer indicated that the future work was very well defined. This reviewer added that, with the big improvement from the previous year, the project was expected to keep the momentum. The reviewer was looking forward to the next year’s progress.

Reviewer 2:
The reviewer said there were good plans to continue characterizing soot, and added that it will be important to investigate the effects of aging on the GPF performance.

Reviewer 3:
The reviewer noted the good plan to evaluate GDI PM exhaust mitigation strategies by analyzing GPF loading and unloading mechanisms further to minimize pressure drop. This reviewer added that—as PM generation periods are limited, cold start, cold transient, warm restart, or with poor injector timing/targeting—it would make the research outstanding to consider the root cause and possible mitigation methods for the formation of PM on GDI applications. This reviewer further noted that future work that proposed action regarding lubrication material considerations, injector or combustion parameters, or other actions to reduce or eliminate GDI PM at the source would be excellent.

Reviewer 4:
The reviewer commented it was good to see that the effects of ethanol mixes had been previously included. The reviewer said that the team should focus now on diversification of the focus (such as on variations from one engine to another, and the role of combustion specifics such as cylinder pressure or injection strategies), as well as further PM and ash characterization, and especially their oxidation

kinetics. This reviewer added that integration of an entity with proper kinetics expertise (such as BASF or experts such as Dr. Koltsakis) might be appropriate.

Reviewer 5:

The reviewer noted that, regarding oxidation behaviors of ash-contacted soot, a lot of work was needed to prove the statement that ash catalyzed soot oxidation. Regarding the interactions between soot, ash, and catalyst, there seemed to be no real clear goal here. Ash sintering effects were probably only interesting for possible pore blockage. This reviewer added that, regarding the evaluation of filtration efficiencies, this reviewer was not sure that filtration efficiency was a priority. Regarding different filter substrate models, the reviewer asked what would actually be done. The evaluation of regeneration efficiencies was very vague. The different filter substrate models did not have much clarity here. Regarding the catalyzed filters, the reviewer commented that everybody was doing that, and asked the project team to be more specific. To this reviewer, the evaluation of aged GPF in terms of filtration/regeneration efficiencies seemed perhaps very premature.

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

Reviewer 1:

The reviewer indicated that GDI engines produced fuel economy and, as such, that this project provided synergy with DOE’s goals.

Reviewer 2:

The reviewer noted GDI soot filtration was not yet required in the United States, and that GPFs have been implemented on European GDI vehicles. This reviewer added that it would not be outside the realm of possibility that this device would be needed on U.S. light-duty vehicles in the foreseeable future. In addition, coating a GPF with a TWC coating appeared to this reviewer, to be a very space-efficient and perhaps synergistic technology that might be very valuable for future production GDI engines. So, overall, this reviewer liked the direction that the work was attempting to go.

Reviewer 3:

The reviewer said GDI engines improved fuel economy, and GPF would be needed to satisfy the low PM standards from such GDI engines.

Reviewer 4:

The reviewer expressed that this was one of the very few particulate-related projects in the DOE’s programs. This reviewer added that, with the ANL team’s expertise and unique capability, the project will answer many known questions that the industry will have to deal with regarding gasoline particulates.

Reviewer 5:

The reviewer stated that GDI is an enabling technology for reducing fuel consumption through downsizing and boosting to provide better power density, and added that PM emissions from GDI may pose a health issue and therefore will soon be regulated.

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

Reviewer 1:

The reviewer felt that an increased scope to address the root causes of PM production could warrant additional funding.

Reviewer 2:

The reviewer said the project team seemed to have enough resources to carry out the proposed research.

Reviewer 3:

The reviewer noted a lot of work had been performed in this project, improving the understanding of GPF operation. This reviewer observed a good balance of resources and funding level.

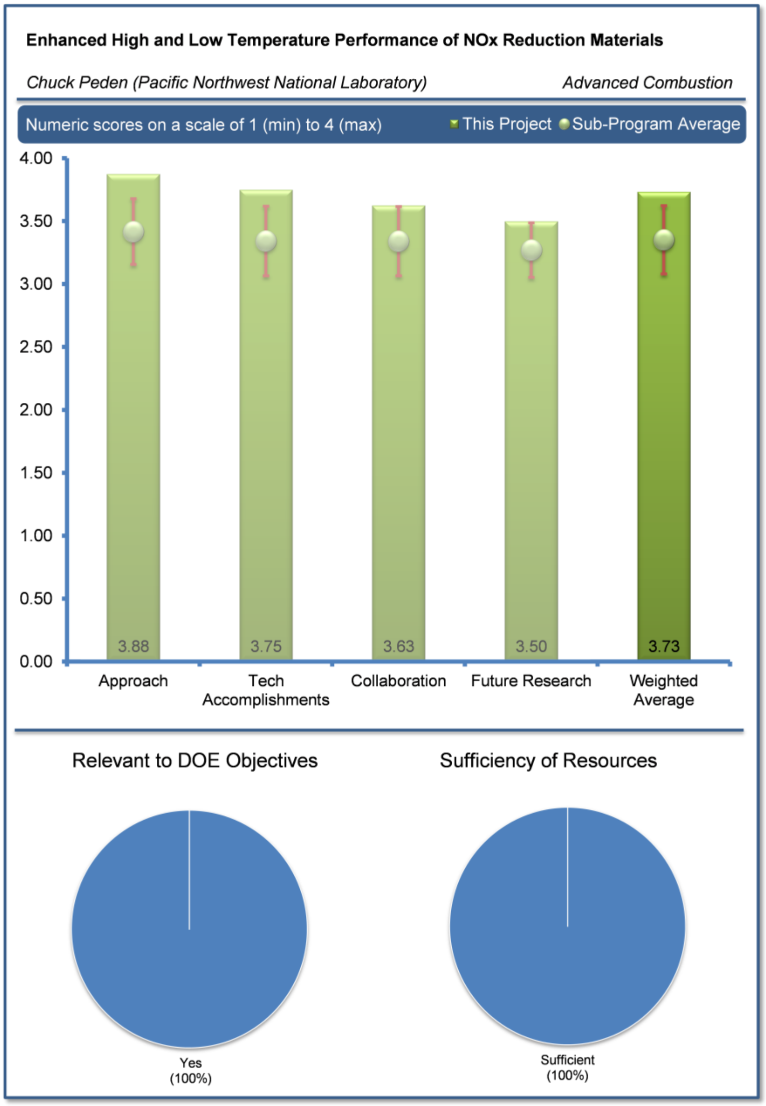
Reviewer 4:

The reviewer commented that, at the present time, the resources were proper for experimental investigations. However, this reviewer added that, to properly generalize the results and impact the field and relevant industry, the team needed to consider integrating kinetics expertise into the project to better explain the observations (i.e., models, theories, and etc.). This person noted that the inclusion of further insights into the kinetics, and integration of proper kinetics expertise, was highly warranted.

Reviewer 5:

The reviewer did not believe that the industrial sponsors of this work were getting a useful product.

Enhanced High and Low Temperature Performance of NOx Reduction Materials: Chuck Peden (Pacific Northwest National Laboratory) - ace026



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 felt that the project was well thought-out and used state-of-the-art samples/techniques.

Reviewer 2:

The reviewer commented that the U.S. DRIVE-sponsored workshop and CRADA industry involvement was an exceptional approach to clearly identify the R&D needs of the industry and continuously redirect priorities for an optimized result. The reviewer noted that the cross-cut workshop accurately captured the top R&D barriers of low/high-temperature performance, natural gas, and cost, and added that the low exhaust temperatures of future engines were a challenge for exhaust after-treatment technologies. This reviewer further noted that NO_x reduction systems would require improved high-temperature performance and stability for NO_x removal during high-temperature system maintenance events, including DPF regeneration. Additionally, NO_x treatment for natural gas engines would also require higher temperature performance. The reviewer also referenced an after-treatment system costs reduction, with a focus on PGM loading with improved performance.

Reviewer 3:

The reviewer indicated the work was of very high quality and directly supported DOE goals. This reviewer noted that the initial focus on high temperature reactivity had shifted towards lower temperature performance. The project team presented interesting results on Cu and Fe-zeolite catalysts, with new promising low-temperature catalyst formulations identified yet not disclosed pending current invention disclosure (i.e., a NO_x conversion percentage in the 90-100% range at low temperatures).

Reviewer 4:

The reviewer mentioned that the industry was moving toward lower temperature operation, and added that much of this LNT work seemed to be directed to higher temperature, and from the future plans this was being discontinued. This reviewer added that the chabazite work was very appropriate and has the capability of impacting the industry.

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

Reviewer 1:

The reviewer stated the project's list of deliverables displayed outstanding results via well-designed research strategy.

Reviewer 2:

The reviewer noted that the readily adaptable dry method for the synthesis of Cu/chabazite catalysts was a significant accomplishment considering its performance was comparable or superior to other methods. The identification of SCR catalyst materials with significantly lower "light-off" temperatures than Cu-SSZ-13 was great progress. The reviewer noted the project achieving over 80% conversions at 150ºC on Fe/chabazite catalysts at optimum NO_2/NO_x ratios of 0.5 (i.e., "fast SCR") was an especially promising result. This person added that new low-temperature catalyst formulations identified light-off temperatures (T50) between 151°C and 193°C, as well as multiple T80 light-off formulations below 170°C to 200°C, showing the depth of work.

Reviewer 3:

The reviewer noted significant progress was made with a focus on low- and high-temperature performance and the stability of aged catalysts. This reviewer mentioned interesting results on Fe and Cu-based SCR catalysts, with Fe-based catalysts showing excellent performance at low temperatures.

Reviewer 4:

The reviewer felt that, regarding Slide 12, having a non-proprietary source of chabazites is very important to moving forward academic and national laboratory research. Regarding Slide 14, it was clear from the historic ZSM-5 experience that different methods of ion exchange do give different activities. This reviewer added that the dry exchange work on the chabazites is very helpful. Regarding Slide 17, there was very nice demonstration of the nitrate formation. The reviewer stated that Slide 18 was pretty much a confirmation of standard zeolite behavior, and asked if Slide 19 was proprietary information.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that having three legs to the stool was excellent for success and stability. This reviewer reported that the project had the following: a national laboratory for basic R&D; Tier1 industry partnering for requirements, testing, manufacturing considerations, as well as further research on promising alternatives; and OEM collaboration to support further the R&D cost and system integration perspective. This reviewer added that the sense of urgency was outstanding, with high frequency status updates and participation.

Reviewer 2:

The reviewer observed typically solid collaborations from PNNL.

Reviewer 3:

The reviewer summarized two industrial partners (Cummins and JMI) are involved. No noticeable miss-coordination or collaboration issues were observed.

Reviewer 4:

The reviewer acknowledged significant collaboration with Cummins, JMI, and universities. It was not entirely clear to this reviewer what Cummins was doing in support of the program, and what JMI did other than provide catalyst samples for reference/baseline characterization. This reviewer noted that perhaps this was covered in earlier presentations.

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

Reviewer 1:
The reviewer stated that the PI shared a clear vision on what to do (and not to do) next, such as continued work on Cu-chabazite materials.

Reviewer 2:
The reviewer commented that the current focus was on improving the fundamental understanding of Fe- and Cu-based catalysts, understanding why Fe has better low-temperature reactivity, the effect of zeolite acidity, and the effect of sulfur on low-temperature behavior. This reviewer added that an improved understanding of the fundamental mechanisms that are important for improving the low-temperature performance of catalysts (as highlighted on Slide 19) should be a focus.

Reviewer 3:
The reviewer said appropriate barriers were on the list such as deactivation mechanisms for new formulations. This person felt cost consideration or advantage would be a great plus for discussion.

Reviewer 4:
The reviewer indicated that bringing down the focus to the zeolite work was the right choice, and all the planned directions with chabazites were fine. This reviewer sure would have preferred more detail, especially since Slide 19 had very little helpful information.

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

Reviewer 1:
The reviewer expressed that, like most other after-treatment catalyst technologies R&D, results from this work could indeed help support the DOE's energy policies.

Reviewer 2:
The reviewer said the work was clearly relevant to NO_x reduction under extended operating limits.

Reviewer 3:
The reviewer mentioned after-treatment requirements were changing to support the use of new higher-efficiency combustion regimes, which result in lower temperature combustion and lower normal exhaust operational temperatures. This reviewer added that cost and PGM considerations for after-treatment are continuously on the radar for OEMs.

Reviewer 4:
The reviewer reported that SCR seemed to be the future direction for both light and heavy duty, and added that LNTs do not seem to be in the future industrial plans much.

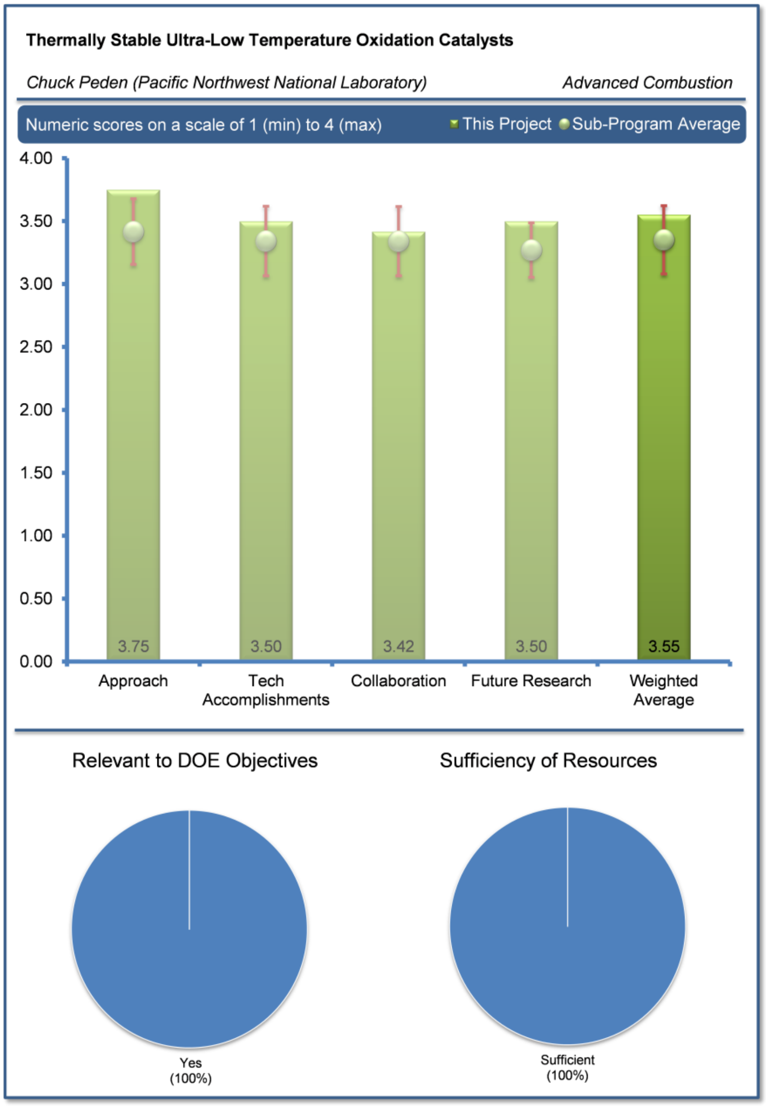
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that leveraging the in-house instrumentation at PNNL made the funding stretch very far.

Reviewer 2:
The reviewer indicated that the funding seemed acceptable, and noted the project was also leveraging other funding sources.

Reviewer 3:
The reviewer commented that the project seemed to have used proper expertise (PNNL's Institute for Integrated Catalysis) and instrumentation (Mossbauer spectroscopy and others) for this project.

Thermally Stable Ultra-Low Temperature Oxidation Catalysts: Chuck Peden (Pacific Northwest National Laboratory) - ace027



Reviewer Sample Size

A total of six reviewers evaluated this project

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

Reviewer 1:

The reviewer said the PI's approach to fundamentals was invaluable. His approach was just as good as it could be (regarding spectroscopy, x-ray diffraction, Brunauer–Emmett–Teller analysis, transmission radiation detector (TRD), the role of low and high temperatures, etc.). This reviewer added it was hard to think of a better way of pursuing this project.

Reviewer 2:

The reviewer asserted that the range of methods is impressive.

Reviewer 3:

The reviewer remarked this was a very novel and promising technology that was consistent with low temperature after-treatment initiatives to meet future emissions standards. The person added that the program participants had considered and demonstrated that barriers related to deactivation from other combustion species had not impacted the CO oxidation performance of the Cu-based catalysts.

Reviewer 4:

The reviewer noted the synthesis and characterization leading to improved understanding and performance of low-temperature non-precious-metal catalysts.

Reviewer 5:

The reviewer observed a U.S. DRIVE-sponsored workshop, with input from a cross section of industry experts and laboratory staff (i.e., Chrysler, GM, Ford, PNNL, and DOE). The reviewer said one clear goal of high-efficiency 150°C operation was established, and added that the low exhaust temperatures of future engines was a challenge for exhaust after-treatment technologies. The reviewer added that the critical barriers and a plan to identify opportunities were presented with a focused plan for R&D and metrics. The sintering of active metal sites is a major barrier to catalyst stability over durability life, and improvements in stability can enable lower temperature performance for light-off. This reviewer noted the metric of T50 for CO and hydrocarbon oxidation of around 150ºC, and stable performance after 750ºC for 72 hours under 10% H_2O/air aging (approximately 120 kilo miles). This person noted a determination of the reaction mechanisms and catalyst structure/function at low temperature is needed for current and developing after-treatment technologies to identify and prioritize opportunities. This reviewer added that the cost-sensitive focus on non-PGM catalyst materials was excellent.

Reviewer 6:

The reviewer agreed that the approach shows promise, and includes starting with GM and other catalysts, analyzing performance and degradation, and then evolving further into extensions or new systems. This reviewer added that the tools and skills of the team are world-class, and the approach will significantly advance the understanding. This reviewer suggested that, before going too far on Cu-based systems, the project team should make sure that dioxin toxicity issues were not going to kill this later.

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:

This reviewer described the understanding developed as excellent.

Reviewer 2:

The reviewer noted a very impressive start in identifying the active species in the catalyst-oxide system. The isotopic oxygen work was quite illuminating and this reviewer was very anxious to see the progress. The results to date raised more questions than answers, but this was very promising and set the groundwork for a valuable program.

Reviewer 3:

The reviewer summarized that the project team developed and tested material combinations to achieve T50 CO conversion efficiency at 150°C. This reviewer also noted the use of a commercial ceria-zirconia (CZ)-supported Cu catalyst (Cu/GMR6), which, after hydrothermal aging, was as active as the fresh CZ-Cu catalyst.

Reviewer 4:

The reviewer remarked that sintering of active metal sites had been identified as a major barrier. This person noted the analysis of commercial CeZrOx supported the demonstrated major structural stabilization benefit of additives. This reviewer added that it was early in the project lifecycle (about 17% complete), so the results were largely preliminary.

Reviewer 5:

The reviewer noted very good progress in characterizing the CO oxidation behavior of the catalyst and showing that there were no negative effects related to HCs or nitric oxide (NO). However, HC oxidation activity under various conditions was only mentioned, but not presented in the slides. The aging conditions used may not be challenging enough for after-treatment applications where high-load conditions may produce higher temperatures. The reviewer noted that other fuel-related poisons, such as sulfur, were under investigation and should be determined early to evaluate the viability of this catalyst.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated effective collaboration between GM R&D and PNNL that takes advantage of each organization's complementary strengths. The kickoff meeting was held at PNNL on November 1st, 2013, and conference calls were held 5–7 times a year to discuss results. This reviewer noted that an annual face-to-face meeting would be scheduled for later this year.

Reviewer 2:

The reviewer mentioned excellent collaboration in the requirements definition from the entire industry, and a detailed scope and division of cost/labor between the OEM partner and PNNL.

Reviewer 3:

The reviewer noted there was a well-designed group to address this new technology, and the researcher and participant organizations were well matched to this task.

Reviewer 4:

The reviewer noted impressive signs of collaboration that used GM catalysts as a starting point, but added that there were not a lot of signs yet on GM's inputs and work on the analytical methods. However, the reviewer added that this role might not be needed given the capabilities of the PNNL researchers. GM's role here needed to be directional, especially on the aging protocols and Cu toxicity in making dioxins.

Reviewer 5:

The reviewer stated that, apart from focusing the work performed via its industrial partner (GM), no major display of resource appeared to be planned outside of the PNNL–GM circle. Synergizing with resources outside of PNNL and GM was an open area, and could only enrich the approach. (The reviewer was cognizant that there would be intellectual property issues to be tackled then.) This reviewer added that one should note that the bulk of the funding was from DOE (i.e., public), hence a larger partnership emphasizing a more enriched investigative team would be desirable.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 emphasized that the project team should keep going. The future approaches seemed very reasonable and would deliver much better understanding. This reviewer added that it seemed important to also test mixed CO-HC systems as the understanding evolves, perhaps sooner rather than later.

Reviewer 2:

The reviewer noted continuity with future work (and synergizing with industrial partner) is properly integrated into the "future work."

Reviewer 3:

The reviewer mentioned that completing Cu/CZ studies to further document and share the results was excellent, and noted characterization, comparison with model materials, and kinetic studies of CO oxidation on fresh and aged catalysts (focusing on mechanisms and limitations for low-temperature performance, while providing CLEERS low-temperature oxidation protocol). The reviewer indicated that the project team was studying materials with the potential for a high value proposition and was on task for its goals, baseline mechanistic studies, and the performance and aging of ceria-supported and mesoporous Cu/ceria.

Reviewer 4:

The reviewer acknowledged the research consortium had a well-considered plan to address the oxidation capabilities of this technology. This person indicated that future research, however, should migrate toward HC feed species and aging schedules that will be proposed by the USCAR organization.

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

Reviewer 1:

The reviewer indicated that low temperature catalyst performance could substantially help with fuel economy enhancements in engines, and hence help further meet DOE's goal.

Reviewer 2:

The reviewer commented that this was relevant work and very consistent with USCAR/U.S. DRIVE initiatives to develop these low-temperature after-treatment catalysts for future powertrains.

Reviewer 3:

The reviewer stated that this temperature range is where improvements are needed.

Reviewer 4:

The reviewer stated that this work could lead to lower-cost catalysts that were more effective at the lower exhaust temperatures that are experienced by more efficient engines (as well as after cold start).

Reviewer 5:

The reviewer mentioned that low-temperature DOC performance was beginning to limit the potential for low-temperature combustion engines. The reviewer added that these combustion strategies were very efficient, but generated a substantial amount of HCs and CO and have chronically low exhaust temperatures. This person said developing low-temperature oxidation catalysts was certainly needed to move these developments forward.

Reviewer 6:

The reviewer noted that after-treatment requirements were changing to support the use of new higher efficiency combustion regimes, which result in lower temperature combustion and lower normal exhaust operational temperatures. This reviewer emphasized that the cost and PGM considerations for after-treatment were continuously on the radar for OEMs.

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

Reviewer 1:

The reviewer felt that $250,000 per year seemed appropriate at this stage, but added that it might be a little low as the program advances. Given the importance and the early promising results, it would seem that more resources might be needed in the out year(s). This reviewer added that this was such an important and fundamental program that DOE should not shy away from providing more funding if promising results are reported.

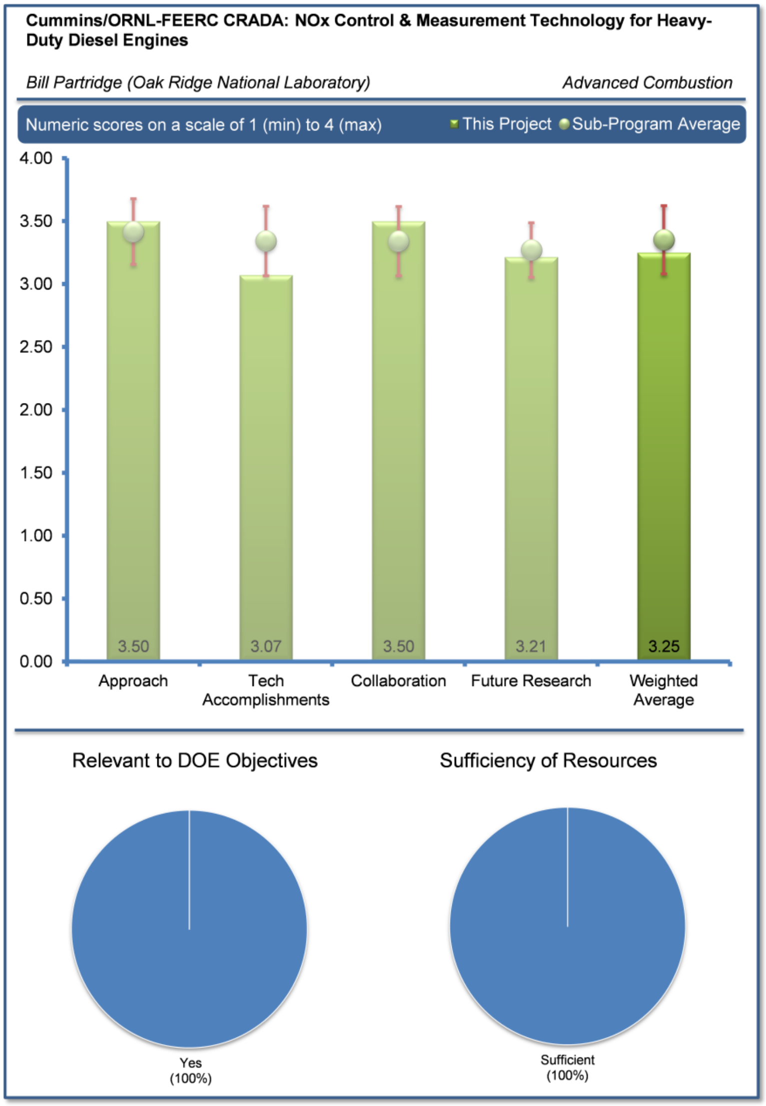
Reviewer 2:

The reviewer stated that this project was appropriately staffed and funded.

Reviewer 3:

The reviewer noted this was a fundamental catalyst project. PNNL has integrated state-of-the-art instruments for this project, and the resources were proper.

Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines: Bill Partridge (Oak Ridge National Laboratory) - ace032



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 stated this was a refinement of both the spacims instrumentation and an evaluation on spatial composition within a catalyst channel of aging. The reviewer noted that either was a good project. This reviewer added that together the project garnered an excellent rating.

Reviewer 2:

The reviewer noted that further refinement and defining of this technique to characterize SCR catalysts as well as other catalyst technologies is essential to obtaining consistent results across many users. However, the use of this technology to answer specific questions related to performance and operating conditions will necessitate the use of different probe characteristics.

Reviewer 3:

This approach is fairly unique, even with other groups doing more SPACI work. This reviewer added that analysis of capillary impact is very interesting, because it comments directly on recent work in Europe claiming an impact using modeling, mainly.

Reviewer 4:

The reviewer stated that the approach seemed rather straightforward (i.e., thermally age catalysts and analyze the impact with the best tools). Understanding the mechanistics is fundamental to this. TU Milano can be very useful here. Understanding the axial profiles of NO_x reduction and NH3 storage and how aging affects these is important base information.

Reviewer 5:

The reviewer stated that ORNL's unique capability, SPACIMS, was a unique tool in developing kinetic models for the monolith based catalyst. The reviewer noted it allowed very comprehensive information under various conditions and added that the PI was one of the pioneers in this approach.

Reviewer 6:

The reviewer observed a thought-out approach; however, challenges remain.

Reviewer 7:
The reviewer felt that characterizing the spatial deactivation of SCR catalysts was interesting. It was not clear to the reviewer how this could be used on a vehicle to improve engine efficiency,

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

Reviewer 1:
The reviewer said good work characterizing the various functions of the SCR catalyst (NOx conversion, ammonia (NH_3) oxidation, etc) as a function of length, both fresh and aged. The reviewer described the effects of the size of the Spaci probe on the measured catalyst activity as interesting.

Reviewer 2:
The analysis of Aging effects is very interesting. It should be possible to separate the effects of ammonia oxidation versus SCR in the formation of N_2. Ways of selectively separating two aging paths should be possible with S or some special aging pathway.

Reviewer 3:
The reviewer stated that the SCR aging data seemed fairly incremental to the current understanding. The reviewer expressed that it was difficult to project how this information would meet the objectives. The reviewer asked what was new and exciting, and how could this be practically used. The reviewer suggested that the team needed to develop models or other methods that could lead to the actual use of these results in practice. Results on SpeciMS invasiveness was very important and has been a major concern out there. The reviewer stated this is an import tool and your results can help ensure results from others are pertinent.

Reviewer 4:
The reviewer noted that last year, the team had accomplished with a good correlation between SCR kinetic models and experimental data over fresh catalysts, and it was planned to move on to the field-aged parts. The reviewer stated however, it seemed that the field aged parts were not available over the last period of the project. The reviewer noted that instead, the team investigated hydrothermally aged parts, which had been done by many other groups previously.

Reviewer 5:
The reviewer noted that there appeared to be some differences of opinion in how to use this probe technique that were application dependent. The reviewer stated however, this work clearly supported catalyst characterization efforts to improve models for optimizing catalyst utilization.

Reviewer 6:
The reviewer noted that technical accomplishments were noteworthy qualitatively, but not quantitatively. The reviewer added that looking at the Accomplishments (Slide 15) the results were insufficient given that the project started in 2012.

Reviewer 7:
The reviewer asked regarding Slide 8, if there was enough information there to tune a mechanism. Regarding Slide 9, the reviewer said asked if the aging was done in a slow flow muffle furnace or a reactor. It seemed to the reviewer as if the front-end aging was characteristic of a reactor aging. If so, the reviewer wanted to know what made it front end aged. This accomplishment does not have enough detail for a reviewer to determine the value of the result. Regarding Slide 10, the reviewer observed no explanation for the aging effect on the parasitic ammonia oxidation, which seemed to occur mostly at the front and the conversion is made up for later in the catalyst. With regards to Slide 11, the reviewer said it was very helpful.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer stated that it was extremely difficult to determine from this presentation how much was contributed from each partner. In addition, this reviewer queried whether the ORNL investigator went to Cummins and brought his instrumentation there, or if some of

the measurement work was done at ORNL. The reviewer added that an outstanding collaboration should be seamless, but the reviewer could not easily review collaboration without knowing what each partner contributed. The reviewer said to repeat last year's comment; please show at least one slide summarizing what the other partners did.

Reviewer 2:
The reviewer stated that this project has a good balance between experimentalists and spectroscopists. The reviewer added that participant organizations and researchers were well matched to this task.

Reviewer 3:
The reviewer noted excellent partner collaboration on this project. The reviewed noted clear evidence in course of project of the interactions here.

Reviewer 4:
The reviewer noted that the project was missing a catalyzer or others with fundamental catalyst understanding - PNNL, universities, etc. The reviewer suggested that the team has good understanding but someone who does basic research to help guide breakthroughs may help. The reviewer asked do you have this in the informal relationships.

Reviewer 5:
The reviewer stated that the ORNL team had an excellent group of collaboration partners including industries, universities, and national laboratories.

Reviewer 6:
The reviewer noted outstanding collaboration that included the integration of Cummins, CLEERS, Professor Luis Olsson (Chalmers University), Professor Tronconi (Politecnico di Milano), Institute of Chemical Technology at Prague, etc. The reviewer stated that a more interactive involvement of the university partners could help boost synergistic capabilities, as opposed to the existing 'informal' interaction set-up observed.

Reviewer 7:
The reviewer noted good collaboration between ORNL and Cummins was demonstrated as well as good collaboration with Chalmers and P. di Milano.

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

Reviewer 1:
The reviewer agreed with characterizing the distributed impact of aging on SCR-catalyst functions and performance, as well as resolving NH_3 capacity distributions via transient analysis.

Reviewer 2:
The reviewer stated that much of this work had already been addressed through other activities.

Reviewer 3:
The reviewer noted that the proposed future work was certainly of interest. Better characterization of axial changes in NH_3 storage is important. The reviewer stated that the development of and comparisons to aging models was important. The reviewer agreed that in the end though, one would not have a SpaciMS, so there has to be some way to take exit sensor data and imply aging stage. The reviewer added that transients and pulsed diagnoses might help develop this. This was the role of fundamental work like this. The reviewer asked if it could be done.

Reviewer 4:
The reviewer hopes the field-aged part will be available this year so that the team can accomplish the original goal.

Reviewer 5:

The reviewer reported that a clear roadmap on what is next will be done (i.e., university collaboration, laboratory aging, and trying various temperatures).

Reviewer 6:

The reviewer stated that looking at field-aged catalysts will be very important to the project. The reviewer said the project team needs to think about how such information could be used on a vehicle to improve fuel economy. It might require some new sensors and possibly several sensors along the length of the catalyst, as catalysts can be deactivated (either temporarily or permanently) in a variety of ways. The reviewer offered that often times the front of the catalyst is aged more than the back of the catalyst, but sometimes the back of the catalyst can be deactivated more (such as from high-speed misfires). The reviewer stated that to account for all the possible deactivation mechanisms, we would need to actively monitor the performance of the catalyst along its length.

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

Reviewer 1:

The reviewer noted that $DeNO_x$ meant low fuel consumption in HD diesel. The reviewer suggested that the main limitation now is SCR catalyst durability. By knowing the state of the catalyst aging, the engine can be calibrated to balance emissions and fuel consumption. The reviewer stated that the OBD is a major challenge for all emissions systems, and this work can shed light on this.

Reviewer 2:

The reviewer stated that this was a very important project in harmonizing the kinetic model development for real-world diesel after-treatment application that enables the large deployment of fuel efficient vehicles.

Reviewer 3:

The reviewer said yes, as a NOx after-treatment solution, this project would help reduce fuel consumption.

Reviewer 4:

The reviewer noted that if the results of this project allowed the engine to operate at its peak efficiency point, it will meet the DOE goals of reducing petroleum use.

Reviewer 5:

The reviewer noted that this supported both the heavy-duty and the light-duty U.S. applications. The reviewer stated pretty much on target.

Reviewer 6:

The reviewer noted that the use of invasive techniques to characterize the performance of after-treatment components under bench conditions was essential in the development of future technologies. The reviewer stated however, that adapting these techniques to in-use after-treatment systems is not necessarily appropriate or practical.

Reviewer 7:

This reviewer opined that improvements lead in that direction.

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

Reviewer 1:

The reviewer stated that funding seemed adequate. The reviewer affirmed that it was not clear how much was internally contributed from Cummins. Cummins benefited greatly from this work and the reviewer hoped that their financial contribution reflected that.

Reviewer 2:

The reviewer observed that this project uses appropriate spectroscopists and experimentalists to derive the required information. The reviewer suggested that the level of funding was correct.

Reviewer 3:

The reviewer noted that the resources seemed reasonable to complete the work proposed. Adding the pulsing work might stretch the resources, but it seemed to fit.

Reviewer 4:

The reviewer stated it seems sufficient.

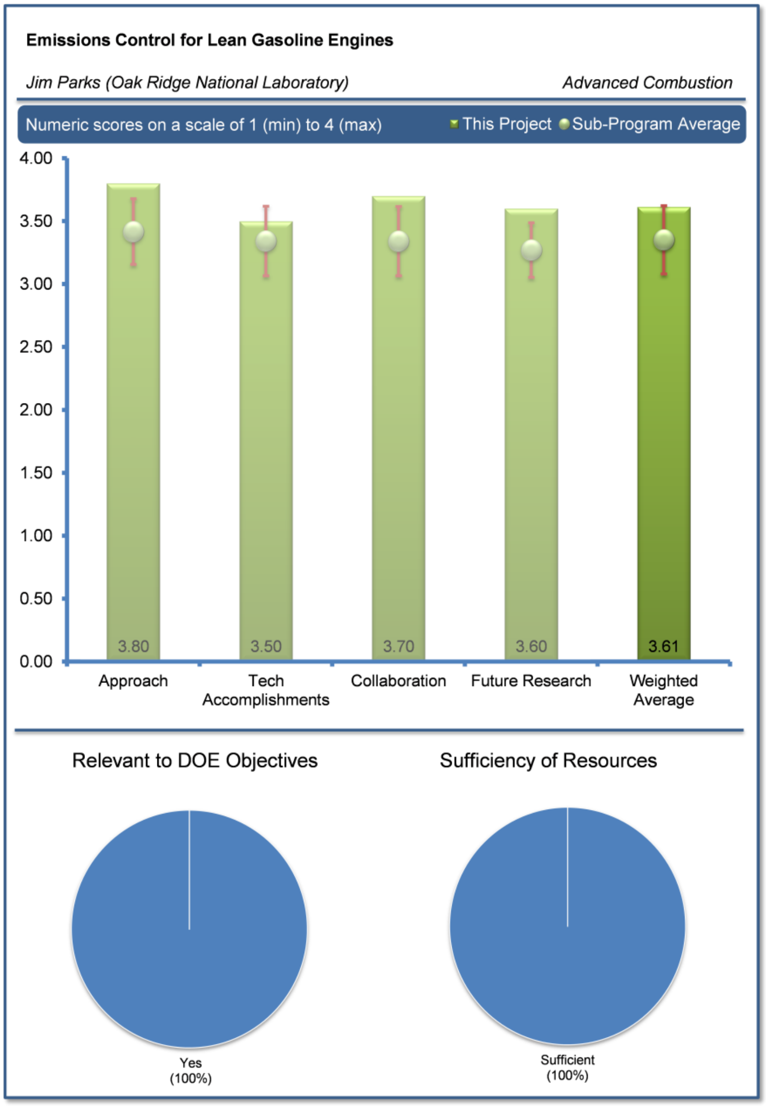
Reviewer 5:

The reviewer noted proper resource planning.

Reviewer 6:

The reviewer stated that the resources seemed to be adequate for the project.

Emissions Control for Lean Gasoline Engines: Jim Parks (Oak Ridge National Laboratory) - ace033



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 suggested that the project approach of investigating alternatives to urea injection for passive NO_x control was highly appropriate. The reviewer added that the low temperature limitations of urea based systems are a well-established barrier. Therefore, in order to meet the newly adopted low temperature after-treatment initiatives, the proposed architectures are worthy of investigation. The reviewer added that in addition, the low temperature NO_x reduction activity of newer, novel SCR and LNT materials would require passive NH_3 generation to be able to function under cold portions of the FTP cycle.

Reviewer 2:

This reviewer observed an excellent combination.

Reviewer 3:

The reviewer commented on the nice evolution of understanding and following adjustment of approach: determining and then optimizing ammonia generation; matching with NO_x and temperature effects; and then looking at system configuration. Matching FC with NO_x and system is comprehensive; however, one major lever is missing. The reviewer stated that using EGR and other engine means to adjust NO_x and potential H_2 and/or NH_3 production is needed. The reviewer stated that building one's knowledge on the capability of the after-treatment system to help guide the engine calibrations seemed like a nice progression.

Reviewer 4:

The reviewer stated that Jim Parks, his team and collaborators have done a thorough job in defining the right targets, setting a strong, collaborative team and devising a strong framework for the project.

Reviewer 5:

The reviewer commented that the combination of lab reactor and vehicle work is a good two-pronged approach for optimizing the system. The vehicle work will be particularly important for understanding the HC emissions during lean/rich cycling, as it is difficult to accurately simulate the HC on lab reactors due to the wide variety of hydrocarbons emitted from engines. The reviewer affirmed that the vehicle work will also be important for characterizing the PM 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 noted that the project had produced an excellent outcome and worthwhile results, providing some foundations on pros and cons of how various emission reduction strategies could meet next generation lean gasoline engines' after-treatment needs.

Reviewer 2:
This reviewer described the level of ammonia production as very impressive.

Reviewer 3:
The reviewer stated that the large amount of fundamental data displayed here was quite impressive. The baseline information would help guide practitioners in the field. The reviewer offered that the focus on NH_3 generation and storage, along with fundamental system architecture was valuable. The data appeared robust, but more may be needed in the regard (e.g., repeatability, aging, poisoning effects, etc.) if only a peak in the box can be done.

Reviewer 4:
The reviewer noted a good analysis on NH_3 production versus air-to-fuel ratio and temperature. The reviewer expressed a need to investigate novel purge strategies to limit CO production during the rich purges. The reviewer suggested that the idea of adding NO_x storage materials to the TWC was good, but the TWC needed to be hot to minimize the HC slip during purges, and that would prevent the TWC from storing NO_x as shown on Slide 23. Placing a LNT in front of the SCR in the underfloor position is a better way to go to provide some lean NO_x storage, although the impact on N_2O production will need to be investigated. The reviewer noted good correlation between laboratory results and vehicle results on Slide 17.

Reviewer 5:
The reviewer noted that in order for passive NH_3 NO_x control to be seen as a viable way of meeting future emissions standards, the fuel penalty associated with $DeNO_x$ events was not the only negative element to consider early on. The reviewer stated that optimizing these events along with $DeSO_x$ strategies were critical to enabling this technology to proceed, and should be considered early in the program. In addition, the effect of SO_2/SO_3 on both the LNT and SCR technologies must be understood and minimized at the same time because ensuring the selectivity of the catalysts towards N_2 formation is high in preference to NH_3 or N_2O formation.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted excellent inclusion of both suppliers and OEMs into the project. Umicore was recognized for their NSC technologies. The reviewer suggested that having monthly conference calls with all the participants was a very good way to maximize the effectiveness of the data collection, direction of the project, and characterization.

Reviewer 2:
The reviewer felt that the team was extremely strong. Umicore developed the Mercedes lean burn system used in Europe. The reviewer stated that GM had reported on lean burn several times and would appear to have good experience. The reviewer commented that University of Wisconsin, University of South Carolina, and PNNL can provide fundamental and testing expertise. The reviewer stated impressive. University of Wisconsin, Umicore, and GM are engaged and this seemed sufficient.

Reviewer 3:
The reviewer noted that the collaborative interactions with CLEERS, PNNL, industry partners (Umicore, GM), University of South Carolina, and the University of Wisconsin provided a strong framework for increasing strengths and reducing failure risks.

Reviewer 4:
The reviewer noted that good collaboration between ORNL and Umicore was evident. The reviewer inquired about GM's contributions.

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

Reviewer 1:
The reviewer noted that emerging technologies such as the combined TWC/NSC may be important enablers for meeting LEVIII and Tier II Bin 2 standards for lean systems. It will be of great interest to determine how the incorporation of this technology into the after-treatment system can be optimized through $DeNO_x$ and $DeSO_x$ regeneration strategies to complement and enhance the emissions performance of the entire system.

Reviewer 2:
The reviewer was anxious to see the aging data. The reviewer expressed mixed thoughts at this stage on whether to focus on transients versus other key engine drivers like EGR or other engine calibrations (one rich cylinder). The reviewer suggested that EGR and that understanding might be better to develop earlier, unless one sees more interesting transient results that can significantly impact the after-treatment fundamentals.

Reviewer 3:
The reviewer stated that the future steps were in sync with the progress made thus far and also relevant to industry needs, including sulfur effects, aging, transients and system improvement to enhance fuel economy.

Reviewer 4:
The reviewer noted the need to include purge strategy development as part of the future plans to limit the impact of the rich purges on CO, HC, and fuel economy. Also, it is important to better understand the PM and HC emissions on the vehicle. The reviewer asked if N_2O production during the purges was looked at.

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

Reviewer 1:
The reviewer stated that the project was very relevant to U.S. marketplace where gasoline powertrains represent the vast majority of the market and the movement toward lean GDI is occurring. The reviewer added that effective $DeSO_x$ and $DeNO_x$ strategies for highly efficient lean combustion strategies must be included in the calculation of fuel penalties as well.

Reviewer 2:
The reviewer indicated that 5-10% fuel consumption savings in the 2020 timeframe may cost OEMs about $75 per percent. This leaves approximately $500 added cost to a lean burn versus a stoichiometric GDI engine. The reviewer stated that this seemed achievable, and several OEMs were working on this. The critical determinate was meeting the Tier 3 emissions requirements. The reviewer affirmed that this program was at the heart of this.

Reviewer 3:
The reviewer asserted that running lean enhancements are needed.

Reviewer 4:
The reviewer noted that the project was well focused on the stated goals of fuel economy targets.

Reviewer 5:
The reviewer stated that the project addressed emission control for lean-burn gasoline engines, which would improve fuel economy and lower national fuel use.

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

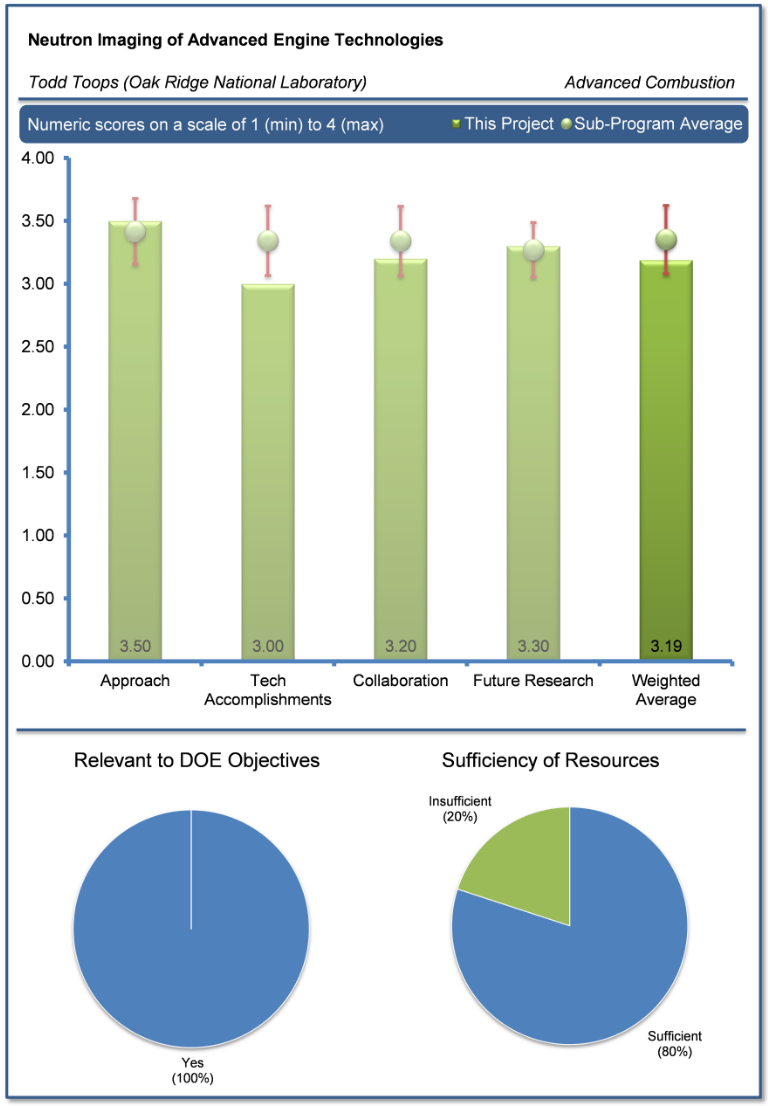
Reviewer 1:
The reviewer indicated that funding and collaboration was appropriate.

Reviewer 2:
The reviewer indicated that the remaining resources were okay for the last year. The reviewer stated that if more were needed to shift some work into the engine approaches, money should be made available, at least enough to get data for a new proposal.

Reviewer 3:
The reviewer noted that the proper use of engine, catalysts, micro-reactors, had been integrated into the project. The reviewer was not sure why modeling had not been integrated into the tasks, especially in regards to catalyst development and performance.

Reviewer 4:
The reviewer stated that the efforts were consistent with the funding level.

Neutron Imaging of Advanced Engine Technologies: Todd Toops (Oak Ridge National Laboratory) - ace052



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 exploring the potential use of neutron imaging as a nondestructive technique to advance the understanding of the internal flow dynamics of injectors, and the distribution of soot, and ash in particulate filters was worthwhile, especially at the modest funding level of $200,000. The reviewer stated this could lead to new insights versus other techniques that were typically used.

Reviewer 2:

The reviewer noted an excellent approach with much potential for studying internal flows (being that they are liquids in injectors or particles in soot filters) through neutron imaging technique. The reviewer stated it was a novel, non-destructive procedure to visualize internal structures of fuel injector and particulate filters.

Reviewer 3:

The reviewer said it was great to see an approach that could better reveal internal features of these parts.

Reviewer 4:

The reviewer stated that it was good to see more gasoline based measurements. The reviewer asked if a neutron imaging technique could be used for fuel spray in an engine.

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

Reviewer 1:

The reviewer observed good progress on milestones and was appreciative of the devotion to efforts to find ways to improve techniques for injector studies. The reviewer stated that it would be interesting to see the results of the changes once fluid injection studies were performed.

Reviewer 2:

The reviewer stated that the injector results were relevant and interesting. Scans of eroded injectors were relevant to improving injector designs and may provide new insights on nozzle erosion patterns. The reviewer noted however, the temporal and spatial resolution possible require additional work before making useful measurements of injector nozzle cavitation. The reviewer noted that the particulate filter loading pattern measurement was also interesting, but also may require temporal measurements of loading and regeneration behavior in real engine operation conditions for a greater impact.

Reviewer 3:
The reviewer observed outstanding imaging and presentation but would like to see how these could impact practical issues of component design or system control.

Reviewer 4:
The reviewer hoped to see fuel spray results rather than plans. It was not clear to the reviewer what to do with the ash loading distribution inside a DPF. The reviewer felt it was interesting, but asked what would be done with the information.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed a good mix of collaborations with industry, universities, and national laboratories. The reviewer hoped the project would be successful in adding a Tier 1 fuel injector supplier.

Reviewer 2:
The reviewer noted excellent collaboration with various industry partners and academic institutions. The reviewer recommended to involve more interested parties (engine, injector, and filtration OEM's for example) to expand the scope of this project. The reviewer noted that the most obvious collaboration/coordination would be with ANL and their x-ray imaging with the APS. Clearly, these two techniques should be compared and contrasted in detail (i.e., how do they complement each other, what are the limitations of each relative to the other, etc.).

Reviewer 3:
The reviewer commented that as noted already, more interaction with industry would seem useful, but maybe this needed to wait until the processes were adequately developed.

Reviewer 4:
The reviewer remarked that it was good that the injector supplier was now involved.

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

Reviewer 1:
The reviewer stated that the progress looked good with work in progress on evaluating the modified approach to the fuel injector studies and analyzing the DPFs.

Reviewer 2:
The reviewer remarked that the future plans looked like logical extensions of work to date, although the comments above should be considered in terms of improving the research and its impact on industry.

Reviewer 3:
The reviewer noted that an upgraded laboratory capability should improve results.

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

Reviewer 1:
The reviewer stated that the use of novel techniques to improve the basic understanding of fuel injection and emissions equipment functioning/performance supported the DOE's goal of design of engine systems with higher efficiencies and lower emissions.

Reviewer 2:

The reviewer noted that improved diagnostics would lead to better modeling tools and, of course, better understanding of the physics which should both lead to improved efficiencies and better comparisons between different fuels (petroleum and non-petroleum based).

Reviewer 3:

The reviewer stated that the technique seemed to offer tremendous potential.

Reviewer 4:

The reviewer expected that the unique diagnostic capability of neutron imaging would provide a unique insight into the behavior of engine components that would lead to improved understanding and insight.

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 progress was being made and there was no indication that funding was not sufficient.

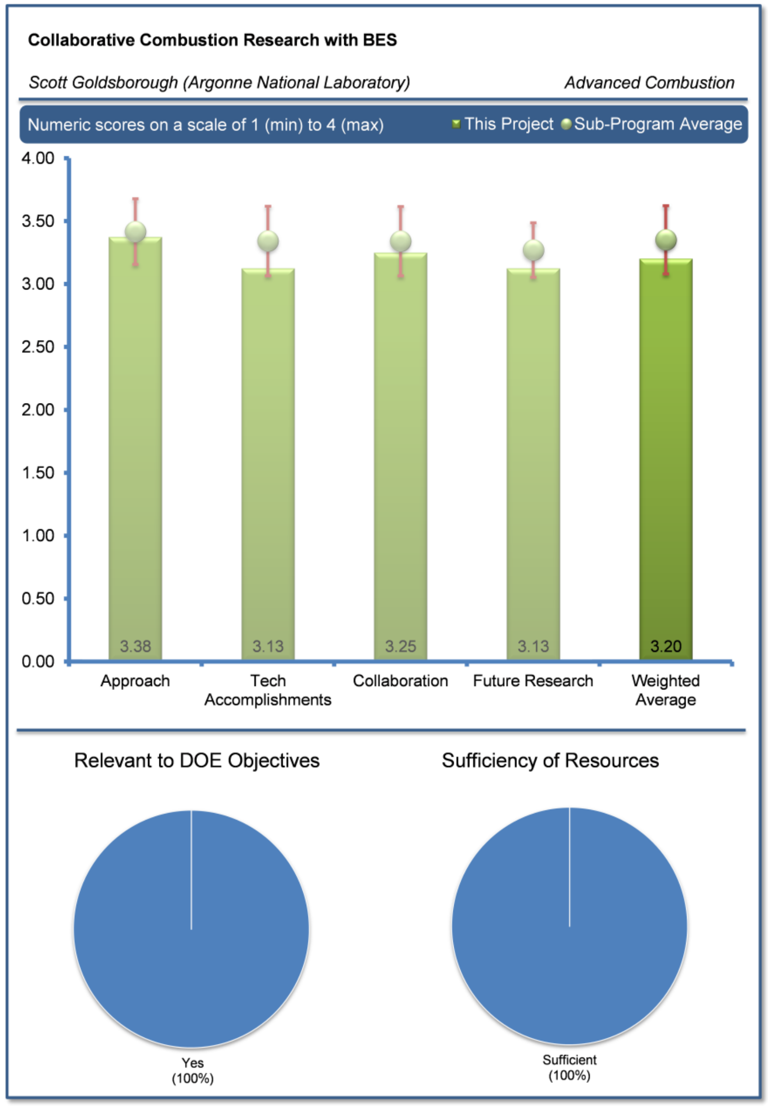
Reviewer 2:

The reviewer lauded the project as a great program for the money being spent.

Reviewer 3:

The reviewer noted that the funding seemed too low to cover any significant development. The reviewer expressed fear that $200,000 per year was largely eaten up by reporting and other non-research activity.

Collaborative Combustion Research with BES: Scott Goldsborough (Argonne National Laboratory) - ace054



Reviewer Sample Size

A total of four reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that RCM was a basic research tool for testing reaction kinetics to develop useful mechanisms for engine modeling. The reviewer remarked that the project has done a good job in overcoming some of the uncertainties associated with the device through development of an adjunct RCM system model. The reviewer added that progressive facility improvements were also underway and that useful data was being generated to guide mechanism development and refinement. The reviewer stated that overall, measured, systematic approach was excellent, if somewhat leisurely paced.

Reviewer 2:

The reviewer noted that the novel approach to interpretation of RCM results to provide chemistry information. FACE fuels and standard fuels are more interesting and should have higher priority than EHN additives.

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

Reviewer 1:

The reviewer stated that the project had focused on a few selected gasoline surrogates and two reactivity modifiers (EHN and Di-t-butyl peroxide [DTBP]), and measured the auto-ignition delay times at 20 bar and low/intermediate temperature regimes. The reviewer noted that the auto-ignition data measured in the two-piston RCM had been successfully applied to verify the predictability and accuracy of the assembled kinetics model of fuel surrogates with or without the additive (2EHN). The reviewer added that the comparison suggested that the fuel's kinetic model (particularly the LTC chemistry pathways), as well as RCM's physics-based system model, needed further improvement. The reviewer noted that while being able to measure auto-ignition delay times, the project (1) has not explored advanced, time-resolved gas sampling and speciation, and (2) has not exercised novel probing techniques (e.g., GSA) and detailed calculations of sensitive processes (e.g., individual reaction rates) for improving kinetic models. The reviewer stated that those features were discussed in the FY 2013 report but were still in the future in this year's presentation. Therefore, it was unclear to what extent the listed milestones could be accomplished in the second half of 2014 and, most critically, how the newly measured data and the RCM physics-based model could help each other to improve the existing kinetic model or to develop the new chemistry sub-model set that can eventually update the existing petroleum fuel's chemical kinetics library.

Reviewer 2:

The reviewer asked what the plan was to address the differences between modeled ignition delay and measured ignition delay.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed good coordination effort with government labs and universities overall. The ECN-like RCM workshop was a great idea that is just taking root. The reviewer stated that time will tell if it will achieve the same level of success. The reviewer felt that it would be nice to see even more collaboration with other researchers using similar RCM/RCF-like devices as well as complementary devices like shock tubes, flame tubes, etc. This reviewer suggested that a coordinated suite of measurements (ignition delays, speciation, flame speeds, etc.) was needed for kinetics testing and it would be great to see all of the facilities doing this kind of work integrated or sharing ideas to ensure data consistency across the board. The reviewer added that greater interaction with engine companies and commercial software vendors would be welcome as well.

Reviewer 2:

The reviewer stated that the international RCM workshop to establish standardized tests was a great idea.

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

Reviewer 1:

The reviewer noted that the proposed future research continued the project's current research direction, including improving kinetic modeling capability with model probing tools (GSA) and stratified reactor approach integrated with RCM model, and measuring and modeling of FACE surrogates and ethanol/gasoline blends. The reviewer also stated that the proposal included the demonstration of a newly manufactured single-piston RCM, designated for high boiling point fuels, together with integration of gas sampling and analytical unit. The reviewer noted that considering the capabilities of the RCM's physics-based model, it was expected that it would be a productive year.

Reviewer 2:

The reviewer asked what the advantage was of the new single piston RCM over the current dual piston RCM.

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

Reviewer 1:

The reviewer stated that the kinetics data and corresponding mechanism development that the RCM provided and promoted was essential for understanding new combustion strategies such as RCCI as well as new fuels and additives. The reviewer stated in this regard, this project was extremely relevant to DOE objectives.

Reviewer 2:

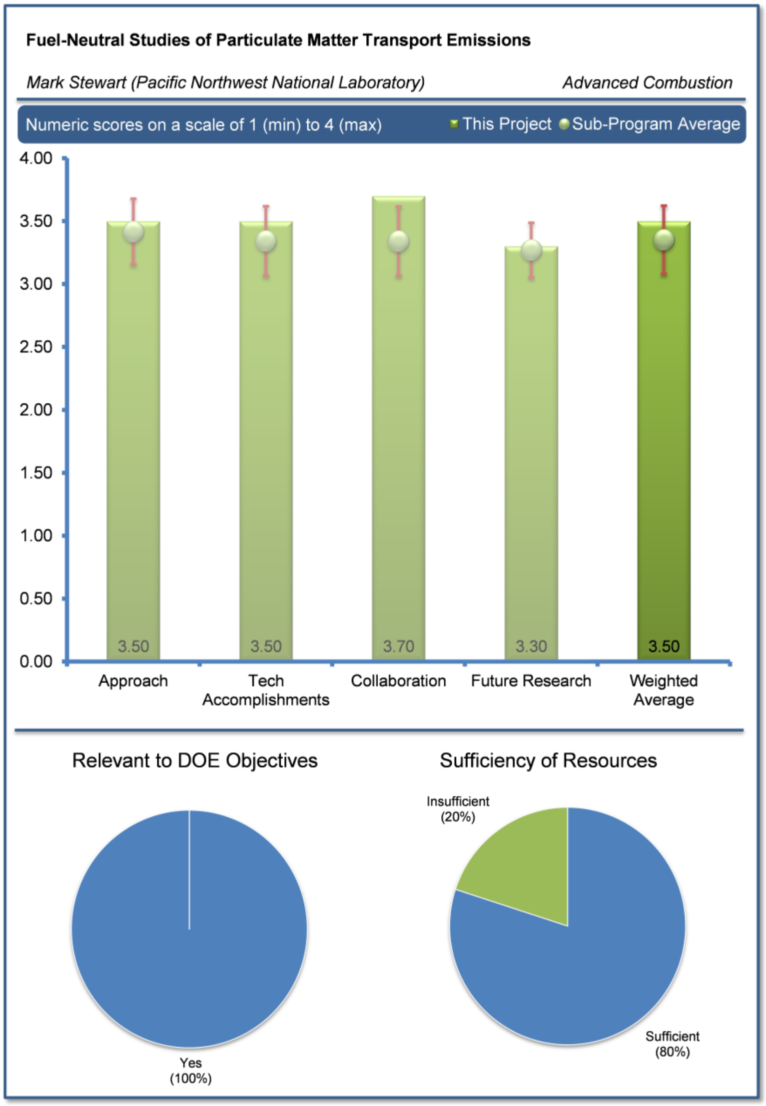
The reviewer noted that this work provides raw data to chemical kinetics models which are crucial for engine combustion simulations used by industry to design and develop engines.

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

Reviewer 1:

The reviewer noted that if all of the targeted technologies could be incorporated, this would be a world-class capability.

Fuel-Neutral Studies of Particulate Matter Transport Emissions: Mark Stewart (Pacific Northwest National Laboratory) - ace056



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 although the title was fuel neutral, it was basically a gasoline study. The reviewer's interpretation of fuel neutral was gasoline and diesel fuel. The reviewer noted that the CT images were absolutely fabulous in giving a visual image of the pore structure of the filter. The reviewer remarked that the work utilized every appropriate tool possible and stated very good.

Reviewer 2:

The reviewer noted that this characterization of particulate matter produced by direct inject engines that are being developed to help address the need for greater fuel economy, would be an important element of effectively treating exhaust PM to meet emerging emissions standards that will be in place in future years.

Reviewer 3:

The reviewer stated that the PI continues to use his expertise in using the Lattice Boltzmann approach to particle transport and deposition. The approach is relevant and is capable of answering the related questions/ barriers in the project.

Reviewer 4:

The reviewer stated that the primary program focus is on developing improved fundamental understanding/ modeling of filtration with attention given to filtration efficiency. The reviewer remarked that the overall modeling approach using Lattice Botzmann flow simulations and multi-scale filtration models seemed reasonable (noting however that the reviewer knows little about heterogeneous multi-scale filtration modeling). The reviewer observed that there is also a parallel effort by GM and the University of Wisconsin to collect experimental data via filtration experiments along with the use of advanced CT imaging and analysis to characterize representative commercially available filter samples. The reviewer added that, to date, it appears that the primary focus has been on filtration efficiency with less focus on pressure drop, albeit the reviewer recognized that an adverse pressure drop is undesirable.

Reviewer 5:

The reviewer noted a good scientific approach for extensively characterizing PM emissions from GDI engines to enable better after-treatment of such PM 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 observed very nice modeling work and experimental work on filtration efficiencies under the representative engine conditions. The reviewer suggested that the results on Slide 17 confirm this. The reviewer felt that not being a modeling expert, it would be helpful to understand the fundamental assumptions and limitations of the models and areas for future improvement, as well as sensitivity of the model predictions to key parameters.

Reviewer 2:

The reviewer observed impressive detailed characterization of the filters that were available to the program. The good fit of the experimental data and the models is impressive.

Reviewer 3:

The reviewer noted that Slide 9 was an excellent example of the variations in substrate from manufacturers that we all have assumed occurred. The reviewer expressed that especially interesting were large flow through channels and very rough walls. The reviewer noted that the computer technology used/developed to analyze the CT scans was very helpful. The CT images found "low porosity regions near the wall surfaces", this seemed to imply that wall inhomogeneities could have a gateway effect on filtration. The reviewer opined that Slide 13 was a step and was unsure if it qualified, yet, as a technical accomplishment. The reviewer also suggested that the project team reference SAE-01-1158. Slide 19 had a very interesting point (i.e., that some of the GDI soot distributions could be diesel-like). The reviewer then commented that "Maximally penetrating particle size shifts from larger to smaller diameter over the course of the experiment," found on Slide 20, seemed to imply that size filtration changes with filtration loading.

Reviewer 4:

The reviewer stated that Hg porosimetry was used primarily, but the pore sizes obtained were not enough to correlate the structure of the material. The reviewer noted that the X-ray CT scan showed the distribution of the pores throughout the wall and the size distribution which is essential for modeling efforts. The reviewer indicated that although this information was important, newer approaches that emphasized dual functional catalysts (e.g., three way filters, SCRFs, etc.) should be considered in these studies as well.

Reviewer 5:

The reviewer stated that the progress shown (relative to 2013) was noteworthy, clear and objective.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that the integration between PNNL and University of Wisconsin/GM Collaborative Research Laboratory appeared to be almost seamless and added that it was a clear recipe for success.

Reviewer 2:

The reviewer stated that the partners on this project included GM and University of Wisconsin, which was very appropriate. The reviewer added that University of Wisconsin has extensive capability to help elucidate the effects of PM size and filtration efficiency.

Reviewer 3:

The reviewer noted that there was integrated collaboration with the University of Wisconsin and with GM also. This work is all about ceramics; in later stages, integration of a substrate supplier strong in R&D could help the fundamental picture.

Reviewer 4:

The reviewer stated that the team appeared well organized. Experiments were performed by UW Engine Research Center with GM serving an advisory role.

Reviewer 5:
The reviewer noted that the good collaboration between PNNL and UW-Madison was clearly evident. The reviewer felt it was not clear what GM was contributing to the project other than consultation and perhaps some of the samples.

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

Reviewer 1:
The reviewer noted that the project/PI were clear on future work at the University of Wisconsin and PNNL. The reviewer stated that this project was all about filters and that nearly all filters were coated (as well as FWC/GPF). However, the PI had staunchly stayed away from introducing catalyst effects (either on the pore structure or on introducing basic reactions) in the investigation. One cannot find the word "catalyst" (or washcoat or coating) in the entire presentation. The reviewer stated that while on one hand it was fine (and a good idea) to start with a simple picture in the earlier project stages (as it did when starting in 2009), it was unclear why at this advanced stage of the work reactions were still being ignored. The reviewer criticized that there was more than sufficient information in the literature to allow integrating at least basic reactions in the analysis; otherwise the project ran the risk of diverging into an irrelevant domain of results and conclusions. The reviewer noted that this was one major area that the PI needed to pay close attention to, not just for scientific reasons but also for reducing the risk of producing results that may never find industry applications.

Reviewer 2:
The reviewer noted that the future work was summarized on Slide 25 and aimed to extend the experimental and modeling work. The reviewer felt it would be useful to use the models and to do a sensitivity study to determine the effect of key parameters (e.g., porosity, permeability, and etc.) on filtration efficiency and also compute pressure drop which could easily be validated by experimental measurements. The reviewer stated that it would also be interesting to see how pressure drop varies with engine operating conditions. The reviewer asked if this was something the models could predict. The reviewer questioned if this was a key goal of the work. The reviewer stated that in future work it was mentioned that additional work may be done with simple surrogate particles. It seemed to the reviewer that this was important for model validation and therefore should be done.

The reviewer stated that it was also noted that fundamental questions remained about the particle formation mechanism(s) yet it was not clear from the planned research how this fundamental lack of understanding would be addressed other than through the obvious collection of data at representative conditions.

Reviewer 3:
The reviewer stated that the extension of the program to include more filters from different suppliers should expand the database and improve the models for GPFs.

Reviewer 4:
The reviewer stated that this project was going in a very good direction and trusted the team to progress on the correct path. The reviewer disliked the following future directions; explore the use of Maximal Inscribed Sphere analysis at higher resolutions to connect 3D microstructural data with data from mercury porosimetry; explore the use of Eulierian Lattice Boltzmann filtration simulations to improve device scale unit collector models. The reviewer stated that the word explore was so vague.

Reviewer 5:
The reviewer noted that the project should also be addressing the need for characterization of hybrid filter systems. The reviewer stated that emerging bifunctional filter systems would strongly impact the porosity and corresponding diffusion characteristics of these components. Also, fuel effects and combustion strategies resulting in additional soot types had not been adequately addressed.

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

Reviewer 1:

The reviewer stated that emissions regulations going forward suggested the incorporation of filter technology in after-treatment solutions. Therefore, optimizing the filter porosity to minimize bandpass (BP) and increasing performance were critical. The reviewer suggested that researchers should examine catalyzed filters and the effect of the washcoat location and particles on the filtration efficiency and back pressure. The reviewer stated that these were important tradeoffs for powertrain providers.

Reviewer 2:

The reviewer noted that within the contribution of after-treatment strategies, the work certainly does help toward DOE's goal and charter.

Reviewer 3:

The reviewer stated that the project is relevant and important for optimizing engine performance while mitigating undesirable emissions.

Reviewer 4:

The reviewer commented that lean-burn GDI engines will improve fuel efficiency. The ability to control the PM emissions from such engines to meet future PM regulations will be critical.

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 pretty limited funding for such an ambitious project. The reviewer stated that this limited level of PNNL funding was very dependent on the funding for the GM/University of Wisconsin CRL. The reviewer hoped that funding continues.

Reviewer 2:

The reviewer stated that this project is adequately funded and staffed with the appropriate researchers to accomplish the intended tasks.

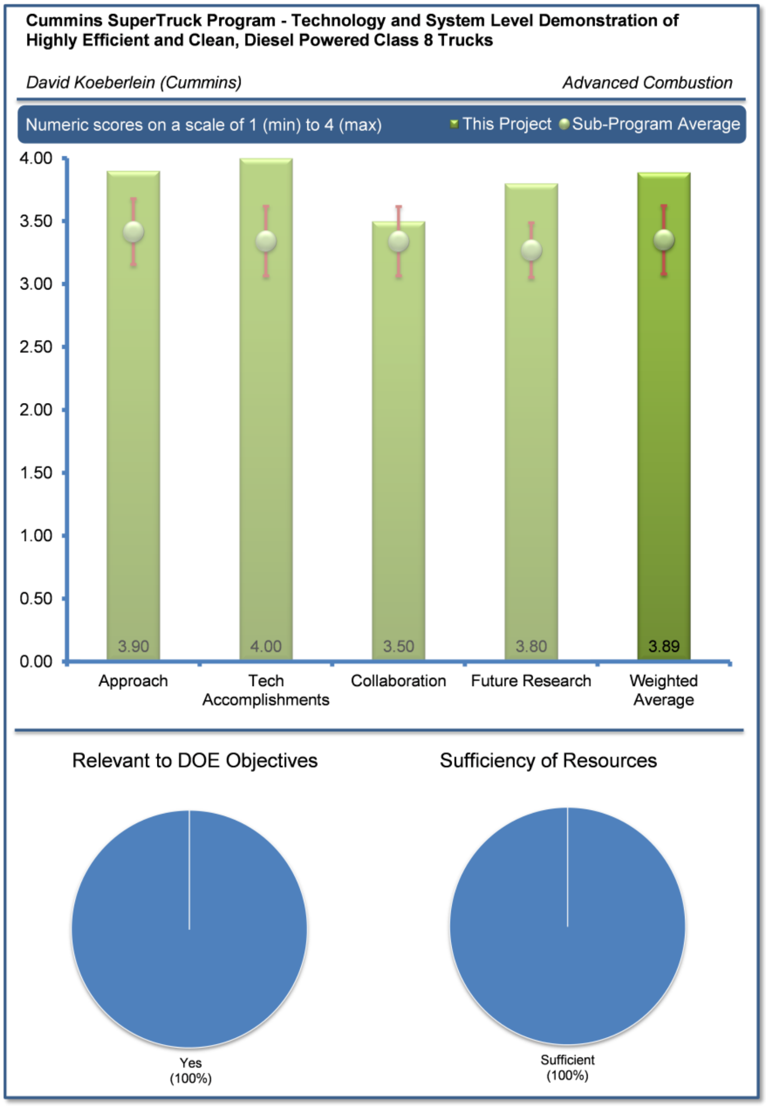
Reviewer 3:

The reviewer noted that the project includes a reasonable mix of modeling and experiments. Proper resources have been used. The reviewer criticized that the comparison with literature is modest and could be more rigorous.

Reviewer 4:

The reviewer noticed a good amount of effort at both PNNL and UW. The reviewer inquired about GM's contribution.

Cummins SuperTruck Program - Technology and System Level Demonstration of Highly Efficient and Clean, Diesel Powered Class 8 Trucks: David Koeberlein (Cummins) - ace057



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed a fundamentally sound, very advanced, and technically complete approach to improving BTE to meet the program goals.

Reviewer 2:

The reviewer noted that this was a technical tour de force by a very competent organization. The reviewer said it was hard to imagine a better package of technologies.

Reviewer 3:

The reviewer stated that the program was delivering on objectives, so the approach had been successful. The reviewer noted that the analyses are world-class, with excellent implementation.

Reviewer 4:

The reviewer stated that the technology list to meet 50% BTE SuperTruck goal was well vetted and many were feasible for near term implementations. The reviewer listed gross indicated gains, calibration optimization gas flow improvements, parasitic reductions, waste heat recovery (WHR) system.

Reviewer 5:

The reviewer noted that it was an outstanding accomplishment as far as 50% goal was concerned. However, the path to 55% was not clear, which was one of the final goals of this program. The reviewer summarized that Slide 13 to 16 showed the technical progress with individual technologies, and Slide 17 summarized the benefits. The reviewer stated that it seemed that the improvement from individual technologies, such as piston, injector, and WHR, are additive, which should not be the case. The reviewer noted that the injector and piston should have some kinds of synergy effect, which would not result in 1+1 = 2. The reviewer felt that Slide 20 needed more clarification. The reviewer criticized that without scale or coefficient of variance (COV), this figure could be misleading. For example, the figure could mean a large variation from cylinder to cylinder by just looking at the way it was presented. The reviewer concluded that no technical path was shown with AFCI toward 55%, and was not so sure that this path could reach the goal too.

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 the results speak for themselves.

Reviewer 2:

The reviewer stated that the objectives were exceeded and even with alternate technology packages. The reviewer said that there were solid analyses to support the test data.

Reviewer 3:

The reviewer observed that the project exceeded engine and vehicle goals by large margins. Credibility and analyses would likely lead to the success in meeting 55% BTE. The reviewer noted a very impressive breakdown of opportunities and preliminary results.

Reviewer 4:

The reviewer stated that the project met the 50% BTE goal. The reviewer stated that the technology list and approach for 55% BTE stretch goal using additional WHR technology approaches and further improvements in combustion design were both mainstream and appeared within reach with R&D. The reviewer noted that also considering dual fuel approach (with WHR) which also showed significant promise at a university and national laboratory level.

Reviewer 5:

The reviewer remarked that achieving 86% and 75% efficiency on two cycles was totally amazing. The reviewer noted that the results on individual technology in achieving 55% also made excellent progress. The reviewer questioned however, if these efficiency results were additive. The reviewer commented that the results on Slide 17 were confusing for showing that they were all additive. The reviewer stated that Slide 7 showed 43% CO_2 reduction, and questioned why this was not the same as the brake l efficiency of engine. The reviewer stated that the HC emission shown in Slide 19 was very high, which would put a lot of burden on DOC. It was not clear how this high HC could be removed at a low temperature, which was a common issue for this type of combustion technology.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that it seemed that given the scope of the program, the number of collaborations might be considered limited. The reviewer noted however, their program had reached outside for collaborations as appropriate.

Reviewer 2:

The reviewer said a solid relation with Peterbilt and suppliers, and ORNL.

Reviewer 3:

The reviewer noted that it seemed that this was all Cummins, but sharing the knowledge with ORNL and Purdue was okay. The reviewer stated that obviously this collaboration delivered.

Reviewer 4:

The reviewer noted a long list of contributors and suppliers on the project. The reviewer commented that the research was well coordinated.

Reviewer 5:

The reviewer questioned why only two partners were used in this program (i.e., ORNL and Purdue University). The reviewer stated that there were no tangible results demonstrated with these two partners in Slide 21.

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

Reviewer 1:

The reviewer noted that the approaches being investigated to achieve the 55% BTE were uncertain, duel fuel, but should be investigated and that was what the program was doing.

Reviewer 2:
The reviewer said that it was hard to criticize anything. The reviewer noted a very fine plan and execution.

Reviewer 3:
The reviewer was looking at all the options. The reviewer stated not being sure the dual fuel approach to 55% BTE was worth it given only a small BTE advantage and the infrastructure/complexity issues with dual fuel.

Reviewer 4:
The reviewer expressed that the 55% BTE approach was well described and vetted.

Reviewer 5:
The reviewer observed very little information about future research in this presentation. The reviewer criticized that it was not clear how the project achieved the 55% goal with the road maps presented in Slides 17 and 18. There was nothing to indicate how HC could be removed or control with AFCI solution.

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

Reviewer 1:
The reviewer noted amazing FE improvements.

Reviewer 2:
The reviewer stated that reducing freight fuel consumption was at the heart of this program.

Reviewer 3:
The reviewer noted that SuperTruck advanced Class 8 truck technologies for fuel economy improvement could significantly reduce fuel consumption as Class 8 tractors were the largest MD/HD fuel users in the fleet.

Reviewer 4:
The reviewer stated that most of the work related to the demonstration of the 50% goal was heading to production, thus improving fuel economy. This, in turn support overall DOE objectives.

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

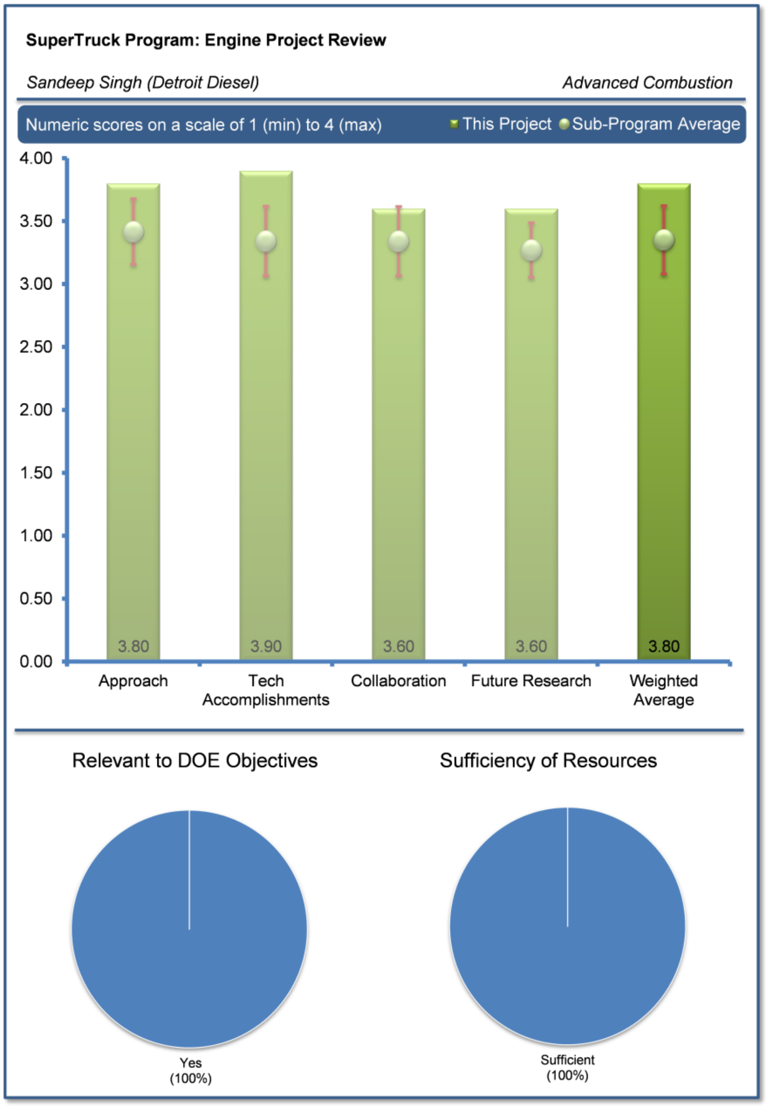
Reviewer 1:
The reviewer stated that this was a huge program, with tough goals and a big budget to accomplish it.

Reviewer 2:
The reviewer noted that this was a well-funded project covering the necessary bases.

Reviewer 3:
The reviewer stated that the project should come in on budget.

Reviewer 4:
The reviewer said just on the way to accomplish the program goal.

SuperTruck Program: Engine Project Review: Sandeep Singh (Detroit Diesel) - ace058



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted the systematic approach, which has differences from the other programs, and mentioned that the investigators had done a nice job identifying the challenges they face. The reviewer stated that the project's approach of real time engine control should provide benefits in real world driving.

Reviewer 2:

The reviewer noted a very solid approach with a broad range of technologies included.

Reviewer 3:

The reviewer stated that the approach was achieving project goals with perhaps a year to go. The reviewer saw very impressive progress in the last year. The reviewer also saw many common threads with others, as expected, but there were some unique approaches (e.g., lube oil, model based controls [MBC]).

Reviewer 4:

The reviewer noted that the team identified a clear path and implementation for the targeted 20% increase via engine improvements, 50% brake thermal efficiency and pathway to 55% brake thermal efficiency via modeling and analysis.

Reviewer 5:

The reviewer stated that the program focused on engine core technologies, where it demonstrated 47.9%, which is quite impressive. However, WHR can only bring up 2.3% benefits, which seemed to be low when compared to its competitors. The reviewer stated that it showed that more work could be done in WHR and its improvement. The reviewer stated that it seemed that the core engine technology was developed based on a bigger engine, and queried whether it was DD13, which include WHR. It was not clear to the reviewer if WHR could be applied directly to a 10.7L engine.

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

Reviewer 1:

The reviewer noted good progress over the last year.

Reviewer 2:

The reviewer stated that very strong results were shown. The reviewer noted solid progress in many areas, meeting program targets.

Reviewer 3:
The reviewer noted very impressive progress in the last year. Objectives achieved on 50% BTE. The reviewer expressed nice success on oil, MBC, SCR, WHR.

Reviewer 4:
The reviewer noted a successful integration of complex technologies (i.e., EHR, hybrid and high voltage (HV) systems, controllers and network architecture, new cooling layout, new hydraulic systems, and powertrain).

Reviewer 5:
The reviewer stated that the overall achievement was excellent. The reviewer indicated that 2.3% on single point with WHR was not too impressive. It seemed to have more potential. The reviewer opined that most technology development was on a bigger engine. The reviewer commented that once downsizing to 10.7 liter, the reviewer was not sure if all technologies could be applied to smaller engine.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed a nice collaboration effort.

Reviewer 2:
The reviewer noted good utilization of various resources.

Reviewer 3:
The reviewer noted very impressive project management with main partners and supply chain. The reviewer indicated that the results showed this.

Reviewer 4:
The reviewer highlighted a highly recognized team and observed a coordinated effort to leverage expertise across the industry.

Reviewer 5:
The reviewer stated that the partners that were involved in engine control in Slides 8 and 9, such as Atkinson, should be acknowledged. The reviewer stated that the entire program seemed only to have three outside partners MIT, ORNL, and Atkinson, but no university was involved, and that more would be better.

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

Reviewer 1:
The reviewer stated that the plan for how the project would achieve the 55% BTE goal seemed to rely heavily on new combustion technology. The reviewer felt it would be nice to see a projection of what would be the best the project can do if those technologies did not pan out. The reviewer noted that it would have been nice if more information could have been given as to the approaches being considered to overcome the challenges identified. As presented, the project was more of an identification of challenges with little information about the approach to addressing these challenges.

Reviewer 2:
The reviewer stated to keep going on the good planning.

Reviewer 3:
The reviewer noted that all the key levers seem to be investigated. The reviewer commented that early scoping on dual fuel and MBC looked good, new, and interesting.

Reviewer 4:

The reviewer stated that for the 55% target, to plan to continue to leverage combustion improvements and waste heat recovery, which if achieved were reasonable production pathways. The reviewer indicated that supporting ORNL development on dual fuel approaches, which also show promise for productive solutions. The reviewer noted that additional discussion of after-treatment needs and costs were also an important topic for 55% BTE and 50% BTE goals.

Reviewer 5:

The reviewer stated that the program seemed to achieve the final goals except 55% BTE goal. The reviewer felt that the path seemed to rely too much on dual fuel, where the actual BTE was not very high due to pumping loss. The reviewer criticized that the program also failed to address the high HC emission issue with this dual fuel or LTC.

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

Reviewer 1:

This reviewer noted direct FE gains.

Reviewer 2:

The reviewer stated that technologies developed to meet 50% BTE goal and 55% BTE stretch goal when implemented on a Class 8 truck could significantly reduce petroleum use.

Reviewer 3:

The reviewer stated that the program was able to achieve over 50% BTE, which supported the overall DOE objectives of petroleum displacement.

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

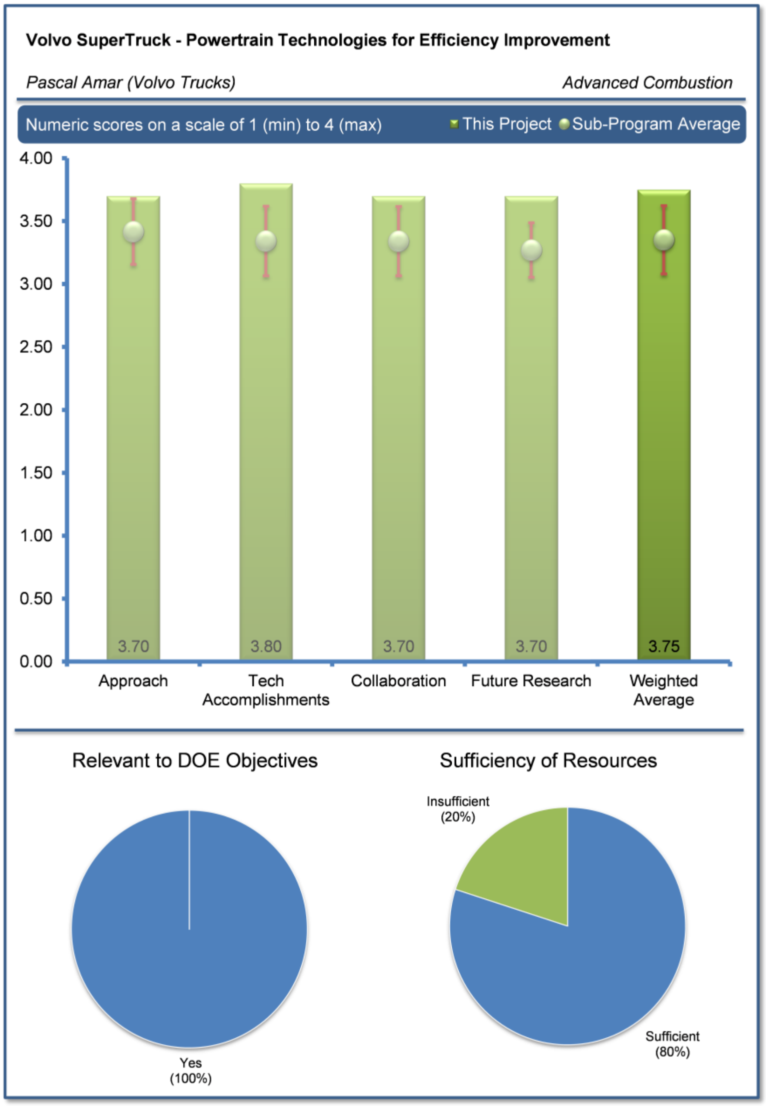
Reviewer 1:

The reviewer indicated seemed appropriate for the effort.

Reviewer 2:

The reviewer stated that it already achieved most of program goals except 55% BTE. It should be on the way to get all, since 55 BTE mainly relied on analysis.

Volvo SuperTruck - Powertrain Technologies for Efficiency Improvement: Pascal Amar (Volvo Trucks) - ace060



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 very nice work. The reviewer indicated that the program started later than the other programs, so the current position was behind, but the project seemed to be on track to meeting the goals.

Reviewer 2:

The reviewer noted a solid plan of comprehensive analysis and testing.

Reviewer 3:

The reviewer stated that the technology screen at first seemed a little backwards - itemize 55% BTE, screen for 50% BTE, and then screen for freight efficiency. The reviewer said however, that this was a nice conceptual model for attaining long term goals. The reviewer liked that the project was running lean on funding, which necessarily required practicality, however, it also had the advantage of coming in late and getting some guidance from others.

Reviewer 4:

The reviewer noted an outstanding approach to meet project goals (test 48% BTE powertrain in concept vehicle, develop powertrain technologies capable of 50% engine BTE in vehicle environment, simulate technologies to achieve 55% BTE). The reviewer stated that with specific consideration for entire vehicle impacts (cost effective and timely evaluation of advanced components and configurations considering added weight, packaging, and complexity of technologies, reduced after-treatment efficiency at low temperatures and integration of interdependent technologies).

Reviewer 5:

The reviewer stated that the path to 55% BTE goal was not convincing. The reviewer questioned how partially premixed combustion (PPC) could just contribute so much for 55% BTE goal. The reviewer commented that for this type of combustion analysis, it could only show indicated thermal efficiency and that HC would be a main issue for this type of concept. The reviewer stated that Slide 8 needed more description and explanation of how 55% BTE was reached. The reviewer indicated that downsizing the engine from 13L to 11L would be challenging to raise the BTE from the current 48% to 50%.

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 very good progress, and an honest presentation of where the challenges were. The reviewer commented that 48% BTE on a generation one system was impressive and led one to believe that the project would be able to achieve the 50% target.

Reviewer 2:

The reviewer stated that the results to date supported the pathway to the targets.

Reviewer 3:

The reviewer noted that getting all those rigs up and running in parallel was a major advance and progress seemed ahead of schedule on 50% BTE. The reviewer stated that downsizing was unique and impressive. The reviewer stated that 48% BTE was being installed to keep vehicle program moving and that next year was key for the project.

Reviewer 4:

The reviewer indicated excellent results in getting the technologies to the vehicle fast. The reviewer recounted that testing was completed for intermediate (48% BTE) powertrain in the chassis, and the 50% BTE powertrain had three engines running and six component stands, maturing technologies in parallel.

Reviewer 5:

The reviewer indicated it was not clear how 48% BTE was achieved. The reviewer pointed out that the figure in Slide 10 had not been updated. The reviewer criticized that specifically, it was not clear how WHR was contributing to the overall BTE improvement, which was the key to the final goals. The reviewer stated that Slide 11 was confused, since many vehicle related technologies were added into the engine program, such as axle and dual clutch transmission.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated very good collaboration.

Reviewer 2:

The reviewer noted collaboration with a wide range of suppliers, universities, and etc.

Reviewer 3:

The reviewer noted impressive collaboration, but much of it seemed internal. The reviewer stated that modeling support was critical from partners.

Reviewer 4:

The reviewer stated leveraging internal capabilities, universities, and suppliers as needed to complete the project’s goals.

Reviewer 5:

The reviewer noted that many partners were involved, which was shown in Slide 17. However, it was puzzling why three universities were involved 55% BTE simulations, which could not be cost effective in terms of spending. The reviewer commented that at the same time, Volvo's funding level from DOE was much smaller than its competitors.

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

Reviewer 1:
The reviewer indicated that the statement that the project is developing different diesel engine architecture to reach 50% BTE without after-treatment is intriguing. The reviewer indicated looking forward to seeing the future reports.

Reviewer 2:
The reviewer suggested continuing with the solid work plan and results.

Reviewer 3:
The reviewer stated that progress to 50% BTE was coming through the long term 55% BTE pathway. This person highlighted the impressive long term perspective. The reviewer further indicated that the team had a high probability of achieving the 50% BTE goals.

Reviewer 4:
The reviewer recounted evaluating alternative combustion cycles through modeling/CFD and single cylinder testing.

Reviewer 5:
The reviewer indicated that 2% BTE more from the current status would be challenging and that the program did not provide a clear path to reach that goal.

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

Reviewer 1:
The reviewer noted high FE for petroleum reduction.

Reviewer 2:
The reviewer noted that technologies developed to meet 50% BTE goal and 55% BTE stretch goal when implemented on a Class 8 truck could significantly reduce petroleum use.

Reviewer 3:
The reviewer noted that focusing on BTE improvement supported the overall DOE objectives of petroleum displacement just like all of its competitors.

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

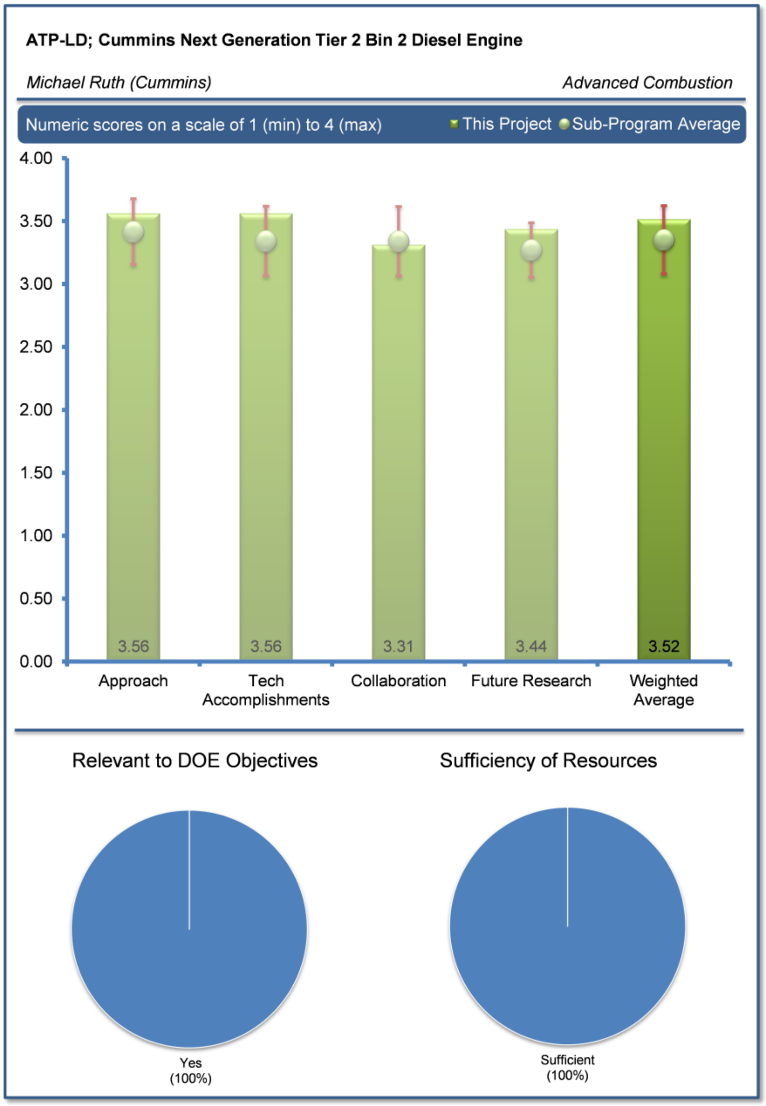
Reviewer 1:
The reviewer felt that this program was funded at a lower level than the others, so the project’s approach to concentrate more on technologies that could be brought to market more quickly, and not engage in highly fundamental concepts that are further from market introduction, made sense.

Reviewer 2:
The reviewer said the resources seemed to be appropriate for the large effort in this program.

Reviewer 3:
The reviewer stated that the project was only about halfway through the program with impressive progress given the resources. The reviewer indicated no resource issues within this project scope and much commitment demonstrated outside of public funding.

Reviewer 4:
The reviewer criticized if the funding was adequate compared to its competitors with the same performance goal, since the funding level was much less than others.

ATP-LD; Cummins Next Generation Tier 2 Bin 2 Diesel Engine: Michael Ruth (Cummins) - ace061



Reviewer Sample Size

A total of eight reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted very thorough development and impressive work.

Reviewer 2:

The reviewer stated that Cummins aims to achieve a 40% fuel economy improvement in a half-ton pickup truck. The reviewer indicated that Cummins has designed and developed a new diesel engine that yields very high engine efficiency while emitting almost Tier 2 Bin 2 emissions. The reviewer noted an excellent engineering approach that combines the benefits from engine optimization with that from after-treatment was followed.

Reviewer 3:

The reviewer noted a very solid program plan with solid assumptions and great results.

Reviewer 4:

The reviewer noted an excellent approach starting with an aluminum-based concept taken from gasoline experience. The reviewer stated nice fundamental design. The reviewer noted that after-treatment was cutting edge in all aspects, which was needed to achieve Tier 3 and important in a government-financed project. The reviewer stated that everyone could learn if more details were provided.

Reviewer 5:

The reviewer noted maintaining weight neutral and meeting performance/F.E. CAFE goals. The reviewer listed using aluminum in a diesel, aftertreatment, CSC, future allowance for cam phasers, and balance shafts.

Reviewer 6:

The reviewer noted an excellent approach to designing a downsized aluminum diesel engine with enhanced emission system (Low pressure EGR, CSC TM series catalyst for NO_x and HC, NH_3 gas system) to replace a state of the art aluminum V8 as it addressed identified barriers (2015 GHG requirements 28 MPG CAFE in a half - ton pickup truck, low emission – Tier 2 Bin 2, cost effective solution) as well as significant clear and appropriate metrics challenges (net zero weight, cost effective production, viable durable design which could meet tailpipe emission goals with a 40% fuel economy improvement over current gasoline V8). The reviewer stated that the engine design also considered future state with capability for variable valve train which may be an alternate solution for cold start emissions and provide further economy.

Reviewer 7:

The reviewer stated that this project addressed barriers to entry of fuel efficiency vehicles into the marketplace and particularly addressed those barriers as related to larger vehicles (pickup trucks, sport utility vehicles [SUVs], vans, and etc.). The reviewer noted that the approach entailed a clean diesel combustion engine design as well as emission control for clean diesel engines; both of these areas were relevant barriers that needed to be addressed. The reviewer stated that cost was part of the barrier as well and was being addressed.

Reviewer 8:

The reviewer stated that this work took a systematic approach toward the goals which were fairly aggressive. The reviewer noted that efforts were excellent in integrating latest technologies in engine design, manufacturing, combustion strategy (LD EGR) and after-treatment (low temperature catalyst to reduce HC and CO during cold start). The reviewer noted that the main concern this reviewer had was that gaseous NH_3 seemed to be a major enabler for the approach to meet the NO_x target. The reviewer stated there were issues with onboard vehicle storage, cost as well as refill infrastructure which needed to be adequately addressed. The reviewer stated that the second concern was the robustness/durability of the concept which has yet to be demonstrated.

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 outstanding work. The reviewer lauded that meeting the weight neutral target was a great accomplishment.

Reviewer 2:

The reviewer stated following an optimal combination of advanced engine technologies with that of advanced after-treatment, Cummins has demonstrated a performance with 40% improvement in efficiency, but emissions were a tad bit short of Tier 2 Bin 2 levels. The reviewer added, moreover the project's technology package also appeared to be cost-competitive with the existing engine.

Reviewer 3:

The reviewer stated that all targets (even the aggressive ones) seemed to have been met.

Reviewer 4:

The reviewer stated that this report was very general but this was not surprising given the new engine design and the need to get it up and running. The reviewer stated that the gains in the CSC system were impressive as was the increased HC efficiency and the freedom this allowed in engine calibration. SCRF advancement was also impressive.

Reviewer 5:

The reviewer stated that the weight goal was achieved with extensive aluminum usage. The reviewer indicated that catalyst results were not with the Cummins engine and asked what engine, Slide 14. The reviewer stated that emissions targets were very close to Tier 2 Bin 2 vehicle. The reviewer stated catalyst technology and questioned if it would be ready for the targeted cafe and emissions targets.

Reviewer 6:

The reviewer noted excellent accomplishments as virtually all metrics and barriers had been met on development engines/vehicle with prototype hardware including weight neutral goal through engine weight reduction of 152 lbs. which reallocated to added diesel exhaust (with catalysts), reductant and delivery system, cooling circuit for cooled EGR, achieving T2B2 engine out targets approximately 0.37 g/mi NO_x and 0.33 NMOG on test cell and approaching with vehicle results, achieving engine cost effective solution with 15-30% change in engine cost and 40% fuel economy improvement. The reviewer stated that the costs of vehicle system integration (cooling system) and aftertreatement (CSC) (multi-dosing locations and multiple components) were significant cost increases, and understood to be 2-5 times base technology. The reviewer suggested mitigating some of these costs and mitigating system complexity risk were likely required for commercial application and an outstanding rating. The reviewer noted that CSC catalyst technology durability demonstrations were also needed for production solution and an outstanding rating. NO_x passive NO_x adsorber (PNA) technology has not historically been durable throughout life use and therefore received limited production application. Complex systems such as CSC, with multiple dosing locations for example, could produce unexpected durability concerns, warranty issues. The reviewer noted good vision as engine design also considered future state with capability for variable valve train.

Reviewer 7:

The reviewer stated that the project was on track and good progress being made with significant improvements in emission control system noted.

Reviewer 8:

The reviewer stated that good progress had been made against the milestones. The reviewer stated that a Tier 2 Bin 5 vehicle had been demonstrated with FE above target and Tier 2 Bin 2 after-treatment technology had been made into scale for actual engine use. The reviewer noted that the performance of the catalyst was very promising. It was reassuring to hear the PI stated that the internal FE goal was higher than the DOE program target.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated a strong collaboration with the relevant stakeholders.

Reviewer 2:

The reviewer noted that Cummins had partnered with Nissan for LD truck integration and with Johnson Matthey for after- treatment development. The reviewer indicated that on both fronts, there were fruitful collaborations that have progressed; however, the task of variable valve engine testing at Purdue University was not well integrated with the rest of the program.

Reviewer 3:

The reviewer observed very good collaboration with a catalyst supplier and an OEM vehicle customer. The reviewer stated that outside this program, Cummins had great collaboration with national laboratories and others.

Reviewer 4:

The reviewer stated that the important parties were there; engine, vehicle, and emissions. The reviewer stated that the Cummins-JM collaboration was obviously close, but it was not clear how Nissan was contributing. However, at this stage, the powertrain development was key to the project. The reviewer stated that in the end, this was government funding to Cummins to develop an engine with one significant subcontractor and that subcontractor would give it their best to satisfy the customer.

Reviewer 5:

The reviewer noted JM catalyst and attributed modeling and camless engine to Purdue University.

Reviewer 6:

The reviewer noted excellent collaboration with OEM, engine manufacturer, and universities with a clear path to production in mind.

Reviewer 7:

The reviewer indicated good collaboration with Johnson Matthey and Purdue University, also a partner on the project.

Reviewer 8:

The reviewer noted good collaboration with partners and subcontractors, especially Johnson Matthey. The reviewer indicated that work with Nissan on vehicle integration and NVH showed good cooperation. Work with Purdue was a good example of applying knowledge gained from different research on the existing hardware. The reviewer stated that the improvement, if any, would be an added bonus.

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

Reviewer 1:
The reviewer stated that Cummins planned to complete a Tier 2 Bin 2 vehicle demonstration as a part of future work.

Reviewer 2:
The reviewer observed every reason to expect successful results and demonstration.

Reviewer 3:
The reviewer stated wrap-up with vehicle testing and demonstrating the whole package. The timeline appeared tight but doable. The reviewer agreed that it was important to benchmark this vehicle to others in the same weight class in Europe, although emissions were an order of magnitude different, a valid compare and contrast would help everyone evaluate the effectiveness of this kind of program.

Reviewer 4:
The reviewer indicated an excellent plan for future work. Emphasis on variable valve actuation (VVA) and calibration efforts to reduce cold start after-treatment requirements and cost were very good priorities for production solution. VVA performance likely also can be leveraged in other regions beyond cold start. The reviewer stated that JMI focus on cost reduction, durability, and simplification of after-treatment are high priority. The reviewer stated a high expectation for demonstration vehicle hitting all targets.

Reviewer 5:
The reviewer saw a good path forward for the project.

Reviewer 6:
The reviewer stated that the project was on the right path. The reviewer noted that the proposed future research was quite logical given the accomplishment so far. Given the new system design and new technology integration, especially with heavy usage of aluminum, the robustness of the concept was a concern. The reviewer stated that it was sensible to conduct some engine life test in parallel with vehicle development.

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

Reviewer 1:
The reviewer indicated that the project intended to develop an engine for light-duty trucks with an improved fuel efficiency of 40%. Thereby it met the overall goal of DOE to reduce our energy consumption.

Reviewer 2:
The reviewer noted a big FE improvement to meet DOE petroleum reduction goals.

Reviewer 3:
The reviewer stated that LD diesel in the pick-up sector would help drop fuel consumption (FC). This sector is now high percentage of diesel due to FC and torque. The reviewer stated getting these to Tier 3 was a real challenge, and critical.

Reviewer 4:
The reviewer stated that yes, 4a 0% fuel economy improvement while meeting Tier 2 Bin 2 emissions on pickup application were critical to petroleum reduction as large percentage of U.S. market sales are pickup trucks.

Reviewer 5:
The reviewer stated that this project directly supported the goal for petroleum displacement. Market penetration of clean diesels could lower petroleum consumption. Many citizens were highly opposed to purchasing smaller vehicles; the demonstration vehicle size for this project was relevant to many customers in the US. The reviewer stated thus, this project was an important approach for market

penetration in the pickup/SUV/van sector where important fuel economy gains must be made. The reviewer concluded that the project addressed emissions as well which was critical to the sustainability of this approach and an important part of the DOE objectives.

Reviewer 6:

The reviewer stated that if the vehicle could meet the 2015 GHG target, it could provide substantial savings in petroleum consumptions, thus supporting the overall DOE objective.

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

Reviewer 1:

The reviewer noted that the team appeared to leverage the resources at Cummins, JMI, and Nissan adequately.

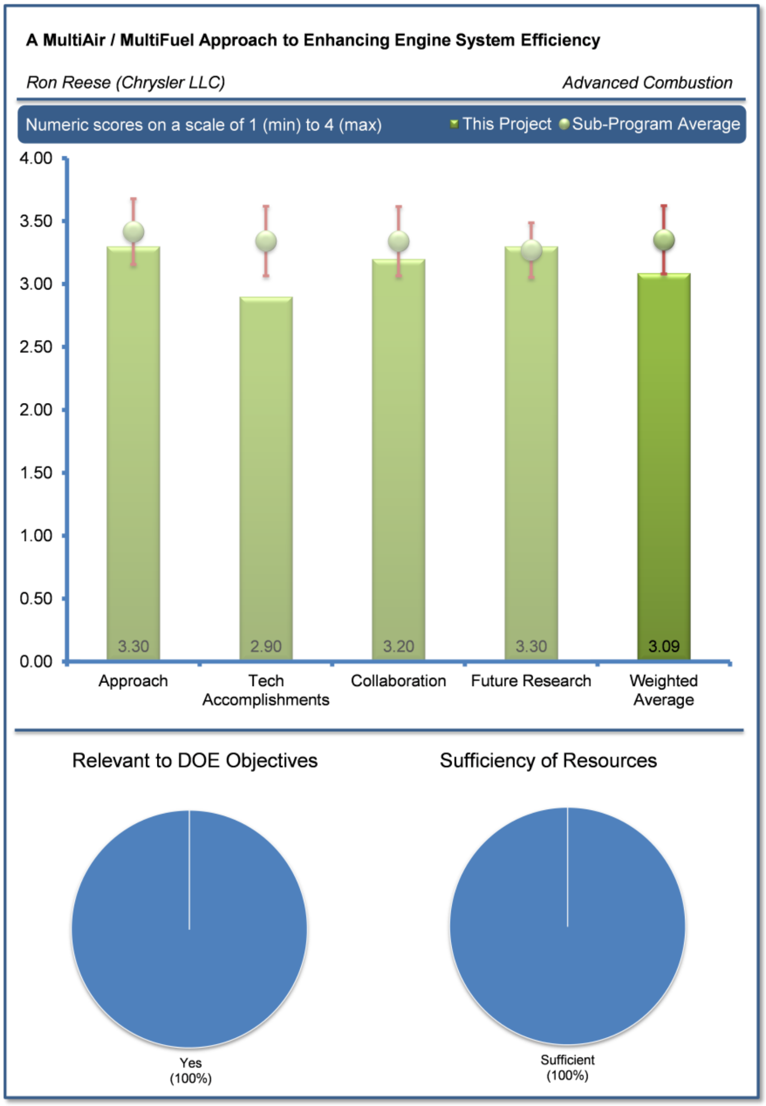
Reviewer 2:

The reviewer stated that the funding seemed appropriate.

Reviewer 3:

The reviewer indicated that the funding appeared to be sufficient for the remaining tasks.

A MultiAir / MultiFuel Approach to Enhancing Engine System Efficiency: Ron Reese (Chrysler LLC) - ace062



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer observed a strong approach. The reviewer said it was good to see such a system run through the design/development process to translate lab research closer to the real world.

Reviewer 2:

The reviewer noted a good approach and technology menu to demonstrate a 25% improvement in combined city FTP and highway fuel economy relative to port fuel-injected 4.0L V6, 6-speed while maintaining comparable vehicle performance and meeting Tier 2, Bin 2 tailpipe emissions. The reviewer stated transmission to nine speeds from six, a high compression ratio, downsized boosted DI, high energy ignition system, PWM alternator, WHR system, low lockup speed crank device all are viable technologies. The reviewer noted value proposition for some technologies on the menu presented significant production challenges. Identifying these challenges and possible mitigation strategies (even if outside the scope of the project) would be highly productive. The reviewer noted a great approach of engine head design to facilitate future dual fuel gasoline/diesel work, however, the additional scope outside the main focus of fuel economy activity path diluted the focus on the mainstream goals of the project.

Reviewer 3:

The reviewer stated that the Chrysler team was developing, a purpose built HEDGE engine. The 3-valve, 3-plug, and 2-stage boosted architecture appeared to be integral to their approach and good progress had been made in these topics. The reviewer noted that the lack of enrichment anywhere in the operating map was a notable achievement as was the smart charging and turbo bypass. It would have been helpful to have heard more details about fuel switching strategies (e.g., how does the engine transition from gasoline to ethanol and what are the challenges with respect to engine controls). The reviewer stated also, given the challenges with dual fuel strategies that it would have been helpful to understand what benefits would be realized from the project if the ethanol fuel piece were to be abandoned. The reviewer questioned in other words, if the project were to build a gasoline only version of this engine what economy advantages obtained would be.

Reviewer 4:

The reviewer stated that this project addresses improved fuel economy for van size classes in the light-duty market. This class is important to address, as a large segment of the U.S. fleet is composed of such vehicles. The reviewer indicated it is also very relevant to Chrysler's business health; so, it is good that the technical work and potential business strengthening outcomes coincide.

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 there were lots of great results so far.

Reviewer 2:

The reviewer observed goals reported to be achieved and providing data to support which was very good. The project reported to meet 25% fuel economy goal, comparable engine performance. The reviewer stated that concern areas were lack of any emission results, value proposition for fuel and technology to production, and possibly a weight comparison to insure that total vehicle weight was downsized. The reviewer criticized that emissions from dynamometer or chassis tests should be presented and it was possible to project FTP with dynamometer test. The reviewer felt that it was unfortunate that to meet engine performance targets required E85 fuel. The value proposition was not clear for many technologies. Some technologies such as PWM alternators had been applied on vehicle since the 1990s to improve cycle fuel economy but in many production cases the value proposition $/FE had been too high for PWM alternators to be used. The reviewer noted that it would be helpful to understand the cost versus benefit value proposition for large powertrain changes relative to unit cost, manufacturing implementation, and risk. Specifically nine speed transmission and crankshaft dampener were effective in the R&D project for the 6% fuel economy benefit, but likely had very high cost/risk. The reviewer stated that reporting relative cost to baseline or relative to other options would improve project value. Other options such as electric assist, start stop 48 volt (or belt-driven starter-generator (BSG) considered in project) electrification options seemed to be in the same or lower value proposition range with a pathway toward vehicle electrification but it was not revealed. The reviewer noted that the cold mass of turbos presenting concerns for cold start light off emissions was well known by the emission development community and that turbo bypass valves have historically had durability concerns and/or cost issues limiting their use to demonstration cases. The reviewer stated that it would benefit the rating to understand which elements of the technology set in the project could be effectively implemented in a near-term successful mass produced vehicle. (E85, 9-speed transmission, active crank damper, twin turbo with a bypass valve, cooled EGR, high energy 3-plug ignition, and WHR). The reviewer indicated excellent work to optimize thermal management system for fast warm-up and concur with challenge of after-treatment solutions for low exhaust temperatures.

Reviewer 3:

The reviewer stated that the project apparently had some setbacks in the program with regards to hardware failures but seemed to be recovering. Progress towards demonstrating power density, emissions and fuel economy appeared to be adequate. The reviewer noted that the work on the turbo bypass and manifold design was good as was the overall focus on thermal management. More discussions on the three plug/three valve architecture would have been helpful as these seemed to be a significant enabler yet little was discussed in detail.

Reviewer 4:

The reviewer stated that the project was making good progress. There was some delay for the final vehicle evaluation, but was understandable due to the intensive work requirements to complete this task. The reviewer stated that there was great progress demonstrated on the design and implementation to improve the exhaust warm-up and catalyst light-off during cold start. Although good progress was made on combustion and dual fuel research, it was unclear how the different combustion approaches would affect the final vehicle fuel economy. The reviewer asked if the dual fuel approach would be integrated into the vehicle.

Reviewer 5:

The reviewer stated that Chrysler had adapted to hardships to meet goals and that achieving a 24% fuel economy improvement was great. Achieving a 25% improvement was marginally better but allowed for checking a box. The reviewer stated that perhaps milestones needed not to have such sharp lines that need to be crossed for success.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated good interaction with a range of suppliers and ANL.

Reviewer 2:

The reviewer noted a good list of partners, however, other than the efforts of Ohio State University (OSU) to optimize the PWM alternator and the warm-up strategy it was not clear how the partners contributed directly to the FE technology menu and overall results.

Reviewer 3:

The reviewer felt that it was difficult to judge from the presentation what value the individual partners brought to the project. One could infer that Bosch and Delphi supplied hardware and that OSU supplied the VES and VEM but it was not clear how the project team worked with the Chrysler team in any way other than suppliers. The reviewer felt that it was not at all clear how the CFD work was supporting combustion development. The work seemed tangential to the project.

Reviewer 4:

The reviewer stated that the collaboration was excellent; collaborations existed with a national laboratory, a university, and other industry (suppliers). The reviewer affirmed that the roles and contributions were well balanced for all.

Reviewer 5:

The reviewer noted that there was a lot of collaboration here, and that the reviewer was giving a good score for this criterion. However, that DOE puts too much emphasis on collaboration (across all projects at AMR). The reviewer stated collaboration was not necessary in every program. Chrysler or any OEM is capable of launching a downsized engine in a vehicle without extensive collaboration. (Many other projects, similarly, can be executed successfully without extensive collaboration).

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

Reviewer 1:

The reviewer stated that the program is nearing the end. The reviewer hoped to see this work continue.

Reviewer 2:

The reviewer noted a good approach to zero in on the goals of 25% with a current target basket of technologies, but to comment on others not selected or needed (BSG). The reviewer pointed out a need to provide emission results. The reviewer indicated that the project scope initially encompassed a large basket of technologies which had been narrowed to the select few, yet had included insights into enabling technologies such as high energy ignition, and 9-speed transmissions, and possibly the novel crank damper system. The reviewer observed that the dual fuel diesel gasoline combustion is at an R&D stage and not mature for vehicle demonstration, so it was good to exclude from the project at this point.

Reviewer 3:

The reviewer stated that the work was 98% complete. Not much left in the way of future work to report.

Reviewer 4:

The reviewer indicated that the project was nearing the end stage.

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

Reviewer 1:

The reviewer observed a large FE improvement.

Reviewer 2:

The reviewer stated that demonstrating 25% fuel economy improvement in a mid-sized sedan with no or limited degradation in vehicle level metrics while also meeting Tier 2 Bin 2 emissions on FTP-75 cycle and a possible path to production for some technologies have the possibility to effect petroleum use reduction in the marketplace in the future.

Reviewer 3:

The reviewer noted that highly dilute, downsized and boosted engines with 9-speed transmissions were likely a prime path going forward and would be integral to meeting future cafe regulations. This work appeared to be accelerating Chrysler down this necessary path.

Reviewer 4:

The reviewer stated that this project could impact fuel economy for the van/SUV market sector which was an important sector for the U.S. market. According to this reviewer, many consumers greatly prefer the larger vehicles in this market; addressing fuel economy for this market is critical to achieving petroleum reduction in the United States.

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

Reviewer 1:

The reviewer thought it seemed to have been sufficient for a large set of efforts.

Reviewer 2:

The reviewer stated that with many divergent paths, the funding was sufficient. Main path vehicle funding was perhaps excessive considering the current vehicle level results. However, because the activities to support other technology developments (not directly applied to the vehicle) enabled other valuable work, this balanced the excessive to sufficient. The reviewer indicated that dual fuel heads, ION sense controls for combustion phasing, BSG, and WHR, which were now not on the main vehicle path, were worthy of R&D and were advanced through funding for this effort.

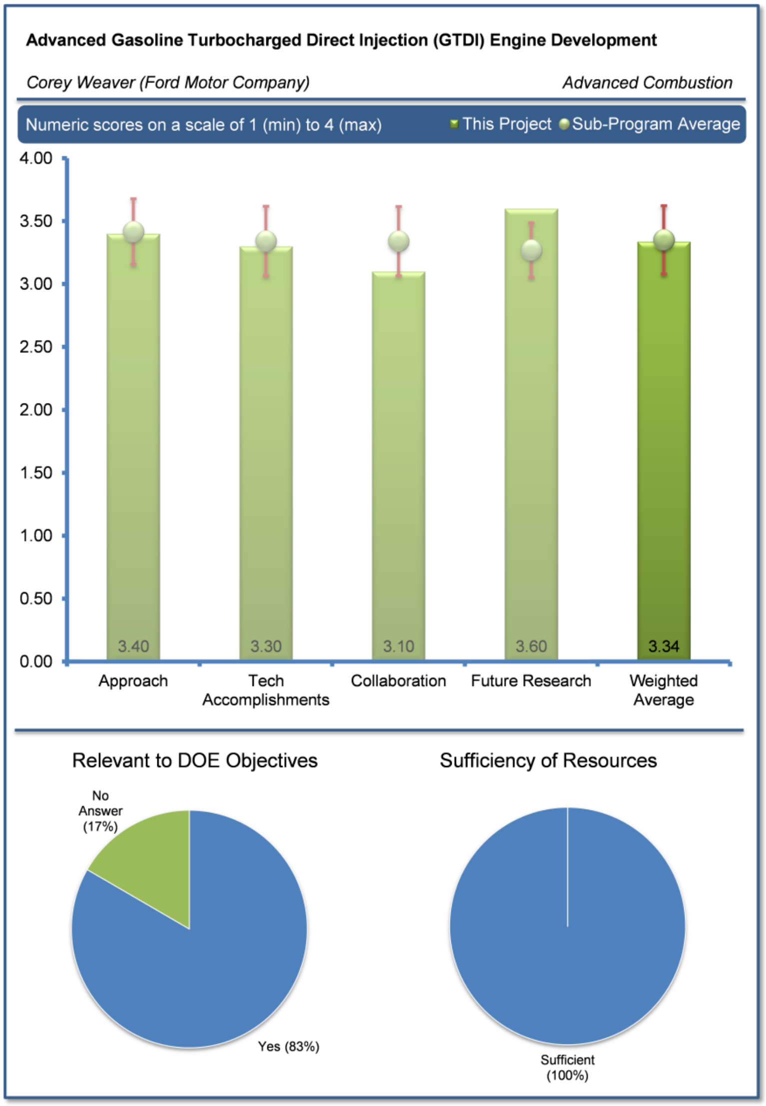
Reviewer 3:

The reviewer stated again, that the project was wrapping up so the question of resources was a bit moot. However, the project did appear to be funded at an appropriate level to make good progress.

Reviewer 4:

The reviewer noted the largest budget of all projects reviewed.

Advanced Gasoline Turbocharged Direct Injection (GTDI) Engine Development: Corey Weaver (Ford Motor Company) - ace065



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted a clearly solid approach launching off Ford's gasoline turbocharged direct injection (GTDI) expertise and pushing it forward in a strong manner.

Reviewer 2:

The reviewer stated assumptions.

Reviewer 3:

The reviewer noted outstanding technology to production development focus to productively implement high percentage of efficiency technology options considered to meet project goals (demonstrate 25% fuel economy improvement in a mid-sized sedan using a downsized, advanced GTDI engine with no or limited degradation in vehicle level metrics while also meeting Tier 3 SULEV30 emissions on FTP-75 cycle). The reviewer stated that effective value proposition analysis, modeling and vetting on the front-end of project and clear integration into the production pathway were outstanding to achieve R&D goals and resulted in timely efficiency gains in the marketplace.

Reviewer 4:

The reviewer stated that the approach was highly conservative and appeared to have a good chance of meeting the programmatic goals. However, very little technical detail was shared and the chance of success could only be gauged by the presenter's comments. The reviewer indicated that most slides simply contained pictures of the car, engine or a CAD drawing with bulleted statements lacking detail. The work on micro stratified charge appeared to have been inserted to show efforts towards advanced concepts but did not tie into the main vehicle demonstration effort in a meaningful way.

Reviewer 5:

The reviewer noted that this project sought to increase fuel efficiency for light-duty vehicles. The Ford EcoBoost is the basis for the vehicle research/demo. The reviewer stated it was nice and appreciated seeing that the team was pursing lean engine operation as part of the project after that effort was seemingly dropped previously based on the previous year AMR. Although extremely challenging, the lean approach does offer potential for greater fuel economy gains and as such is an excellent pursuit for a government-funded project. The reviewer indicated that the engine advancements shown were notable and good for lean combustion.

Reviewer 6:

The reviewer stated that the project was resulting in a nice demonstration, and had achieved all fuel economy and emissions goals. Ford is very capable and has done a good job; however, a more extreme downsizing would have been more relevant. The reviewer noted that Ford has a 1.0 liter EcoBoost in the market today, and a 2.0 liter engine available in the target vehicle on the market today. The reviewer stated that many of the engine improvements are simple near-term off-the-shelf technologies.

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

Reviewer 1:

The reviewer noted a lot of good data meeting objectives and illustrating a solid understanding of the technical issues. The reviewer suggested that it would be nice to know more about how the optimization of so many engineering variables was done. The reviewer inquired about how one would know when at the right, optimal place.

Reviewer 2:

The reviewer stated optimization, engine dynamometer testing. The reviewer questioned if there were any modeling that the extensive data was verifying. The reviewer said yes with single cylinder testing. The reviewer listed that the vehicle build engine would be stoichiometric, not lean combustion, fuel premium E10.

Reviewer 3:

The reviewer stated that targets were met with productive technology in dynamometer engine using standard test points to predict performance and emissions. The reviewer noted that the clear production pathway in vehicle development process demonstrated convincing results beyond the reported data.

Reviewer 4:

The reviewer stated that basic engineering work appeared to be progressing well but little had been reported in any of the ground breaking technologies other than some results with twin spark timing and some initial results on the micro stratified work. The reviewer added that the progress towards the vehicle demonstrations looked to be on track.

Reviewer 5:

The reviewer noted good progress on the GTDI engine efficiency and the system level engineering on the project. This reviewer also reported that low pressure EGR benefits were displayed. The reviewer indicated good progress on ignition both for the base engine case and the lean operation (collaboration enhanced ignition progress).

Reviewer 6:

The reviewer stated that despite the somewhat routine approach, the project has been executed very well and achieved all targets.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer indicated good interaction with Michigan Technological University (MTU). The reviewer added that, undoubtedly, there were many collaborations with component and system suppliers that were not visible in this presentation.

Reviewer 2:

The reviewer highlighted MTU papers and PhD. The reviewer added that the two strike spark dwell between strikes must be optimized, and also noted multiple flame kernels.

Reviewer 3:

The reviewer noted excellent results so expected that supplier base has supported Ford in the effort but no details specified. Interesting ignition results from MTU on multi-strike ignition are valuable. The reviewer stated that for outstanding, additional collaboration for methodologies to move the industry bar up.

Reviewer 4:

The reviewer stated that the only partner mentioned is MTU. This person also described the work on spark discharge as interesting. Apparently, the relationship has added value to Ford as it was indicated that Ford is now directly funding the school. The reviewer felt this project could have stood to have more partners involved from the beginning. The MTU role, while good, was fairly small with respect to the overall effort.

Reviewer 5:

The reviewer stated that progress via collaboration with MTU was good, but that overall, there was not a great deal of collaboration with other entities on the project.

Reviewer 6:

The reviewer stated that DOE puts too much emphasis on collaboration (across all projects at AMR). It is not necessary in every program. Ford is capable of launching a downsized engine in a vehicle without collaboration (many other projects, similarly, can be executed successfully without extensive collaboration).

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

Reviewer 1:

The reviewer stated there is every reason to expect a successful completion of the development and demonstration, with a high likelihood of much of this technology leading to production improvements.

Reviewer 2:

The reviewer stated that continuing parallel pathway with productive technology stoichiometric engine vehicle development and dynamometer based lean development with focus on combustion and after-treatment are excellent. The reviewer stated it was excellent that final vehicle demonstration performance of 25% FE improvement and SULEV emissions efforts appeared to be on production path for the possibility of real world benefit in the short term beyond the R&D project.

Reviewer 3:

The reviewer stated that this project had always put emphasis on hardware build and testing. The team seemed to have a solid plan toward getting to final vehicle calibration and test. The reviewer noted that the project appeared to have a good chance of success toward final goals.

Reviewer 4:

The reviewer stated that the project was generally on track. The future plans were suitable.

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

Reviewer 1:

The reviewer observed that the project directly addresses reduced petroleum objectives.

Reviewer 2:

The reviewer stated that demonstrating 25% fuel economy improvement in a mid-sized sedan with no or limited degradation in vehicle level metrics while also meeting Tier 3 SULEV30 emissions on FTP-75 cycle and the clear path to production for many technologies have a high probability to effect real petroleum use reduction in the marketplace in the near term.

Reviewer 3:

The reviewer stated that projects such as these which help the U.S. auto industry accelerate its portfolio to meet future CAFE standards are, by design, focused on improved fuel efficiency which then directly relates to the DOE objective of petroleum displacement.

Reviewer 4:

The reviewer indicated this project directly involved integrating fuel efficiency improvements into vehicles suitable for market introduction and thus was directly in support of the DOE goal of petroleum displacement (reduction). The reviewer added that it was good for DOE to have projects like this that translate new technology to market ready products.

Reviewer 5:

The reviewer stated that improved fuel economy through engine and vehicle technology advancement was very relevant, although it seemed that the technologies demonstrated were all in production or ready for production. The reviewer was glad to see some effort toward lean burn, even if it was not implemented in the final demonstration. The reviewer continued to say that it would be nice to see the work published.

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 there seemed to be sufficient funding.

Reviewer 2:

The reviewer stated that the given the amount of hardware developed and tested, it would appear the project was adequately funded and staffed. No resource issues were noted.

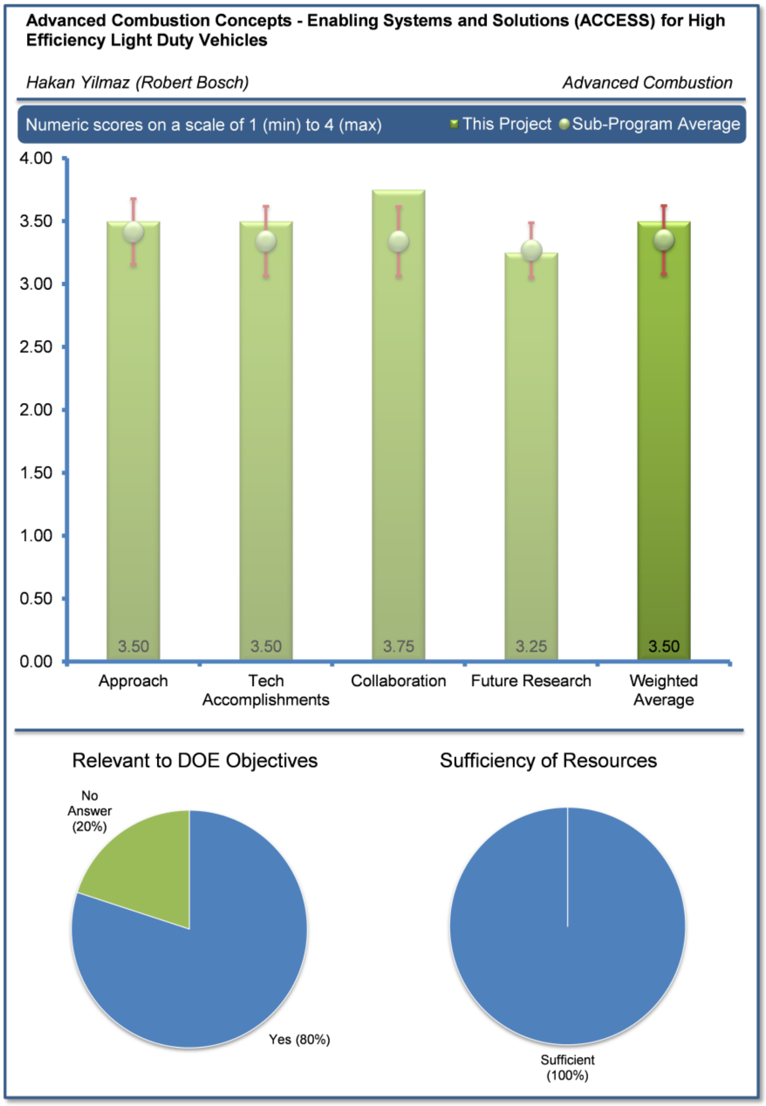
Reviewer 3:

The reviewer stated that the resources are sufficient, but the balance of resource allocation could be better. It was good to see the project devote more resources to the higher risk research of the lean engine approach. The reviewer indicated further resource allocation in that direction (higher risk approach) would be nice.

Reviewer 4:

The reviewer stated that the budget was large compared to most of the AMR projects, but that it was one of the smaller OEM light-duty vehicle demonstration projects.

Advanced Combustion Concepts - Enabling Systems and Solutions (ACCESS) for High Efficiency Light Duty Vehicles: Hakan Yilmaz (Robert Bosch) - ace066



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer indicated first that it was comforting to see a GDI baseline rather than a multi-point injection (MPI) baseline. Multimodal engines were also nice opportunities, and the project was using all, with the possible exception of lean SI. The reviewer stated that managing the controls would be critical and that the project was addressing this.

Reviewer 2:

The reviewer stated combustion controls were integrated into the engine control unit (ECU) including a combustion pressure sensor, combining several technologies with improved controls.

Reviewer 3:

The reviewer indicated a good balance of solid engineering approaches with advanced research technologies. Like most others, this team is looking at practical approaches like downsizing and start stop. The reviewer stated at the same time the team was investigating an interesting blend of combustion modes, including a novel spark assisted compression ignition concept. Overall the project was doing a good job in balancing these activities.

Reviewer 4:

The reviewer stated that this project addressed very challenging goals of implementing HCCI and SACI together with downsized GDTI engine technology. Such goals are aggressive and very appropriate approaches for government funded research in the VTO program. The reviewer noted that the unique structure of the collaborations in this project was also quite impressive and was a critical part of the approach.

Reviewer 5:

The reviewer indicated that the project leadership made appropriate down selects in this short program to ensure that both fuel economy and emissions targets were met. The reviewer appreciated that advanced combustion was maintained in the final demonstration. The additional gains available with more advanced aftertreatment were clearly spelled out and will contribute toward future research and development programs.

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 stated that it was quite the achievement to develop and control such a complex multi-mode strategy and achieve SULEV. The results to date as expressed verbally appeared to be able to meet the goals (24 vs. 25% FE improvement). The reviewer stated that the oxygen storage issue in transitions was quite interesting.

Reviewer 2:

The reviewer listed HCCI, SOCI, SI/EGR, Si, and SI/EGR. The reviewer stated that after-treatment becomes a challenge with the multi-mode combustion. The reviewer questioned controls and transitions. The reviewer stated high octane pump 98 RON with 10% ethanol.

Reviewer 3:

The reviewer stated that the team had done a good job in describing the technical approach, the challenges they were facing and their plan to address these challenges. The team appeared to be well managed and had a rational plan moving forward.

Reviewer 4:

The reviewer indicated that the project had made good progress getting to the vehicle stage. Excellent progress was made on the challenge of mode switching between conventional and advanced combustion modes and the corresponding effect on emission control devices.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer criticized that the project has too many players with something like 35 names mentioned over seven organizations. However, the bottom line is that the program shows a strong indication of being successful.

Reviewer 2:

The reviewer listed Stanford, Michigan, Chevron AVL, Emitec, USOEMx and asked what the feedback mechanism was.

Reviewer 3:

The reviewer indicated that a good blend of partners was indicated. It was valuable that the project had Emitec onboard for after-treatment development and AVL on board for combustion work. The reviewer stated that the project seemed to utilize the team members appropriately and in an integrated fashion.

Reviewer 4:

The reviewer noted outstanding collaboration across a broad range of partners. It would be interesting to know how much of the project resources were devoted to managing the multiple partners (versus R&D work) for the purpose of understanding the ideal balance between collaborating and independent R&D for projects.

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

Reviewer 1:

The reviewer stated that more refinement, mode extension, 50% more emissions reductions with cold start and lean NO_x challenges, all appeared to be the upside with plenty of margin to meet the project objectives.

Reviewer 2:

The reviewer stated higher compression ratio (CR), single cylinder.

Reviewer 3:

The reviewer indicated no issues or concerns were noted with regards to the future plans. The team is well positioned to complete the project deliverables as indicated in the presentation.

Reviewer 4:

The reviewer stated that the future direction was good, but there was some confusion regarding the future direction of the advanced combustion role in the project. It seemed that much had been learned, but it was not clear what the next steps were for the SACI/HCCI roles in the final vehicle.

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

Reviewer 1:

The reviewer associated the United States with gasoline. Mode switching is a way to optimize gasoline engine performance and certainly worthy of investigation. The reviewer emphasized that 25% FE improvement over GDI was a challenge and apparently within reach.

Reviewer 2:

The reviewer stated that this work was quite relevant. As noted above, this team was using a good blend of solid engineering and research. The reviewer indicated that the knowledge gained should certainly help the industry move forward to achieve the fuel economy challenges brought forth by CAFE regulations.

Reviewer 3:

The reviewer stated that petroleum displacement was enabled by the greater fuel economy of the vehicle being demonstrated in this project.

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

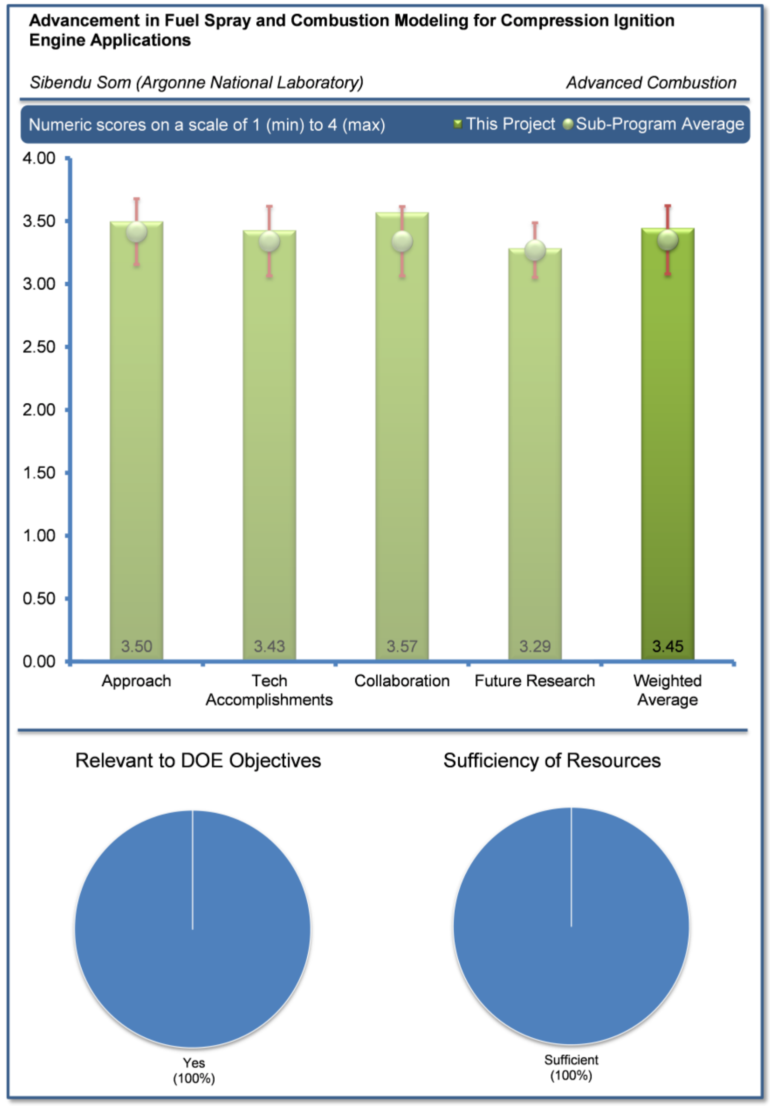
Reviewer 1:

The reviewer stated that the program was closing and funding seemed adequate to finish and meet the objectives.

Reviewer 2:

The reviewer noted that the presenters made no mention of shortfalls due to the budget. The activities seemed to be well staffed and progress was good, indicating that the resources were adequate.

Advancement in Fuel Spray and Combustion Modeling for Compression Ignition Engine Applications: Sibendu Som (Argonne National Laboratory) - ace075



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 stated that the work was unique in providing an analytical means of understanding variability in fuel injection systems, and the effects in near-field spray behavior.

Reviewer 2:

The reviewer noted that the approach of using high performance computing coupled with detailed chemistry combustion models, high fidelity LES based turbulence models, and 2-phase physics based fuel spray and nozzle flow, seemed reasonable.

Reviewer 3:

The reviewer stated that the projective approach is commendable, seeking to develop reliable engine modeling capability with fewer tuning constants. The sub-models are published in open literature and available to the industry through commercial software. The reviewer observed a simulation approach encompassed three prongs, spray and nozzle modeling, combustion modeling using detailed chemistry, and high performance computing.

Reviewer 4:

The reviewer stated that the PI was pushing the envelope on the capabilities of a current engineering CFD toolset by leveraging high-performance computing capabilities available at ANL. The reviewer indicated that the PI was able to push the upper limits on mesh refinement to demonstrate grid convergence with the goal to minimize model turning.

Reviewer 5:

The reviewer noted a solid approach to an interesting problem. The reviewer indicated a useful approach to generate understanding and ultimately industrially useful models.

Reviewer 6:

The reviewer noted excellent coupling of experimental and simulation work.

Reviewer 7:

The reviewer stated that the approach was sound in that a commercial code like Converge was being used as the platform to conduct simulations. The focus is more on developing reliable models of fuel spray and combustion kinetics by comparing to experimental data.

The reviewer stated that grid dependence is also being explored. The number of processors is being kept around 50 so it is within reach of OEM capabilities. The reviewer indicated that these important steps have to be extensively carried out before predictive simulation of engine combustion can be accomplished.

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

Reviewer 1:

The reviewer stated that the initial progress on injector wobble and the effects on spray is very insightful for efficiency, emissions performance and local mixture prep at SOC conditions. The progress toward understanding of computational overhead tradeoffs will also be useful going forward, as hardware advances.

Reviewer 2:

The reviewer noted good progress in meeting milestones. The reviewer added that there were interesting results on simulation of plume-to-plume variations due to needle wobble during needle transients. The reviewer indicated that in the near nozzle region, the EE model, LE model, and decoupled EE model, performed as well as the coupled EE model, but was three times less expensive.

Reviewer 3:

The reviewer recounted that the work performed includes nozzle and spray research. The project provided a thorough plume-to-plume variation owing to needle wobble effect. The reviewer emphasized that the work included needle transients focusing in the end-of-injection. The work is very good and one suggestion given here by the reviewer is that the project may be better served by documenting these effects with respect to the manufacturing tolerances of a typical injector. The reviewer stated that performance measures may be given with respect to overall flow variability. The reviewer added that the work covered the validation of the coupled Eulerian spray model, including its advantage over the Lagrangian approach. Finally, the work documented the multi-component diesel surrogate mechanism validation composed of n-dodecane and m-xylene.

Reviewer 4:

The reviewer observed noteworthy technical accomplishments in terms of simulating at sprays, flows, and combustion. The reviewer said the work was very relevant to industry and indicated by the CRADA agreements that are currently in place. The reviewer indicated that there had been discussion and debate in the industry over the accuracy of the cut-cell treatment at the domain boundaries. The reviewer encouraged this group to help the industry understand the accuracy of this approach. The reviewer questioned if this work was important as many engine CFD users were placing significant efforts into LES simulations. As the PI transitions from cluster to super-computing, the reviewer asked if the PI could comment on plans to improve code scalability.

Reviewer 5:

The reviewer noted good results and significant progress. The understanding of wobble and its effects, as well as the modeling of cavitation at edge on impact (EOI), are very useful.

Reviewer 6:

The reviewer stated that when experimental imaging revealed needle wobble, it was not clear how this would impact the spray. The reviewer lauded the great work in showing the variation in mass flow among the various nozzles as a function of needle wobble. The reviewer noted that the next step is to show the impacts on combustion.

Reviewer 7:

The reviewer stated that the computational results on plume-to-plume variation of sprays, as a result of needle wobble, was very interesting and exciting. The physics of the ingested gas in the sac at the end of injection is also very enlightening. The reviewer indicated that the work done on the various Eularian and Lagrangian approaches, the validation of reduced models for diesel surrogate fuel, and the diesel engine simulation performed are all very important steps of progress that have been made.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer noted an excellent collaboration, but that more diverse collaboration with industry, especially other fuel injection system manufacturers, would help to better guide future work.

Reviewer 2:
The reviewer said it looked like good collaboration with a few heavy duty engine industry partners (Cummins and Caterpillar), other national laboratories, and two universities and also through the ECN.

Reviewer 3:
The reviewer noted that the team was very complete, including OEM representation, a commercial software developer, and other national laboratories and universities. The team was also part of the Engine Combustion Network Organization.

Reviewer 4:
The reviewer stated that the PI had strong leveraging with the ECN, in-house measurements, and industry. The reviewer would have liked to understand the linkage between the applied chemistry solver and improvements being proposed by LLNL to the simulation work at ANL. The reviewer added that it seemed like there should be tighter linkage between the groups.

Reviewer 5:
The reviewer stated that participation in ECN the interaction with Convergent Science, along with the related CRADA work showed strong collaboration and movement of the knowledge gained into others' hands.

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

Reviewer 1:
The reviewer stated that future work should include the effect of biofuels on spray formation, as well as distillation curve effects on entrainment and mixing.

Reviewer 2:
The reviewer noted very good elucidation of plans for future work and seemed reasonable.

Reviewer 3:
The reviewer stated that the project outlined the future work. LES and Eulerian-Lagrangian model work is planned. The reviewer noted that the in-nozzle flow simulations with Cummins hardware would be particularly interesting.

Reviewer 4:
The reviewer stated that the current efforts have been mostly diesel-focused and that the group was encouraged to ramp-up the investigation of gasoline spray and combustion modeling.

Reviewer 5:
The reviewer noted excellent plans to continue and expand the work.

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

Reviewer 1:
The reviewer stated that the work provided a greater understanding into secondary effects that were important to achieving high efficiency with low engine-out emissions, with more robust controllability.

Reviewer 2:
The reviewer stated that improved models should lead to better engine design, leading to improved engine efficiencies and lower fuel consumption.

Reviewer 3:
The reviewer stated that the project promoted improved modeling tools that would help in the overall fuel efficiency roadmap.

Reviewer 4:
The reviewer affirmed that the proposed work and plan were very relevant to industry by demonstrating the capability and best practices of toolsets that were commercially available.

Reviewer 5:
The reviewer stated that spray was critical to both diesel and gasoline DI engines and combustion systems and therefore to the DOE mission.

Reviewer 6:
The reviewer stated that this project was extensively involved in the development and validation of computational capabilities that have a chance of being used in industry.

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

Reviewer 1:
The reviewer indicated that the resources were sufficient for the work undertaken.

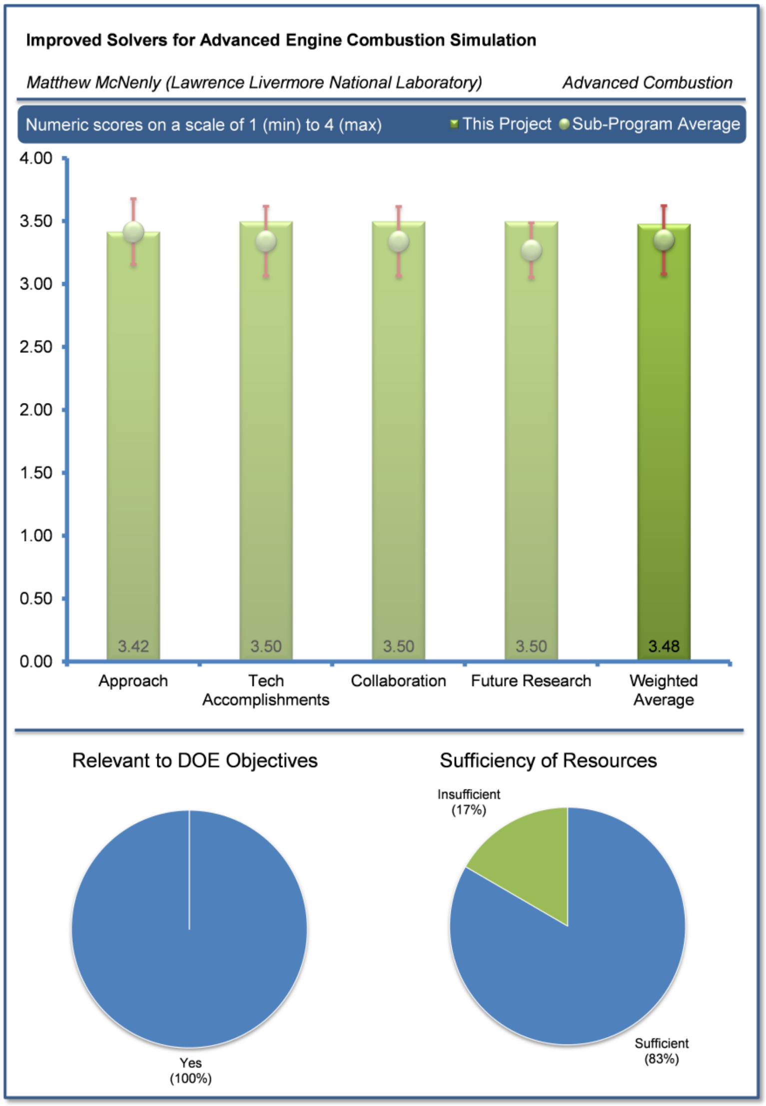
Reviewer 2:
This person stated that the resources seemed sufficient.

Reviewer 3:
Sufficient resources were observed by this reviewer.

Reviewer 4:
The reviewer stated that the investment seemed to be allocated to developing a good team of post-doctoral scholars.

Reviewer 5:
This reviewer noted that funding seemed to be appropriate for the effort required.

Improved Solvers for Advanced Engine Combustion Simulation: Matthew McNenly (Lawrence Livermore National Laboratory) - ace076



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer stated that the approaches of developing better algorithms, new compiling architecture, and improved physical models should enable the development of faster models with better predictive capabilities. According to the reviewer, the identification and resolution of model/simulation solver bottlenecks should help greatly.

Reviewer 2:

The reviewer stated that the group was leveraging expertise in advanced mathematics and GPUs to improve combustion solvers in engine CFD codes which traditionally have limited the industry from using highly detailed chemical kinetics schemes.

Reviewer 3:

The reviewer stated that the approach addressed challenges to using engine simulations for product development in industry.

Reviewer 4:

The reviewer noted that this project appeared linked to ace012 and thus had an inherent synergy. The continue attempt to validate solvers against as-realistic-as-possible engine relevant conditions is critical as linked to ace012. The reviewer recommended that the project team incorporate these types of benchmarks 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 toward DOE goals.

Reviewer 1:

The reviewer observed significant recent accomplishments, including completion of initial scaling analysis of chemistry and multi-species transport in CFD, and completion of multi-processor reaction rate sensitivity tool that reduces wait time from days to less than 1 hour.

Reviewer 2:

The reviewer stated that the PI had shown results improving both the speed-up combustion and improved the physical sub-models. The reviewer questioned what the pathway for industry was to have access to these solver routines. The reviewer questioned if it would be available as a user-defined function or if the industry would have to bear the burden of paying additional licensing cost.

Reviewer 3:

The reviewer said it was amazing that there was continued progress toward further speed up of the chemistry solver.

Reviewer 4:

The reviewer stated that the past year's work has shown a significant speed-up in computational speed for selected problems. To this reviewer, this was excellent progress to date, but the future work should focus on demonstrating continual speed-up on as realistic as possible engine type combustion problems.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the impression was that there are significant interactions with OEMs (Ford, GM, Bosch, Volvo, Cummins), the national laboratories and universities, and software developers.

Reviewer 2:

The reviewer said that it was good to see a nice mix of industry and academia partners.

Reviewer 3:

The reviewer stated that there is a strong linkage of industry and national laboratories with commercial software providing software improvements to help simulate advanced engine concepts. The PIs decided to invest resources in improving CONVERGE. The reviewer questioned if the work in the project could also assist in the development of the new KIVA code being developed at LANL. Tabulated chemistry approaches (such as flamelet generated manifold (FGM)) are an alternative method to running larger chemical mechanisms. The reviewer asked if the PIs had done a comparison (e.g., time, accuracy) of the current approach with tabulated chemistry formulations.

Reviewer 4:

The reviewer observed good collaboration with NVIDIA to improve the use of GPUs.

Reviewer 5:

The reviewer stated that this project was linked to work at another national laboratory and continued to have this type of strong partnership. The reviewer suggested that another partner that can bring metal engine type experimentation be considered for future work (validation).

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

Reviewer 1:

The reviewer stated that proposed plans should enable good continued progress in meeting the ultimate goals of this project.

Reviewer 2:

The reviewer expressed that the PIs propose to improve the species transport solver in the future. The reviewer believed this was the correct direction. However, the reviewer questioned if the PIs anticipated having the necessary source code access, assuming these improvements would be demonstrated in CONVERGE.

Reviewer 3:

The reviewer noted the need to find the next bottleneck to help further speed up the computations.

Reviewer 4:

The reviewer stated that the only recommendation was to consider more comparison to realistic engine combustion problems as outlined in earlier commentary.

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

Reviewer 1:

The reviewer stated that the development of better algorithms, new compiling architecture, and improved physical models would enable the development of faster models with better predictive capabilities which are needed for design of high efficiency, clean combustion engines.

Reviewer 2:

The reviewer noted that faster and more accurate CFD was critical to advancing combustion technology.

Reviewer 3:

The reviewer stated that this work was relevant and the key to many low-temperature combustion concepts (e.g., the intermediate temperature heat release shown by John Dec) required for high-fidelity kinetics schemes in model validation.

Reviewer 4:

The reviewer stated that this work had improved simulation speed used in industry and was therefore highly relevant. Collaborating with Converge and NVIDIA is an enabler for this improvement and should continue.

Reviewer 5:

The reviewer indicated that this was another project working key details that ultimately would enable engineers to explore various combustion strategies for future direct injection engines with improved thermal efficiency and acceptable engine out emissions.

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

Reviewer 1:

The reviewer stated that good progress on milestones suggested that resources were sufficient.

Reviewer 2:

The reviewer indicated good utilization of the allocated resources.

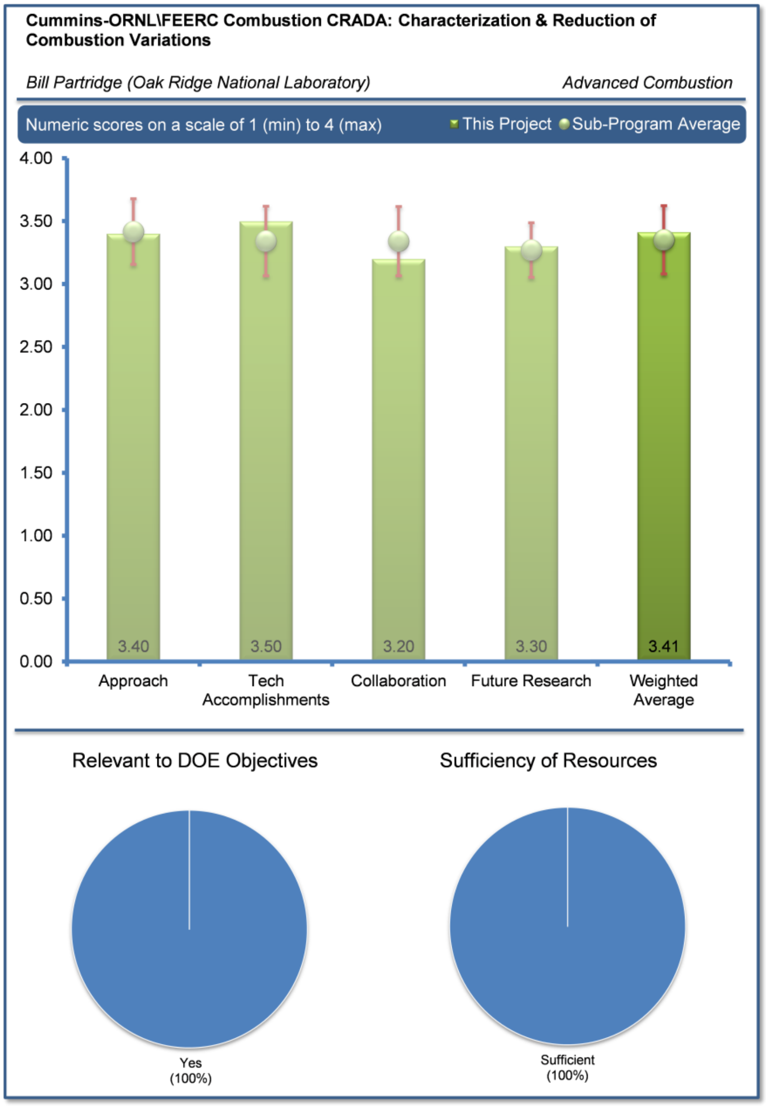
Reviewer 3:

The reviewer stated that if additional resources could be used to accelerate progress, then more funding should be pursued.

Reviewer 4:

The reviewer stated that it would be useful to see a funding breakdown comparing this project with ace012.

Cummins-ORNL\FEERC Combustion CRADA: Characterization & Reduction of Combustion Variations: Bill Partridge (Oak Ridge National Laboratory) - ace077



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 felt that Slide 6 was the holy grail of tracking gas distributions in the intake manifold and the cylinder. This person expected huge differences in the development of engine combustion technology, if totally successful.

Reviewer 2:

The reviewer stated that this project has a very unique approach via a smart way of monitoring EGR variations to stabilize combustions supporting high efficient engine development program. However, the practicality of this probe would still be questionable.

Reviewer 3:

The reviewer stated that the project included a creative approach to some of the challenges; it combined test, modeling and methodology well. On the flip side, however, the project focus was heavily on EGR and the effect of other combustion parameters did not appear to have received as much attention as EGR has.

Reviewer 4:

The reviewer stated that the primary focus and approach was to acquire experimental data on internal and external EGR with the use of a laser based EGR probe that quantifies CO_2 and H_2O concentrations in addition to local temperature. The goal was acquire baseline data and compare/ validate 1D and 3D model predictions (Slide 3) and ultimately use the data/ models for advanced control strategies. The reviewer noted that the approach seemed reasonable and made sense.

Reviewer 5:

The reviewer noted the innovative technique to measure external EGR and backflow in each cylinder using CO_2. The reviewer said that particular interesting was the ability to distinguish hot CO_2 (backflow) and cold CO_2 (external EGR).

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 an impressive design in Slide 8. Regarding Slide 9, this was the information that was needed routinely with each engine design change. The reviewer also noted an impressive design in Slides 10-11.

Reviewer 2:

The reviewer noted a very good outcome. The PI has demonstrated quite a solid achievement for the last few years.

Reviewer 3:

The reviewer stated that the project appeared on course with the scheduled progress. There was a rather long list of what was to be accomplished next. The reviewer emphasized that the team (presenter) was clear that some of the remaining tasks would be challenging.

Reviewer 4:

The reviewer stated that the 2013 and early 2014 milestones had been achieved with the primary focus on extending the probe to measure H2O and temperature (used to correct CO_2 measurement at elevated temperature). Initial measurements are presented on Slide 9 showing the ability to measure external EGR and residual gas backflow. The reviewer felt it would be interesting to compare measured date to model predictions mentioned earlier in the presentation. Also, it would be of interest to the reviewer, to discuss the effect of the probe on the EGR as it is intrusive noting that resonance of the probe with engine harmonics was mentioned and apparently addressed. The reviewer questioned if any effects of the probe on the hydrodynamics. The reviewer questioned in practice, if there were any issues with quantification due to obscuration of optical probes/windows with carbon/soot. The reviewer wanted to know if so, how this issue would be addressed.

Reviewer 5:

The reviewer observed good progress had been made to characterize the contributions of external EGR and backflow EGR to the total charge of the cylinder. The ability to measure H2O and to estimate the temperature with the water spectra was also innovative. The reviewer stated that the re-design of the probe to better measure backflow EGR was good.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that the contribution of Cummins seemed to be quite supportive; it showed good team work.

Reviewer 2:

The reviewer stated that the collaboration was limited to one key partner (Cummins). The project had successfully looked into and integrated applications in Cummins's SuperTruck pursuits. The reviewer indicated that collaboration with the University of Central Florida had been developed (though limited to the probe development). The reviewer noted that room existed to include another key partner (e.g., an engine development partner from the supplier industry) into the project, in order to increase the impact of the project deliverables across a much wider, relevant industry.

Reviewer 3:

The reviewer observed that the relationship between ORNL and Cummins was mature and successful. There was very little more upside to this relationship.

Reviewer 4:

The reviewer noted collaboration with Cummins. Cummins was working on the modeling and controls. The reviewer stated that little information on Cummins accomplishments were presented including modeling results and control strategies that work with the laser EGR probe. The reviewer indicated that in future presentations, it would be helpful to detail both Cummins progress with comparisons between model predictions and measurements. Perhaps this was covered in other/ earlier presentations and not included due to limited time.

Reviewer 5:

The reviewer noted good collaboration between a national laboratory, a university, and an industrial partner. The reviewer was not sure from the presentation what Cummins was contributing to the project. The reviewer questioned if Cummins would apply this diagnostic technique to one of their multi-cylinder engines in the future. The ability to measure CO as well as CO_2 with the UCF contribution would be valuable.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 was not sure how this could be done better.

Reviewer 2:
The reviewer stated that this proposed future plan seemed well-planned and executable.

Reviewer 3:
The reviewer stated that the project lead was clear on what was left in the overall course and what needed to be done next.

Reviewer 4:
The reviewer noted that the program ends in September 2015. Significant progress has been made demonstrating the EGR CO_2/H_2O/T laser probe. The reviewer stated that significant work remained to quantify results and apply it to the CRADA/ SuperTruck campaigns, etc.

Reviewer 5:
The reviewer noted that it was not clear how the residual contribution would be measured or estimated.

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

Reviewer 1:
The reviewer stated yes, for both fuel economy and in cylinder emissions reduction.

Reviewer 2:
The reviewer stated that this work was very much related to high efficient engine development and one of enabling technologies to meet 55% fuel economy improvement; however, the implementation of this probe would be still challenging in a cost-effective way.

Reviewer 3:
The reviewer stated that EGR and fuel economy had direct, one-to-one correspondence. Hence, success in this EGR study could potentially translate into fuel economy.

Reviewer 4:
The reviewer indicated efforts to quantify EGR composition and temperature were relevant and useful for extending operating limits and reducing fuel consumption/displace the use of petroleum.

Reviewer 5:
The reviewer stated that this effort to measure cylinder-to-cylinder and cycle-to-cycle variations would lead to improved engine designs which minimize these variations and thereby improve the engine efficiency and fuel economy.

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

Reviewer 1:
The reviewer stated that the integration of the ORNL and Cummins resources was so seamless that it was difficult to tell where one began and where the other took over. However, the reviewer would like to know where the edges are.

Reviewer 2:
The reviewer stated that the resource seemed to be at the right level.

Reviewer 3:

The reviewer indicated that the project had not shied away from developing synergistic use of testing, CFD modeling and innovative use of probes in the study.

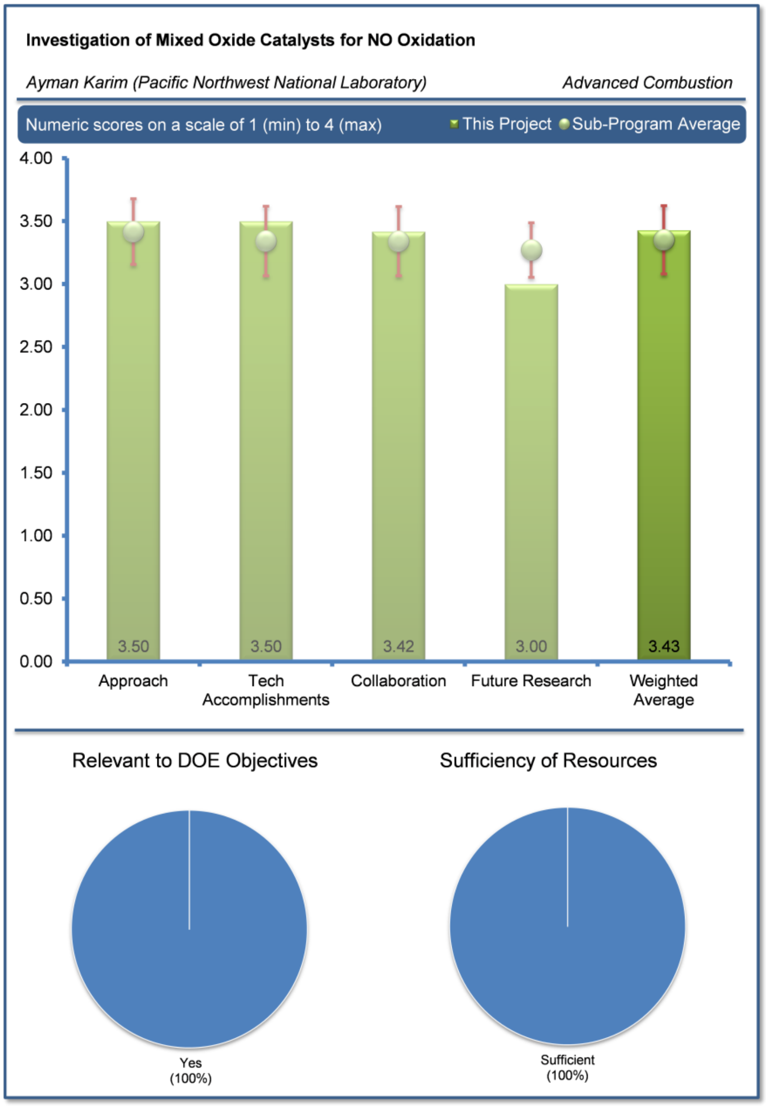
Reviewer 4:

The reviewer said it seemed acceptable.

Reviewer 5:

The reviewer stated that the progress seemed to be consistent with the funding level.

Investigation of Mixed Oxide Catalysts for NO Oxidation: Ayman Karim (Pacific Northwest National Laboratory) - ace078



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted potential for using this system as a low-temperature NO adsorber. Still need another component to oxidize CO. The reviewer indicated sulfur tolerance reversibility was shown only once and questioned what happens when it is repeatedly poisoned and regenerated (some unreported data indicate that higher temps and greater H_2 percentages increase regeneration to a greater degree). The reviewer observed a combination of analytical and experimental approaches.

Reviewer 2:

The reviewer stated that this technology was intended for a platinum (Pt) replacement technology. As reduced Pt, catalyst showed good NO oxidation capability, but did not address the CO oxidation activity that is needed by a DOC for lean systems. The reviewer questioned how much Pt could one really reduce to maintain a high CO conversion rate.

Reviewer 3:

The reviewer stated that work on zero-PGM materials could only be handled by tackling the very fundamentals of oxides in catalysis formulation. Dr. Karim's approach capitalizes on the fundamentals and uses state-of-the-art instruments at PNNL.

Reviewer 4:

The reviewer stated that focus on low temperature conversion was needed for advanced combustion regime and PGM thrifting was always a continuous improvement effort for cost due to scarcity. The CRADA approach generally insures focused priorities for R&D.

Reviewer 5:

The reviewer stated that catalysts were prepared and tested, x-ray photoelectron spectroscopy (XPS), x-ray absorption fine structure (XAFS), FTIR experimental measurements made and DFT calculations performed. A comprehensive approach was presented for determining the activity and stability of the catalyst with improved understanding of the reaction mechanism associated with performance of MnO_2- CeO_2 and Mn-doped ceria.

Reviewer 6:

The reviewer stated that the reduced use of PGM was a critical need, particularly with expanding car markets in China and India and other countries. The use of labeled gases to better understand the mechanisms is commendable. The reviewer indicated however, it might be appropriate to focus on reactions other than NO oxidation, such as HC and CO oxidation.

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 milestones were being achieved and objectives were being addressed. Non-intuitive results were observed and validated the value of this research.

Reviewer 2:

The reviewer said the project showed very good NO oxidation activity down to very low temperatures which is consistent with the low temperature after-treatment challenges of future, highly efficient combustion engines.

Reviewer 3:

The reviewer stated that the project appeared to have met initial goals; some of the aging/sulfur work was promising but still preliminary. More application-based type sulfur testing was needed.

Reviewer 4:

The reviewer indicated excellent accomplishments and potential with MnO_x and CeO_2 and ZrO_2 into MnO_x-CeO_2 activity to improve hydrothermal performance and poisoning characteristics.

Reviewer 5:

The reviewer stated that the program was wrapping up. With a relatively modest budget, the project performed impressive experimental work with mixed metal oxide reactivity and stability for NO oxidation. The reviewer noted that the project considered two synthesis techniques with different MnO_2 weight loadings and determined no impact of MnO_2 percent with incipient wetness technique. Further, the project showed mixed oxide was more active and more reducible than either MnO_2 or CeO_2. The reviewer noted performing aging and sulfur tolerance tests in collaboration with GM.

Reviewer 6:

The reviewer noted a good understanding of the active MnO_2/ceria structure.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer stated that GM and PNNL were performing somewhat different but complementary tasks that leveraged the strengths of each; catalyst formulation, and characterization, respectively. The reviewer noted that the person doing the DFT calculations at Tianjin University left during the project, so additional calculations were done by PNNL.

Reviewer 2:

The reviewer observed an excellent inclusion of both suppliers and OEMs in the project. Umicore is recognized for their NSC technologies. The reviewer stated that having monthly conference calls with all the participants was a very good way to maximize the effectiveness of the data collection, direction of the project, and project characterization.

Reviewer 3:

The reviewer stated that the partnership was limited to PNNL and GM. No university or another national laboratory had been integrated into the project, which could have expanded the diversity of the investigation scope and reduced the associated risks. The reviewer felt that given its proprietary nature however (an industrial partner is on-board), this was understandable on practical ground, but not on scientific ground.

Reviewer 4:

The reviewer noted a good scope split with CRADA partner GM developing new catalyst formulations, aging/testing and providing real world vetting for PNNL characterization and synthesis processes /performance assessments.

Reviewer 5:

The reviewer noted work with GM and Tianjin University. Repeated all Tianjin DFT calculations having better facilities after Tianjin personnel reported left project. The reviewer questioned what other role Tianjin had.

Reviewer 6:

The reviewer noted a very clear delineation of effort between PNNL and GM.

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

Reviewer 1:

The reviewer stated that the goals for future work were appropriate.

Reviewer 2:

The reviewer stated that the program was nearing completion with active work being done on stability and sulfur tolerance. The reviewer was highly confident the results would be lasting. The reviewer indicated interest in upcoming invited presentation and publications.

Reviewer 3:

The reviewer criticized that the suggestion that LNT technologies were less important than SCR for NO_x control was not necessarily correct. New, passive NO_x control systems that are capable of addressing low temperature challenges of more efficient combustion systems and vehicle drive cycles may have to rely on NO_x storage technologies that are active at lower temperatures. The reviewer stated also, many hybrid catalysts are incorporating LNT/NSC functionality into a TWC or a filter.

Reviewer 4:

The reviewer stated that a vision into future work was observed, but appeared limited. Given that this is the third (and final) year of the investigation, it was not clear why such fundamental considerations such as effects of sulfur and regeneration had not progressed further and still required much work. The reviewer stated also, a faster transition to full-size sample testing was warranted.

Reviewer 5:

The reviewer noted that the CRADA was scheduled to end in September 2014. The reviewer noted much work to do in this area.

Reviewer 6:

The reviewer observed a need to evaluate durability under more realistic thermal environments, such as 800 degrees Celsius for at least 50 hours (1 hour at 700 degrees Celsius is basically de-greening the catalyst). Also, if there are plans to apply this to gasoline applications, the reviewer said there was a need to assess the effects of rich operation on the durability.

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

Reviewer 1:

The reviewer observed that the project supported petroleum displacement by seeking to lower the cost and strategic material requirements of the exhaust after-treatment systems necessary for highly efficient diesel engines to meet emissions requirements.

Reviewer 2:

The reviewer said the proposed future work was very appropriate for emerging lean GDI after-treatment solutions that must work with lower exhaust temperatures associated with emerging combustion strategies.

Reviewer 3:

The reviewer stated that proposed future work appeared focused on the main questions and targets of the project. A faster transition to integrating the aging, sulfur-doping, testing and evaluation of full-size samples is warranted. The reviewer indicated that low/no PGM catalysts could help accelerate proliferation of light duty diesel in the United States, which could substantially help support the DOE's goal of reduced petroleum consumption (as diesel vehicles provide fuel economy beyond what gasoline ones can).

Reviewer 4:

The reviewer stated that the reductions in PGM and identifying new catalyst solutions are a continuous focus for automakers to improve fuel economy and keep vehicle costs competitive.

Reviewer 5:

The reviewer noted that the proposed future work was clearly relevant to reducing PGM catalysts and developing low temperature catalysts.

Reviewer 6:

The reviewer stated that the project was more aimed at reducing PGM use than reducing fuel use; although a lower cost LNT might allow more use of lean-burn operation and thereby reduce fuel use.

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

Reviewer 1:

The reviewer stated that this level of characterization and testing appears to have sufficient resources in this investigation.

Reviewer 2:

The reviewer stated that the PI has integrated fully PNNL's capabilities into the project. The reviewer added that even though the project showed a promising outlook, integrating a university research team and/or a catalyst supplier with good R&D capabilities (of course within some bounds of confidentiality and possibly intellectual property (IP) sharing) into the project could have accelerated the rate of the progress dramatically.

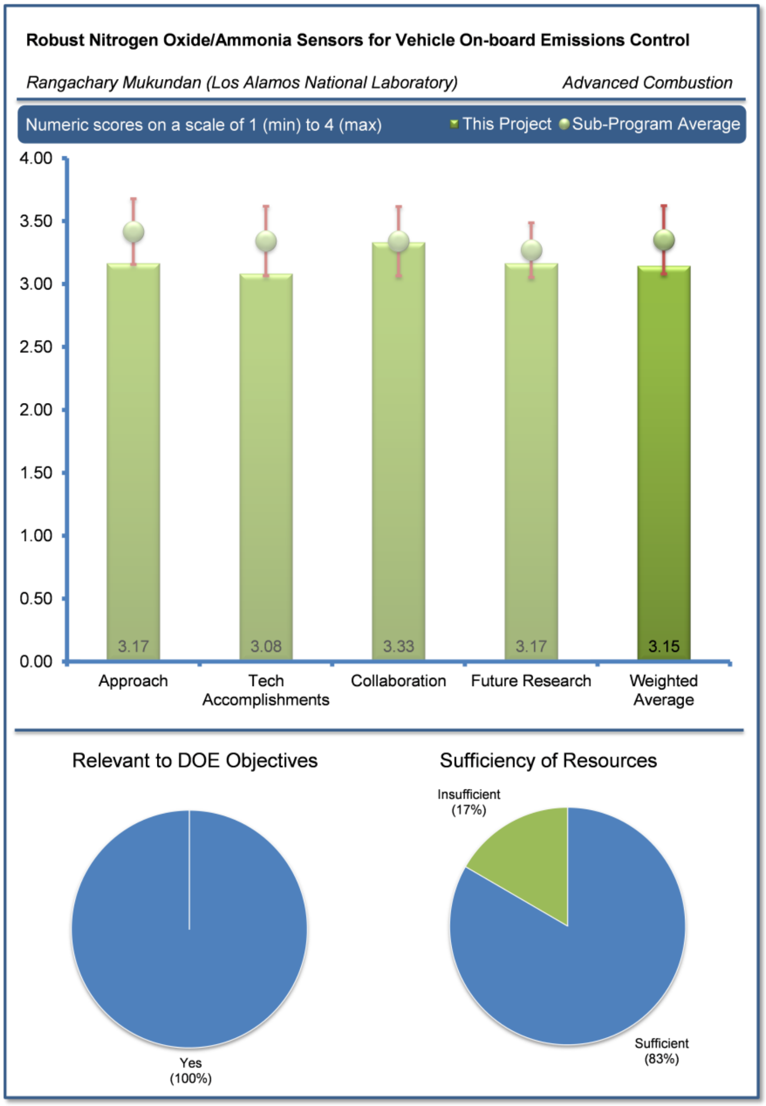
Reviewer 3:

The reviewer indicated significant work was done with modest resources.

Reviewer 4:

The reviewer stated that the funding level seemed consistent with the effort and progress.

Robust Nitrogen Oxide/Ammonia Sensors for Vehicle On-board Emissions Control: Rangachary Mukundan (Los Alamos National Laboratory) - ace079



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer said that the approach favored a unique make of the sensor for improved sensitivity and robustness. These include dense electrodes, porous/thin film electrolyte, and controlled interface. The reviewer judged that a valuable contribution of the project is the integration of mixed potential sensors (NO_x, HC and NH_3).

Reviewer 2:

The reviewer commented that this was a project to develop an interesting set of sensor concepts, and remarked well set-up.

Reviewer 3:

The reviewer found that the project generally had a good approach. The reviewer summarized that the project takes LANL fundamentals, puts into sensor, evaluates, and if good, then goes to engine.

Reviewer 4:

The reviewer observed a nice approach to increasing the sensitivity of the NO sensors. This reviewer had some concern that the signal would depend to a certain extent on the ratio on NO_2 to NO, and whether this would be viewed as a limitation to commercialization.

Reviewer 5:

The reviewer thought that the overall approach was good but the presentation could be clearer in discussing which sensor (NO_x. HC, etc.), or which function of mixed sensor was being discussed at the moment. The reviewer commented that Slide 7 for example, seemed to be talking about both NH_3 and NO_x functions but was not clear which milestone was being discussed and seemed to jump back and forth without clarity. The reviewer commented that testing appeared to be effective in establishing appropriate conditions, including the dilution with air for comparison with atmospheric conditions. The authors had done a good job in demonstrating that the sensor tracks qualitatively total NO_x concentration at start-up and at different flow-rates in steady states regimes and that the sensor tracked quantitatively the total NO_x concentration at different EGR levels. However, according to the reviewer the sensor calibration work for total NO_x had not been tested yet in actual engine conditions and needed more attention due to the non-additive NO and NO_2 concentrations properties.

Reviewer 6:

The reviewer recommended that the barriers identified (sensitivity, stability, interference, response time) were good but should be substantiated through industry survey or input U.S. Council for Automotive Research (USCAR), or perform an OEM survey. Targets from development/OBD engineers for cost and performance (with some justification) would improve. The reviewer pointed out that identification of competitive baseline cost /performance options would also improve.

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 that the project had made very good progress. The project demonstrated quantitative correlation of NO response of optimized sensor to FTIR response during engine testing. According to the reviewer, the project also demonstrated an NH_3 sensitivity of 10 ppm in an ESL manufactured sensor.

Reviewer 2:

The reviewer observed good initial results, and commented that there were many more conditions to be considered.

Reviewer 3:

The reviewer found that the project had addressed many of the practical issues associated with stability, selectivity, sensitivity and time response. After 400 hours of testing, the NH_3 sensor showed good stability, but more testing hours were required. The reviewer thought that selectivity could be improved for HC and NO_x by using bias currents. The pulse discharge technique (PDT) shows that NH_3 selectivity could be ensured through increased pulse amplitude, while it is invariant to pulse duration. The NH_3 sensitivity of 10 ppm had been demonstrated too. The reviewer found that the work so far had been productive and convincing but it was not clear yet if all the barriers (not just some) such as selectivity, sensitivity, stability (durability), reproducibility, response time, limit of detection, and cost will be passed for mixed NO_x and NH_3 sensors. Again, a clearer presentation would help. The reviewer was looking forward to final testing and calibration under actual exhaust gas conditions to see whether damaging effects, such as temperature spikes during active regeneration or presence of other harmful gases, could be withstood or may deteriorate the sensor prematurely.

Reviewer 4:

The reviewer commented that answering the question about poisoning was important.

Reviewer 5:

The reviewer said that it was excellent to have successful engine testing results using commercially viable element and mounting for HC, NO_x, and NH_3 sensors. The reviewer commented that there was significant risk with very low full range voltage in automotive engine environment. The reviewer said that on-sensor amplification would likely be required and would have to withstand significant absolute temperature ranges and thermal shock. The reviewer commented that baseline requirements from industry and value proposition relative to competitive products or industry potential savings would make the project outstanding.

Reviewer 6:

The reviewer commented that the presentation was not clear with too much data. The best plots are response to concentration. Time plots are only useful for time response, not for concentration response. The reviewer detailed that Slide 12 showed low sensitivity of NO_x to HC between 25 and 60 ppm. At 30 ppm HC, the sensor was good to about 10% (60 vs 66 ppm NO_x give same reading). The reviewer observed that Slide 13 showed good lab results with mixed NO/NO_2, but the EGR results were troubling with EGR and off versus the sweep. The reviewer noted that with EGR on at 20 ppm, 180 mv versus 210 mv at same NO_x level. The reviewer exclaimed that this was a 70 to 400 ppm NO_x range as indicated by the sweep. The reviewer commented that there was something strange here in the exhaust. Slide 15 showed decent lab data on HC sensor. The reviewer pointed out that the sensor read 12 to 55 ppm HC depending on 50 or 150 ppm of NO_x. The reviewer commented that perhaps this is not critical. However, according to the reviewer engine results are troubling. The scatter is 150 to 400 ppm diesel at approximately 80mv response and 10-20 ppm HC at 20 mv. The reviewer said that higher levels were not so good. The reviewer concluded by commenting that the NH_3 sensor looking promising.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the collaboration is very good.

Reviewer 2:
The reviewer found that the project appeared to have engaged university, national laboratory, and industry partners effectively and was commended for actively seeking commercialization paths for this innovative technology.

Reviewer 3:
The reviewer commented that this was a well-organized project.

Reviewer 4:
The reviewer remarked good so far. The reviewer suggested that a real sensor manufacturer needed to be recruited.

Reviewer 5:
The reviewer observed nice feedback loops and the involvement of right kind of partners. This reviewer suggested doing development work on sensor, testing in a lab, and if okay, moving to engine. This reviewer suggested that if engine exhaust showed unexpected anomalies, the project team needed to find out why and simulate it in the laboratory. The reviewer noted that engine work could get expensive, and it was not clear if LANL was engaged on improving sensor sensitivity and refinements.

Reviewer 6:
The reviewer observed good R&D effort beginning to take shape with a sensor manufacturer. The reviewer suggested that next must be OEM or Tier 1 automotive manufacturer input to confirm requirements and critique of implementation to significantly improve the product development speed and final result.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 study had begun to report on NO/HC sensor response optimization studies. The project planned to continue with a demonstration of greater than 10 times NH_3 selectivity with respect to HC. The reviewer noted that other activities were outlined, including the optimization of NO_x sensors and testing and would try to engage OEMs for validation.

Reviewer 2:
The reviewer said that the proposed work looked thorough and promising. Nevertheless, according to the reviewer, there are many barriers to consider before claiming success, including the following: selectivity; sensitivity; stability (durability); reproducibility; response time; limit of detection; and cost.

Reviewer 3:
The reviewer observed a good plan, though more conditions and aging were needed in the long run.

Reviewer 4:
The reviewer observed good next steps to develop controls and package hardware. The reviewer suggested that the project should focus on cost and value equation for the next round.

Reviewer 5:
The reviewer remarked pretty standard approaches. The reviewer suggested that sensitivity improvements should be accomplished before going into expensive vehicle testing.

Reviewer 6:

The reviewer commented that it would have been nice for these results to have been cast into a framework of what the various targets were, cost being a big one, for commercialization.

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

Reviewer 1:

The reviewer noted that sensors were needed for emission controls at high efficiency.

Reviewer 2:

The reviewer said that the project content was relevant. The development of low cost, robust, and accurate NO/NH_3 sensors would help improve efficiency and lower emissions. The reviewer commented that it would help validate models for the degradation of exhaust after treatment system, and would help develop better engine controls.

Reviewer 3:

The reviewer said that sensors are currently expensive. This person further noted only one supplier of NO_x sensors and possibly two suppliers of NH_3 sensors, and noted that these sensors are critical to high-efficiency closed loop control and OBD.

Reviewer 4:

The reviewer said that inexpensive constituent sensors could support fuel savings through the implementation of fuel saving technologies, which could be optimized with sensor feedback or which would require OBD for implementation.

Reviewer 5:

The reviewer remarked that improved sensors would aid in meeting emissions and performance goals leading to increased efficiency to reduce petroleum use. The reviewer commented that presumably these same sensor technologies would work just as well with non-petroleum fueled engines.

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

Reviewer 1:

The reviewer said that resources seemed sufficient, but perhaps a little on the low side depending on how difficult it would be to solve sensitivity issues. The reviewer noted that the project was halfway through the program and that the obstacles might be large to take next steps.

Reviewer 2:

The reviewer commented that if the team could substantiate the value proposition with industry interest and need, substantial new funding would be needed to implement a commercially viable sensor technology. The reviewer observed good initial work to get stable linear output, and, as mentioned above, improving the full range signal would likely require on-sensor electronics development and continued engine testing for sensor stability. The reviewer concluded that the current budget did not appear to comprehend these activities in whole. The reviewer recommended an OEM/Tier 1 partner for additional funding.

Reviewer 3:

The reviewer found that the resources were sufficient.

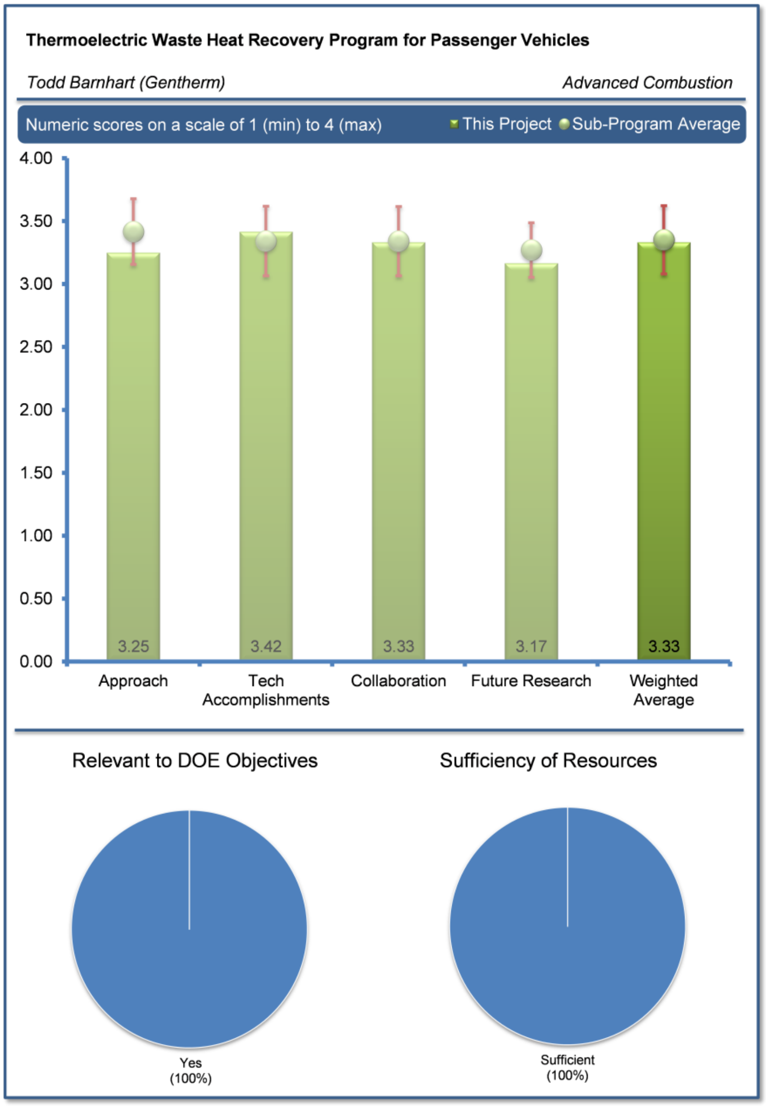
Reviewer 4:

The reviewer said that resources seemed appropriate for the projected work.

Reviewer 5:

The reviewer said that resources were sufficient for now. Expansion would be needed as the project achieves real sensor and testing conditions.

Thermoelectric Waste Heat Recovery Program for Passenger Vehicles: Todd Barnhart (Gentherm) - ace080



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that the PIs had been performing the tasks as proposed.

Reviewer 2:

The reviewer found that the approach is considered excellent because the Gentherm team knows how difficult the task is in harvesting power using the hot exhaust gas as a heating medium for thermoelectric generator (TEG). According to this reviewer, the project team has demonstrated their knowledge by focusing on every critical aspect of the project, such as design and engineering of the TEG cartridges, heat transfer modeling, thermoelectric (TE) material selection, and vehicles' exhaust system integration, besides TEG performance evaluation and durability testing.

Reviewer 3:

The reviewer found that the team had a balanced approach in materials development and TEG development.

Reviewer 4:

Although this reviewer agreed that significant improvement to material properties would not come easily or quickly, this reviewer believed that this project could spend a bit more effort in monitoring pertinent materials research to understand how future breakthroughs might impact the designs. Otherwise, this reviewer would have scored this project a 4.0, Outstanding. The reviewer noted a very good focus on reducing product cost, variability, and manufacturing.

Reviewer 5:

The reviewer commented that the Gentherm work has two focus areas (i.e., DOE application and U.S. Army Tank Automotive Research, Development and Engineering Center [TARDEC] application). The TARDEC work seems like it was of low emphasis and successful, but the scope was unclear. The reviewer pointed out that in the overheads, an egregiously large radiator was shown in an image, and the reviewer would like to know if that was only with the mock-up, or if the radiator was an integral part of the Bradley. The reviewer would like more discussion about the anticipated lifetime of the TEGs. Because both are used for DOE and TARDEC it would be good to know if there will be a recurring cost of replacing the cartridges after some years of service. The reviewer commented that the abandonment of enamel coating suggests that while the life may be long, it will be finite. The reviewer would like to know what that time is in years, and what happens if there is a failure. In general, the reviewer said that there was an excellent mix of performers in the program, and all have been successful. The reviewer found that the work was properly scoped and funded, and that the project team had offloaded appropriate tasks to other team members suggesting excellent management by the PI. The reviewer pointed out that the presenter mentioned other ways to increase the improvement in fuel efficiency beyond the immediate waste-heat recovery, so maybe that should be clarified or described in private to the Merit reviewers to evaluate the approach.

Reviewer 6:
The reviewer found that the approach includes materials development, TEG design and evaluation, and vehicle integration. These subjects are nicely presented, easy to follow, and make sense.

The reviewer found that what was missing was a strong link, or any link for that matter, to fuel efficiency. For example, a lot of data were presented on ZT as a function of temperature. The PIs do not inform to what extent the ZT values presented link to FE. If, say, n and p type ZTs were doubled from the data presented (which would be an extraordinary development) the reviewer would like to know what would be the precise impact on FE. For this reviewer, the project team should always be mindful of this sort of question when developing tasks. It is fine to engage in an array of subtasks for a given year. However, according to the reviewer, unless there was a better understanding of the impact and cost/benefit ratio of pursuing those tasks on system level FE, the overarching goal of the project would not be met. This person found that the presentation was missing information that considered this link between subtasks and system level performance.

The reviewer recommended that the PIs, in future presentations, should provide data or analysis that specifically and clearly establishes a quantitative connection of their results to vehicle efficiency. Everything the project team does should be with this in mind, and not just from a broad perspective. For example, the reviewer suggested that instead of presenting figures like ZT versus time, the project team should present charts showing FE versus ZT, or FE versus TEG mass flow rate. For this person, this will provide far more useful information and establish that the PIs are keeping their eye on the ball. The reviewer pointed out that to prepare such plots may require collaborating with someone that has an accurate system level analysis; perhaps Ford or BMW have this. ANL is claimed to have it.

This reviewer envisioned that the materials effort could be eliminated and the funds directed toward expanding the system-level modeling or cost analysis – both of which are potentially show-stoppers (i.e., no matter how high the ZT, if the TEG was not efficient or the myriad of interfaces not well characterized, material gains would have little impact on FE). The reviewer found that the PIs are hedging their bets that skutterudites are the best for waste heat recovery in an automobile. The reviewer would like to know why this material system was better than half-Heuslers, which are being pursued by others in the program, or vice versa.

Finally, the reviewer pointed out that there is the matter of cost, for example as expressed as cost per watt generated by an installed TEG. The reviewer observed that it was not just the TEG but that the installation of it that will contribute to the overall cost of the design. The reviewer recommended that the PIs must present this in their presentation, or at the least inform DOE about it if it is proprietary. The reviewer noted that DOE was investing millions to pursue this technology and that DOE should have a right to such information since it would be the basis for continued funding (i.e., no agency was going to invest in a technology that is not cost effective).

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 the integration of TE and heat exchanger were on target to goals. Materials selection and production appeared to be done effectively.

Reviewer 2:
The reviewer commented overall good work and good progress. Perhaps this reviewer did not understand all the work that had been done, but the reviewer got the impression that the analysis could be used more effectively to verify durability requirements and reduce design iterations.

Reviewer 3:
The reviewer noted that over the past year, a lot of data were taken to evaluate the performance of skutterudite materials (n and p type). ZT had been measured and research on stability of the materials reported. The reviewer noted that a performance evaluation of the

compact heat exchanger that incorporated integral fins with the materials showed interesting levels of electricity generation. The reviewer commented that the TEG module seems to perform well over the operating cycle (e.g., seven days, with little loss of performance). The TEG design seemed to have been completed. The reviewer recommended that the PIs needed to indicate the cost of the units designed. Unless the PIs do that, there would be little hope of widespread use in an automotive system. The reviewer also recommended that some discussions on alternator down-sizing should be mentioned because this is apparently where increased FE will be derived from.

Reviewer 4:

The reviewer found that there appears to be excellent progress. The reviewer would like to know if there was still materials development work being pursued. The reviewer remarked that it seemed late in the game if so. This reviewer thought there should have already been a down-select of the n-type and p-type skutterudite compositions, and those should be close to optimized for integration into product. The reviewer commented that the mention of the phase diagram development by the Caltech partner suggested that there were still materials R&D for further improvement of ZT, which seemed out of place for this stage. Generally, the reviewer found that the accomplishments and progress were excellent. The reviewer was interested in knowing yield. In other words, the Gentherm approach was unique in that the claim that thermal expansion issues are mitigated. The reviewer asked what fractions of modules (or strings of devices along the cartridge) fail, and whether all are fully functioning. The reviewer would like to know if a cartridge has ever failed.

Reviewer 5:

The reviewer found that technical accomplishments and progress toward overall project and DOE goals are excellent. The reviewer commented that it was clearly shown in the oral presentation that Gentherm is making good progress toward the overall objective of having a 5% improvement in fuel consumption. The design of TEG cartridges and TEG configuration is excellent. The performance of TEG has been evaluated and the milestones have been met as scheduled.

Reviewer 6:

The reviewer found that technical accomplishments and progress were on track with the original plan. The team is realistic in the material performance. The reviewer noted that the TEG module approach was a flexible design with scale-up in mind. The reviewer found that the skutterudite performance is reasonable. The known issue of sublimation of Sb at high temperature was not being addressed directly. The reviewer noted that the cost model is not clear, especially on the materials and “module” cost.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed good partnerships and collaboration.

Reviewer 2:

The reviewer remarked that Gentherm worked well with their collaborators from other institutions and used their collaborators' expertise to overcome critical barriers such as selection of good TE materials to reduce cost, heat transfer modeling, oxidation and sublimation suppression coating with enamel, vehicles' system integration, and testing, etc.

Reviewer 3:

The reviewer remarked that the partnerships were managed well and highly focused on the assigned sub-tasks. The project team had sought out external expertise (Tenneco) to facilitate rapid progress, and to reduce overall costs to the Program. The reviewer pointed out that the TARDEC work seemed to be lagging because of the TARDEC partner, so the project team should rapidly identify a back-up plan so that progress can continue at the Gentherm pace.

Reviewer 4:

The reviewer found that the collaboration brings together a strong team from OEMs (BMW, Ford), a company proficient at system integration (Tenneco), an academic partner for materials development (Caltech) and a government laboratory National Renewable Energy Lab (NREL) for confirmation of the TEG-level and vehicle performance. The role of NREL was not clear here and more should be provided about its role, and what it is (and has been) doing.

Reviewer 5:

The reviewer found that the contributions from Caltech were not clearly described beyond a very generic statement (i.e., "deepening understanding of material structure..."). The reviewer concluded that contributions from other partners are properly summarized.

Reviewer 6:

The reviewer stated that the roles of TARDEC and the DOE project were not clear. It seems to be a separate project funded by TARDEC and not collaboration originally planned to meet VTO goals.

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

Reviewer 1:

The reviewer concluded that this project was progressing towards a productive final year in 2015.

Reviewer 2:

The reviewer commented that the proposed future research was technically sound and clear with the prospect that there were still challenges for the project, especially when it reaches the point of mass production for commercialization. However, as shown in the presentation, Gentherm has a good plan to resolve those challenges by continuing to build up their expertise and knowledge through executing this project carefully in order to overcome technical barriers. The reviewer concluded that degree to which the project has been planned is effective and mitigates risks.

Reviewer 3:

This person remarked that the future work was clearly focusing on some of the TEG uncertainties. Vehicle level performance, confirmation testing, and in particular cost analysis are all important to move thermoelectric technology forward. The reviewer considered that perhaps it was planned, but somewhat more effort could be directed towards component reliability and overall durability testing as part of the confirmation activities.

Reviewer 4:

The reviewer noted that future work and milestones are described. However, for this reviewer the role of Caltech was still not clear. This reviewer was unsure if this was a research project; it is more development. But because a research question was asked, this reviewer would say there was really not much research done.

Reviewer 5:

The reviewer found that the future work seemed to be a simple continuation of past years' work. Unfortunately, the PIs were not presenting their results in a form where it was easy to see the benefits of gains in individual tasks (e.g., more power output or higher ZT) on FE targets. The reviewer commented that the project team needed to now start doing that and the future work should endeavor to make that link in everything the team does. This effort will be facilitated by a systems level model that bridges across scales from materials to TE couples to interfaces to heat exchangers and fin efficiency and optimal spacing, to flow rates to electricity produced by modules to reduction in alternator power and ultimately to reduction in FE. That way, according to the reviewer, the team can scope out the limits of impact of each element, craft their work accordingly and provide more useful results. When reviewers see a figure like power versus mass flow rate, reviewers wonder how FE is affected by it. The reviewer recommended that the PIs should tell the reviewers.

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

Reviewer 1:

The reviewer concluded that this project supported the overall DOE objectives of petroleum displacement well. It is an excellent example of how we could reduce the fuel consumption of vehicles, light, heavy and military, by harvesting energy through waste heat recovery and direct energy conversion. The reviewer highly recommended that DOE have more projects like this because every watt of electrical power that can be harvested could save many problems due to shortage or high cost of fuel/energy supply.

Reviewer 2:
The reviewer found that this work would reduce the fuel utilization on automotive platforms, and also reduce the fuel needs on large platforms of the U.S. Dept. of Defense (DOD) TARDEC such as the Bradley Fighting Vehicle.

Reviewer 3:
The reviewer remarked that TEG was not the only solution for the petroleum displacement. However, it was a piece of solution on the table to be used. The reviewer concluded that the development of TEG certainly supported the DOE objectives.

Reviewer 4:
The reviewer identified that the loss of waste heat was a significant source of overall inefficiency in any petroleum fueled system and thermoelectrics were one of several potential ways to reduce this loss. Although significant barriers remained, good progress was being made.

Reviewer 5:
The reviewer commented that getting to 5% might be a real challenge. At the end of the project, the team should be asked very specifically whether the 5% goal had been reached.

Reviewer 6:
The reviewer detailed that the ultimate goal of this project is to achieve a 5% reduction in FE by incorporating a thermoelectric module in the exhaust stream of an automobile. If successful, the project would certainly be relevant to DOE's objective of petroleum replacement. The issue here is the extent to which the activities being pursued are working to that end.

The reviewer commented that the PIs have a TEG design that appears promising. A lot of data was presented. However, according to the reviewer, none of the figures actually addressed the efficiency question. Reviewers saw graphs that showed the influence of temperature on ZT, power dissipated as a function of air flow rate and voltage as a function of current to illustrate the stability of diffusion barriers, but nothing that addressed efficiency specifically. Another concern is the efficiency target the PIs are working toward. The reviewer asked if 5% was realistic, and where this number came from. The reviewer wondered if the project team was working toward an unattainable goal (e.g., is 5% being too radical an improvement). The reviewer remarked that surely the results would be dependent on the type of automobile and drive cycle performance it would be measured against, but none of this was mentioned. Finally, according to this reviewer, cost will be an issue. The PIs should be forthcoming on cost, either in public or privately to DOE. If developmental funding is to continue, presumably the sponsors would wish to know if the model that Gentherm has developed is cost effective or ultimately too expensive. The reviewer said that this was a major concern. A strong recommendation was to cast the project team's results in terms of the prime motivation for this project, which this reviewer commented to be efficiency. If the PIs cannot do that, the PIs are not working in the best interests of DOE.

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

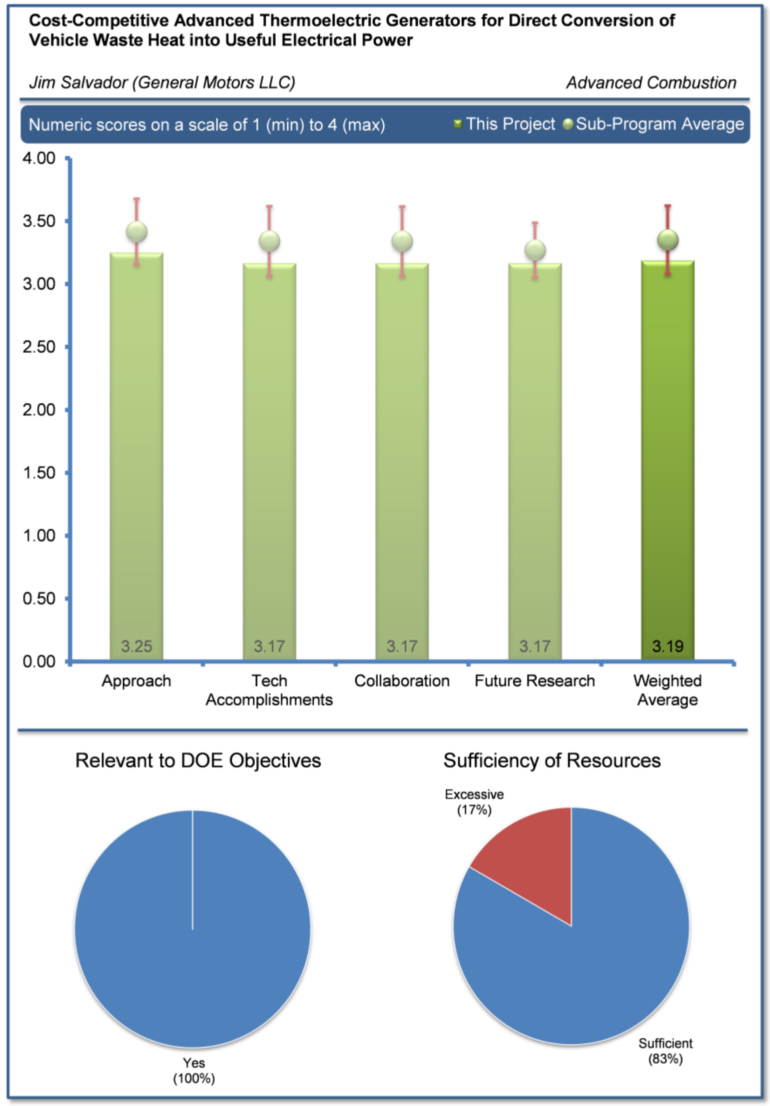
Reviewer 1:
The reviewer commented that the overall project scope had been well aligned with budget.

Reviewer 2:
The reviewer commented that the resources are sufficient for the project to achieve the stated milestones in a timely fashion. The reviewer recommended that this project continues to be funded so that our mission in reduction of fuel consumption can be achieved.

Reviewer 3:
The reviewer found that the budget seemed high. It could well be reduced and still provide useful information. The reviewer provided as an example, if the materials effort were eliminated, in the remaining period of the project, the team could develop (or use) an accurate

systems-level model that establishes a bridge across sub-tasks and a direct link to FE. The reviewer concluded that this is missing from the current work.

Cost-Competitive Advanced Thermoelectric Generators for Direct Conversion of Vehicle Waste Heat into Useful Electrical Power: Jim Salvador (General Motors LLC) - ace081



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer remarked that the collaboration with many listed partners appeared to be making good progress.

Reviewer 2:

The reviewer found that the approach from the GM team was effective. It represented all effort to overcome critical barriers. The reviewer noted that we all know that the good TEG design requires not only TE materials but also how much heat it can transfer in and out effectively. The GM team has taken into account all the critical elements that are important in designing a good TEG system. According to the reviewer, these are the heat exchanger, modeling work, TE materials, TE module fabrication, TEG design and engineering, power electronics, performance testing, system integration and cost reduction scheme in TEG design.

Reviewer 3:

The reviewer remarked that the overall approach was good, although it seemed that an earlier component level validation would be helpful.

Reviewer 4:

The reviewer remarked that the team approach was focused on TEG development. Many barriers on TEG built are being addressed down to the nuts and bolts.

Reviewer 5:

The reviewer commented that the approach by the GM group appeared to be sound and well represented by the well-described team. There were some open questions about the lifetime of the modules, and overall system. The reviewer pointed out that in one response to a verbal question there seemed to be an issue with failure modes. The reviewer may have misheard, but this reviewer thought that a description of failure modes of the devices and modules would be useful. The reviewer asked if a module fails, then what happens electrically to mitigate that. The reviewer asked if the entire system needed to be disassembled so that a drop-in replacement module could be installed, and, in a similar vein, asked what the expected service lifetime of the TEGs and individual devices are, and how long the lifetime is of the TEGs that have the enamel/coating/aerogel protectant, compared to unprotected devices and TEGs. The reviewer wondered what the performance penalty is to thermal shunts from the protection strategy. It was somewhat unclear to this reviewer why flexible circuit assemblies were needed. The reviewer asked if that was to manage CTE issues. The reviewer recommended that the project team clarify if the flexible circuit adds a thermal interface penalty for dissipating heat to the heat sink.

Reviewer 6:

The reviewer commented that this project incorporates a set of tasks that the PIs believe will achieve the ultimate objective of reaching the targeted efficiency gain of 5% using a thermoelectric device to recover exhaust waste heat. The reviewer remarked that the contribution of the individual tasks to the targeted 5% goal was not well established. For example, in the entire presentation (and in the online slides) there was no graph or discussion establishing a link to FE. Rather elaborate figures were shown on the TEG prototype build, but it was not mentioned precisely what about this design would assist achieving the 5% goal. For this reviewer, the choice of skutterudites needs to be better justified in light of other options. For example, the reviewer asked why it was better than half-Heusler materials, which are being pursued by other groups in the DOE program (and, of course, vice versa).

The reviewer commented that as the PIs enter their third year of funding, and if this project is continued, it would be essential for the project team to address the targeted efficiency, how each task contributes to it, where the project team is now with the results obtained to date (e.g., the reviewer asked that if not at 5%, did the aggregate of what the team has accomplished put their results at 2%, 4.5%, etc.). In continuing their approach the project team needed to quantitatively show the link of the individual tasks to the 5% goal. The reviewer noted that in comment one of the Responses to Previous Year Reviewer's Comments – "...a closer connection is needed ....to know the actual percent improvement in Fuel Economy (FE)..." – the PI did not answer this comment. The reviewer recommended that if the PIs are unable or unwilling to quantitatively link each task to the efficiency target, the project needs a serious reorganization and redirecting of effort.

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 concluded that good progress has been made. Hopefully, the hot side temperature can be improved to more than 525°C in the future.

Reviewer 2:

The reviewer found that the team has made significant progress towards TEG development. Although materials development is a still an ongoing task, the focus on TEG prototype is important. The reviewer noted that the team seems to be less certain of the role of interfaces on device performance.

Reviewer 3:

The reviewer commented that technical progress is good, although some of the design decisions are a bit questionable and are not well supported with analysis or component level testing. The reviewer noted flexible circuit board reliability would seem to be a high risk, but there was no work to understand or define the risk better.

Reviewer 4:

The reviewer indicated that the GM team has made good technical accomplishments and progress in this project. For example, the reviewer noted that the project team had particularly paid attention to how to reduce contact resistance, which is one significant source of power loss in TEG system. Other important technical accomplishments included transient thermal modeling of TEG, TEG design, module construction, module performance and durability testing. The reviewer pointed out that unlike the Gentherm team, the GM team has different TEG designs and also different approaches for solving the problem of oxidation and sublimation at operating temperature. According to the reviewer, the project team's ideas of using enamel coatings for oxidation suppression and aero gel encapsulation for suppression of sublimation at TE legs are good.

Reviewer 5:

The reviewer complimented that the GM team appears to have made significant progress towards the overall goals. The project team seems to be zeroing in on a final composition of TEG material, and a strategy for integrating the material into a modular unit for automobiles. The reviewer noted that the reported electrical contact resistivity is good, but that is known to be a somewhat dynamic property. The reviewer wondered if it would be useful to know if the contact resistivity values are from as-prepared samples, from samples that have had thermal annealing, maybe RTA, or processing. The reviewer wondered how thermally stable that value will be in service life. The reviewer also asked what the project team's definition of delamination is. The reviewer noticed that the project team used this term, but it remains unclear. The reviewer asked if delamination is a separation of the enamel. The reviewer asked is it off of electrical contact to the hot-shoe (hot-side contact). The reviewer recommended that a better description of the described burn-in process would also be helpful.

Reviewer 6:

The reviewer said that the accomplishments reviewed at the meeting involved TEG modeling, heat exchanger design, system level modeling in which the TEG is incorporated into a vehicle, prototype build, and materials advancement. The list of publications, numbering almost 30, shows 70% of these are related to materials development alone and three seem to be more review-type articles. The reviewer commented that the TE problem is certainly not, or should not be viewed as, a materials development effort alone, though the disproportionate effort devoted to materials in this project would suggest otherwise. The reviewer observed that the discussions were presented at a rather higher level than would be commensurate with a detailed review. For example, a "heat exchanger" was mentioned but the design was not presented (perhaps it is in some of the publications; if so, the PIs should not place the burden on the reviewers to dig through publications at a review meeting with the format of the AMR, to obtain them, and assess the efficacy of the design). The reviewer noted that some of the results were presented in a way that was difficult to link to the targeted efficiency gain. For example, for the transient thermal model output a graph was presented of "circuit maximum power" versus time. The reviewer would like to know the link here to efficiency. Similarly, the TEG model output includes a figure of circuit voltage with time. Again, the reviewer would like to know the link to efficiency. The prototype build notes various components of exhaust gas inlet, bottom side heat exchanger, etc. The reviewer asked what the relationship is between the inlet gas flow rate and FE or efficiency. The reviewer commented that answers to these sorts of questions will put in focus the approach and the accomplishments that come from these answers.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer remarked that compared to other teams, the GM team has the most collaboration from industry, national laboratories and academia. The project team is able to work with all collaborators well and the workloads are reasonably assigned among the team members based on their expertise.

Reviewer 2:

The reviewer commented that the PI seemed to be able to coordinate the many collaborators effectively. The reviewer acknowledged that a thermal model has been developed during this past year.

Reviewer 3:

The reviewer observed a good project team with most of the necessary expertise. The reviewer thought that it would be good to add a vehicle OEM to the list.

Reviewer 4:

The reviewer noted that GM has identified leaders in the field and has established good partnerships to facilitate progress. The project team has offloaded appropriate tasks to experts better suited to mass-production, while maintaining core expertise in-house.

Reviewer 5:

The reviewer found that as the end-user and developer of TEG, the GM team is large and well organized. The reviewer acknowledged that the role of JPL is important in assuring the success of the TEG development.

Reviewer 6:

The reviewer noted that the team includes a large number of components, 12 in all. The coordination and interrelationship between the various team tasks and teams was not clear. As example, the reviewer cited that the Jet Propulsion Laboratory is listed as modeling "heat exchangers," while Purdue is listed as "heat exchanger modeling." The reviewer would like to know what the difference is. Similarly, Molycorp is listed as "materials synthesis," Brookhaven National Laboratory is listed as "materials synthesis," and University of Washington as "TE materials research and development." It seemed to this reviewer that none of these three efforts could proceed independently of the other. The reviewer recommended that the lead PI show a clear differentiation among the team capabilities to prove little redundancy, or at the least close coordination and complementary work.

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

Reviewer 1:
The reviewer found that future work plans were good, although some targeted reliability testing to address the flex circuit would be better.

Reviewer 2:
The reviewer commented that the GM team appeared to have a good perspective on future needs and the work requirements to conclude the present work in 2015. The reviewer observed that the tasks are realistic and the near-term goals are well-scoped.

Reviewer 3:
The reviewer remarked that proposed future work is reasonable and towards the final goals. There is not much research in the project, mostly development/engineering type of work.

Reviewer 4:
The reviewer concluded that proposed future research is technically sound and clear with the prospect that there are still challenges for the project, especially when it reaches the point of mass production for commercialization. Because the GM team has many more collaborators compared to other teams, this reviewer suggested that the proposed future research should be well thought to effectively utilize the collaborators' expertise without duplicating the work. Thus more comprehensive results can be obtained from different collaborators in a timely manner. The reviewer found that the degree to which the project has been planned is effective and risks mitigating.

Reviewer 5:
The reviewer concluded that the plan for future research is good. The path to lowering the cost is not well defined. The reviewer expressed concern that uncertainties such as long term stability and performances under cyclic conditions are still unknown.

Reviewer 6:
The reviewer strongly encouraged the PI to specify targets for his team to shoot for in their individual tasks. As it stands, it seems that the project team's objectives are only to get the highest ZT possible, or design the most efficiency heat exchanger, etc. The reviewer expressed that while it cannot be argued that tasks formulated in this way provide over-arching motivation for the individual work, the project team does nothing to put in focus objectives for each team. The reviewer cited previously-noted concerns about a tenuous link to efficiency targets of the individual or collective tasks, and remarked that none of the planned future efforts seem to address this link.

The reviewer encouraged the PI to better focus his team toward targets with specific metrics that impact overall efficiency gains. Not just get the highest ZT, or shoot for a ZT that may well be unattainable, but a ZT target that, all other things being perfect would reach 5%. The reviewer thought that some discussion of alternator down-sizing is necessary to fully address this point and how much the system the project team has thus far developed can reduce the load on the engine's crankshaft (engine testing would address this matter). The reviewer explained that this would require perhaps using a system level model to draw such a link, then identifying specific deficiencies in the ingredients to a complete package that make it currently unable for the targeted efficiency to be reached.

Finally, this reviewer commented that it was essential for the PIs to provide some cost estimates of the module and integration of it into an automobile. It is highly unlikely that GM will ever pursue a technology (e.g., even if GM reaches the 5% target) if the project team cannot do it without driving up the cost to levels that the consumer will find unacceptable. The reviewer recommended that the project team consider this matter in their next presentation.

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

Reviewer 1:
The reviewer noted that waste heat was a major loss in a petroleum powered system and thermoelectrics are one potential method of reducing the loss.

Reviewer 2:
The reviewer remarked that TEG development was one of the available solutions to petroleum displacement. The reviewer remarked that even with a 3% FE improvement, the TEG will be an important solution to the DOE objectives.

Reviewer 3:
The reviewer commented that the GM approach will improve fuel utilization on automobiles, and provide useful electrical power for the user.

Reviewer 4:
The reviewer found that this project supports the overall DOE objectives of petroleum displacement well. According to the reviewer, the project is an excellent example of how we could reduce the fuel consumption of vehicles, light, heavy and military, by harvesting energy through waste heat recovery and direct energy conversion. The reviewer highly recommended that DOE should have more projects like this one because every watt of electrical power that can be harvested could save many problems due to shortage or high cost of fuel/energy supply.

Reviewer 5:
The reviewer noted that the 5% goal appeared to be very challenging. The reviewer recommended that DOE should really make sure that this goal is achieved.

Reviewer 6:
The reviewer confirmed that certainly, a project of this type will be consistent with DOE's overall objective of petroleum displacement if successful. This reviewer's concern is that the ingredients toward reaching DOE's targeted efficiency are not in focus. The PIs target a value of 5% for a FE improvement, apparently as a DOE specification. It is important that the PIs be clear about what the project team is shooting for. The reviewer did not observe in the presentation a justification for the 5% target. The reviewer asked if the PIs believe that the 5% target can be reached, and if not, what the project team is working towards. The reviewer strongly encouraged the PIs to scope out the performance limits before proceeding too far, and then craft the individual elements so they are consistent with those limits. The reviewer commented that 5% may not be the right limit, or even theoretically unattainable. The reviewer remarked that unless it can be proven that the 5% target is rooted in sound scientific bases given the complexity of a vehicle, the individual components of the project (materials development, synthesis, TEG design, heat exchanger development, modeling, etc.) may not be appropriate. The reviewer asked if this stellar PI team believed that 5% was achievable. If so, the reviewer asked what targets in the individual tasks need to be reached. According to the reviewer, the answer should be considered an essential element of the project team's research plan going forward.

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

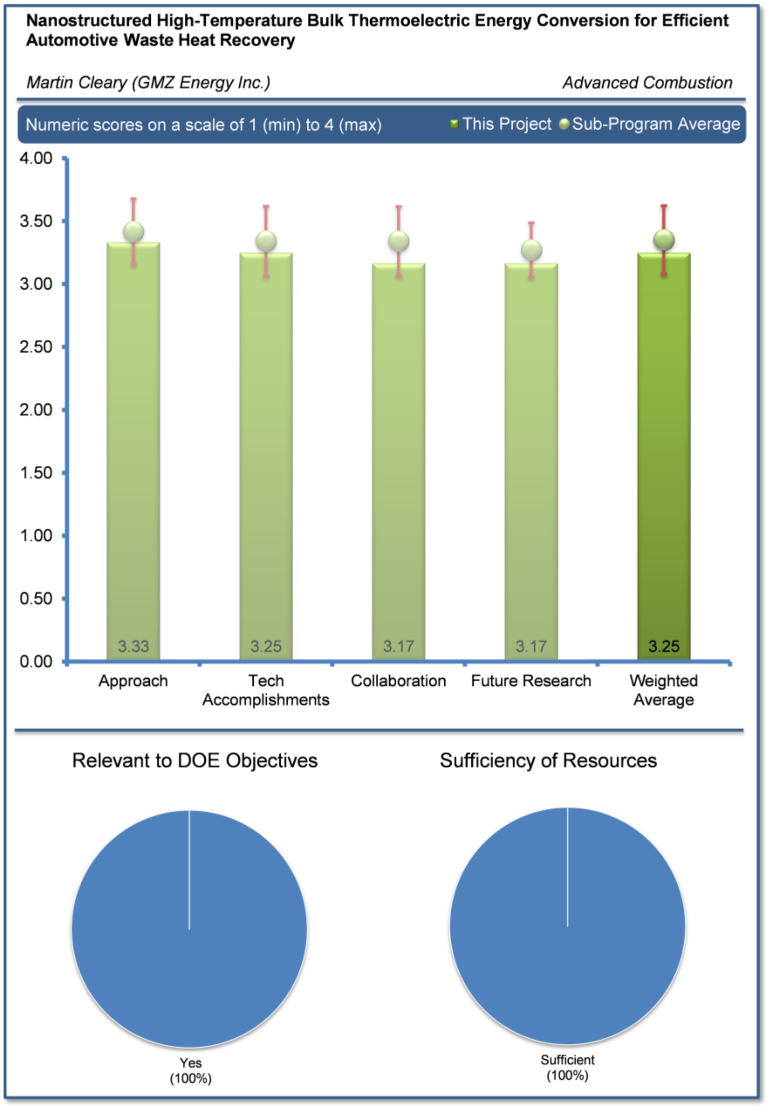
Reviewer 1:
The reviewer commented that resources for the project to achieve the stated milestones in a timely fashion are sufficient. The reviewer recommended that this project continued to be funded so that the mission in reduction of fuel consumption can be achieved.

Reviewer 2:
The reviewer said that the project plan was well aligned with resources.

Reviewer 3:
The reviewer commented that the budget seemed high though understandable given the very large team. According to the reviewer, the problem here is that the link to FE is weak, and the PIs did not make much effort to establish it for the individual subtasks the project

team is pursuing. It seemed to the reviewer that much of the work could be reduced or eliminated, but still provide value to the overarching project goal by making the link to FE. For example, if the materials effort were eliminated and a model there would still be significant value to the work. The reviewer concluded that as it stands, the value is much weaker the way the project is developed.

Nanostructured High-Temperature Bulk Thermoelectric Energy Conversion for Efficient Automotive Waste Heat Recovery: Martin Cleary (GMZ Energy Inc.) - ace082



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 applauded that the team had a balanced approach to develop the TEG. The materials selections and the efforts to reduce the cost while maintaining the performance directly addressed the barriers.

Reviewer 2:

The reviewer concluded that the overall approach was outstanding. The reviewer found that the project is well thought out and comprehensive, yet flexible enough to accommodate learning and changes throughout the project.

Reviewer 3:

The reviewer noted that this project is entering its final year. The reviewer concluded that the project appears to have accomplished the goals/milestones as proposed, and optimization work has been conducted and tested on engines/dynamometer.

Reviewer 4:

The reviewer found that the GMZ team's approach was effective and logical, and contributed to overcoming most barriers. The project team uses nano-structured bulk half-Huesler material instead of skutterudites for high temperature. The reviewer acknowledged that the team clearly presented the reason to use half-Huesler TE material and their TEG design. The reviewer concluded that GMZ has shown in their approach that keeping the cost down is a main objective.

Reviewer 5:

The reviewer described that the goal of this project is to improve fuel efficiency of light duty vehicles by 5%, which the reviewer pointed out is DOE’s goal; TARDEC has a different objective. The project team has identified three broad tasks of scale-up, TEG packaging and durability to that end. The reviewer specified that the team is including tasks associated with materials development, TEG design and integration and vehicle modeling and component integration.

For materials, the PIs choose half-Heusler. The reviewer inquired why this was a better choice than, say, skutterudites. The module design incorporates a hermetically sealed system, which is good. However, the reviewer indicated that the design shown for the automotive TED design seemed quite complicated, if not heavy and potentially very costly. The reviewer inquired about what the PIs project as a cost for the integrated TEG (with cold plates, modules and heat exchangers) that was presented, whether it will be economically effective, and justification for engaging in a detailed investigation of such a design if its cost would be prohibitive. The reviewer commented that this highlighted a concern with the approach that broad targets are used as a basis to motivate the project, but that the individual tasks are not well linked to the broad target. The reviewer offered that perhaps a system level model would provide this link but the presentation did not indicate that.

Reviewer 6:

The reviewer found that GMZ Energy's approach is sound and the barriers appear to have appropriate focus. The reviewer detailed that GMZ's work is focused on two different set of tasks (i.e., those for the DOE, and those for TARDEC). Both applications are being addressed by the half-Heusler modules, which have less TE performance, but far superior mechanical and lifetime expectations. The reviewer suggested that more discussion about the modules would be helpful, but given the time constraints and the public forum, lack of complete transparency is understandable. The reviewer sought clarification about whether the modules are backfilled, and whether the sidewalls of the half-Heusler legs are protected against oxidation/sublimation. The reviewer would like to know what the lifetime of the assembled modules is, and how frequent are device failures. The reviewer asked if the GMZ system is installed on a vehicle, and there is a failure, is the system modular enough to accept a drop-in replacement, or is the system is so hard-wired that an entire new system is needed. The reviewer pointed out the ruggedized requirements from TARDEC, and asked whether the TEG is going to able to withstand impulse forces that might be experienced in combat.

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 up to this point, the GMZ team is making good progress and accomplishing many technical objectives, such as low cost half-Heusler material synthesis, vehicle modeling using AUTONOMIE vehicle modeling platform, TE module performance evaluation, thermal cycling and vibration testing, etc. The reviewer concluded that the project is on schedule.

Reviewer 2:

The reviewer observed that a 200 Watt TEG had been successfully fabricated, and that a 1-kilowatt (kW) unit was being developed.

Reviewer 3:

The reviewer observed that GMZ has chosen a different TE material than most others and justified their decision. The reviewer found that the project team was progressing well though initial design and testing and on track for vehicle demonstration. The reviewer observed that component level reliability testing was more comprehensive than others.

Reviewer 4:

The reviewer found that the use of half-Heusler and the module development had been well planned. However, the reviewer expressed concern that the module performance testing seemed to lack confirmation. The reviewer pointed out that vehicle testing and especially system/device level modeling seemed to have started late in the project.

Reviewer 5:

The reviewer observed that the GMZ work began with both bismuth telluride modules and half-Heusler modules. The reviewer would like to know if an explanation can be given for why the bismuth telluride technology seems to have been dropped. The reviewer acknowledged that without the bismuth telluride lower-temperature stages, there will be a performance penalty, but would like to know what the difference is. The reviewer believed that the he materials work on the half-Heusler materials appeared to be matured, and would like to know if this was true, or whether there was more materials development ongoing.

Reviewer 6:

The reviewer found that the team has pursued activities, and made progress, in materials development and production, TEG design and module reliability, and vehicle modeling. The reviewer described that as to measuring this progress against performance indicators, especially the project team's link to the overall goal of a 5% FE improvement, the accomplishments are weaker. The reviewer expressed concern that there did not seem to be a quantifiable link between the specific work carried out over the past year and how results from that work puts the team quantifiably close to the FE target. The reviewer said that to an extent, the results reported seem removed from fuel efficiency because the PIs did not establish it clearly. The reviewer wondered, for example, regarding the influence of packing fraction, power dissipated and the optimized fin design, what is the precise link of the optimized fin geometry to fuel efficiency. Obviously, this is a complicated question that requires linking all of the sub-system elements to engine load. The reviewer observed that the PIs have not endeavored to address it. The reviewer concluded that, as such, when the accomplishments are viewed against the overarching goal realizing a certain target (in this case 5%) FE improvement, the accomplishments are lacking.

The reviewer noted that the PI reports an “advanced assessment analysis” was carried out. This is an important effort though it was unclear what was involved with it. The reviewer also noted that the PIs reported a cost for the half-Heusler compositions being investigated, which seems to have been taken from a U.S. Geological Survey data. The reviewer wondered if this was the extent of the cost analysis. Also, TEG design appeared to be quite complex as evidenced by the photograph of the assembled TEG shown. The reviewer recommended that the PIs need to indicate the expected cost of this design. Of greater concern for this reviewer could be the tolerances in assembly, especially interface resistance. The reviewer concluded that this matter did not seem to have been addressed in the work presented.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer remarked that the GMZ team appeared to have organized a highly competent and talented group that was well-suited to make continued progress.

Reviewer 2:
The reviewer found that the project team consisted of a good mix of universities, engineering consultants, Tier 1 suppliers and an OEM.

Reviewer 3:
The reviewer remarked that GMZ had demonstrated an ability to work well with collaborators and utilize collaborators' expertise effectively. Because Honda was a collaborator, the reviewer hoped the technology would be commercialized faster for passenger vehicles. The reviewer noted that the transition of a TEG system to the U.S. Army for use on Bradley Fighting Vehicles was also an excellent application within TARDEC's program.

Reviewer 4:
The reviewer observed that added efforts from Honda helps.

Reviewer 5:
The reviewer detailed that this project is collaboration among eight institutions, and GMZ is the lead. The reviewer commented that some of the work assigned to the team members seems to be a bit overlapping. The reviewer pointed out that GMZ, Bosch and Houston are indicated as working on materials. For the reviewer, the differences among these groups and how the results are coordinated was not clear. The PIs indicated that Bosch had reduced their work, or possibly dropped out, with AVL apparently taking over as a replacement for Bosch. The reviewer requested that some clarification on what motivated Bosch to drop out should be provided. The reviewer noted that the oral presentation gave a quite different picture of Bosch’s involvement. The reviewer observed that other elements seem to be in some flux, for example GMZ’s need for a partner to work on the direct current (DC)-DC converter.

Reviewer 6:
The reviewer remarked that as a materials and TEG developer, this team seems to be weaker on the role of vehicle makers. There is a lack of details and planning on actual vehicle integration and involvement of the company.

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

Reviewer 1:
The reviewer concluded that the team should really get the 5% FE improvement in its last project year.

Reviewer 2:
The reviewer commented that the future plan was very good and the team appeared to be on track to complete the planned tasks.

Reviewer 3:
The reviewer found that future work was well balanced between addressing outstanding risk issues and demonstrating performance.

Reviewer 4:
The reviewer remarked that the proposed future research was technically sound and clear with the prospect that there are still challenges for the project, especially when it reaches the point of mass production for commercialization. The project team's proposed tasks, as shown in the presentation, are to continue working on materials, device and module, subsystem and vehicle systems. The reviewer concluded that the degree to which the project had been planned was effective and mitigates risk.

Reviewer 5:
The reviewer acknowledged that the future work planned for DOE seemed considered and thoughtful. However, the reviewer found that there was not really a description of the future work planned for TARDEC, and what the TARDEC needs are.

Reviewer 6:
The reviewer commented that future work includes tasks associated with the broad categories currently part of the work presented in the 2014 review (i.e., materials, modules, heat exchanger design, and vehicle system integration). As this reviewer had noted elsewhere in this review, it was not evident what the specific targets for these sub-tasks are and how success in these efforts would realize the overall objective of a 5% FE improvement.

The reviewer stated that as noted last year, 5% did not seem to be achievable for the US06 cycle based on what GMZ reported last year. The reviewer noted that GMZ established targets in last year's presentation of between 3% and 4%. The reviewer would like to know why the project team sticks to 5% now. The reviewer strongly recommended that the PIs put more effort into quantifying the actual benchmark efficiency target in the remaining period of their effort, and work toward those targets before using more DOE funds to develop what may not be achievable. The reviewer offered that this could be accomplished by expanding the system model to identify all parasitics that contribute to degraded performance (and, thus, would be appropriate to invest with more research efforts to improve), and then identifying from this model how improving materials, interfaces, heat exchanger design, etc., would contribute to efficiency target. Alternatively (or in parallel), the reviewer suggested more vehicle testing of the type reported last year could be useful to establish guidelines on realistic FE targets for a waste heat recovery technology (TE or any other technology for that matter) could realize.

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

Reviewer 1:
The reviewer noted that waste heat was a major loss in efficiency for any petroleum fueled system and TE was one potential method to reduce these losses.

Reviewer 2:
The reviewer found that TEG development, especially using an alternative TE material, was important. With the predicted 3% FE improvement, the TEG was going to be a part of the solution to achieve DOE's petroleum displacement objectives.

Reviewer 3:
The reviewer found that the GMZ work would result in reduced fuel consumption and improved fuel utilization both for civilian applications as well as military (TARDEC) applications.

Reviewer 4:
The reviewer commented that this project supported the overall DOE objectives of petroleum displacement well. It is an excellent example of how we could reduce the fuel consumption of vehicles, light, heavy and military, by harvesting energy through waste heat recovery and direct energy conversion. This reviewer strongly recommended that DOE have more projects like this one because every watt of electrical power that can be harvested could save many problems due to shortage or high cost of fuel/energy supply.

Reviewer 5:

The reviewer offered that this project, indeed any project, would be consistent with DOE's objective if it realized a reduction of petroleum use. The reviewer summarized that the PIs' approach here is to use TEG modules with half-Heusler materials to recover waste heat from the exhaust stream. The result of this effort would presumably alleviate the electrical requirements that normally would be derived from an alternator, lighten the load on the crankshaft and thereby improve FE.

The reviewer summarized that the presentation noted the DOE objective of a 5% FE improvement as a goal in the work (the project team also noted the TARDEC relevance of developing a 1kW TEG for a Bradley Fighting Vehicle; this component is not specifically evaluated in this review though the tasks to achieving it are undoubtedly folded into the work related to the DOE objectives). As the reviewer previously noted, GMZ's 2013 presentation appeared to call into question the relevance of the 5% target, though the project team continues to use 5%. The reviewer commented that some clarification is needed. This target would be very specific to the drive cycle and specific model used. It seemed to the reviewer that, based on last year's presentation, a more target would be between 3% and 4%. The reviewer found that it was unclear why the project team would work towards a target that past work suggests may not be achievable.

The reviewer observed that the presentation also noted relevance in terms of materials, production of TE modules, reliability, finalizing the design, and vehicle modeling and testing. The precise connection between these activities and the efficiency target was cast only in the broadest terms. The reviewer said that this is likely the result of not quantifying or knowing how all the ingredients to a successful TE integration into an automobile would combine to influence efficiency. All of the following will have an impact: materials; TEG design; interfaces; heat exchanger and flow configuration; and temperature. The reviewer concluded that without a good handle on how the broad tasks will impact efficiency, it is unclear how specific goals or targets for the individual tasks are realistic or well thought out.

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 were well matched to the project plan and goals.

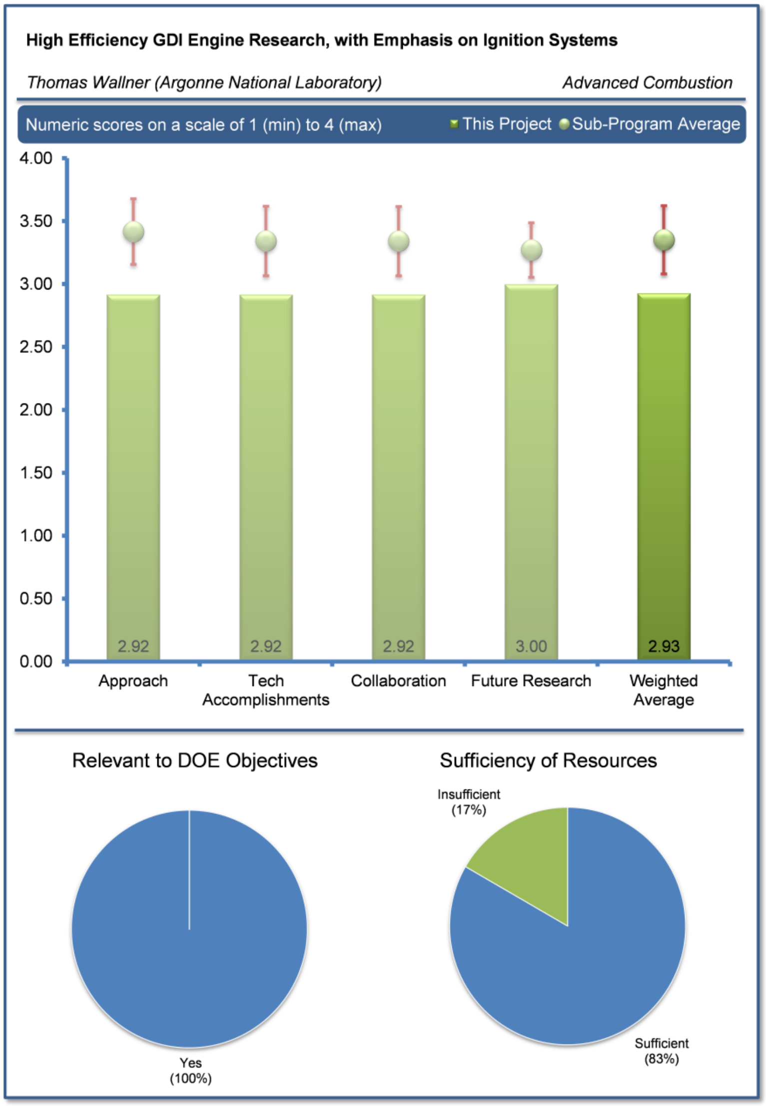
Reviewer 2:

The reviewer commented that the resources for the project to achieve the stated milestones in a timely fashion were sufficient. The reviewer recommended that this project continue to be funded so that the mission in reduction of fuel consumption can be achieved.

Reviewer 3:

The reviewer found that the budget was in line with other projects of this type. The reviewer was worried that the target FE goal may not be achievable. The reviewer suggested that more effort should be put into those aspects of the project that will help better specify what the PIs should be working toward than to simply continue on the current path. The reviewer thought that this can, at least over the next year, be done at a much reduced level compared to the 2013 expenditures by some vehicle testing along the lines of what was reported last year.

High Efficiency GDI Engine Research, with Emphasis on Ignition Systems: Thomas Wallner (Argonne National Laboratory) - ace084



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer remarked that the experimental methods are creatively designed to address the critical barriers to dilute combustion. The modeling and experimental program has suitable objectives, enhancing the probability of success.

Reviewer 2:

The reviewer commented that the approach of coupling single cylinder engine test results with 3D CFD modelling is useful.

Reviewer 3:

The reviewer said that the ignition function is critical, and careful experiments and modeling will be very useful. The reviewer found that the plan to identify what features are critical and how these features interact with engine flows is very useful.

Reviewer 4:

The reviewer detailed that the PIs were using a RANS approach to correlate to cycle-to-cycle variability. This approach in CFD has been of debate in the recent literature. The reviewer would like to know if the PIs considered running an LES computation to test if the conclusions hold true.

Reviewer 5:

The reviewer summarized that the project seeks to provide robust lean-burn and EGR-diluted combustion technology and controls, relevant to boosting and downsizing engines. The project seeks to overcome limited lean and EGR-diluted operating range, lack of ignition systems for lean/dilute combustion, and absence of robust modeling tools. The reviewer suggested that the roadmap, including targets and specific milestones, may be better laid out. The reviewer expressed concern that there is a sense the project is improvising as it moves ahead. This could be better represented.

Reviewer 6:

The reviewer cautioned that there seemed to be duplication of effort between this work and ace006 by Isaac Ekoto in SNL. Both were proposing to evaluate advanced ignition systems. The reviewer detailed that this work only involved a metal engine and no optical diagnostics. The reviewer also observed that a RANS model was being used to predict cyclic variability, which may not have the necessary physics. The reviewer asked why the project is not using an LES model.

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

Reviewer 1:

The reviewer complimented that the technical accomplishments, though incomplete, were poised to provide very useful insight into the fundamental causes of combustion instability and variability that are the chief barrier to highly-efficient dilute combustion.

Reviewer 2:

The reviewer found good progress on meeting milestones. The reviewer commented that results from analysis of cyclic variability had led to evaluation of alternative ignition concepts.

Reviewer 3:

The reviewer commented that so far, the project team had a good experimental base. The addition of optical access will be very helpful.

Reviewer 4:

The reviewer remarked that the work seemed to be progressing well, status shows it has upgraded to spray-guided DI configuration, it has completing ranking of ignition systems, performed cyclic variability study with dilute operation, evaluated various advanced spark-based ignition systems, and have begun to meet with SNL to coordinate collaboration on ignition system projects.

The reviewer suggested that cyclic variability study and the correlation between efficiency and COV, especially the mechanism for introducing the perturbation, may need to be explained better. The reviewer also suggested that authors may need to tie in the overall goals with the specific work performed, which will require maintaining visibility on the performance targets sought for the improved performance.

Reviewer 5:

The reviewer detailed that the PIs were correlating COV of indicated mean effective pressure IMEP with variation in pressure traces for 10 cycles. To better understand these results, the reviewer would like a better understanding if the predictions are an artifact of the physics or the numerical setup. The reviewer asked do these conclusions continue to hold true with greater than 10 cycles. The reviewer offered as an example, if the PIs removed the first 10 cycles, would the same conclusions be drawn when sampling cycles 10-20. The reviewer would like to know what flow boundary conditions are being used, and whether the PIs are actually modeling the flow through the intake manifold or simply specifying constant conditions at the port entrance. The reviewer asked how sensitive the computations for a given set of boundary conditions were and small perturbation to the ignition model. The reviewer would like to know how many engine cycles were used for the experimental data shown in Slide 7 and Slide 10.

Reviewer 6:

The reviewer commented that the spark duration results shown with the Altronic Ignition system seem low with respect to industry standard. The reviewer pointed out that both the single as well as the multi spark durations are in the range 0.4 to 1.2 ms. The reviewer noted that typical automotive production ignition systems result in about 1.0 to 2.0 ms for the secondary arc duration. This parameter may have a very strong influence on the dilution tolerance. The reviewer expressed surprise that doubling the ignition energy did not have much of an effect in decreasing COV in the 0% to 20% range. Data should be taken at smaller increments beyond 20% EGR to properly assess ignition system differences, and not just base it on one point at an EGR of 27%. The reviewer said that the induced ignition and injection perturbation experiments can be mined further by plotting results as a function of ignition delay (0% to 10% mbf) and also plotting just the -1 deg. and the +1 deg. data. The reviewer would like to know what new knowledge this work contributes. The reviewer observed that these kinds of studies were conducted by industry 20 years ago and effects are well understood.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed good project team collaboration, and remarked that the optical engine work will be very important.

Reviewer 2:

The reviewer observed that collaborations were mainly with the U.S. DRIVE ACEC Tech Team, several ignition system developers, and one other national laboratory.

Reviewer 3:

The reviewer commented that the partnerships appeared to be appropriate for the present project objectives, but ultimately closer collaboration with industry will be needed to transfer the understanding gained toward commercial LD engines.

Reviewer 4:

The reviewer suggested that the team could be revised to include various suppliers in the ignition area, and that the presentation mentioned that there is an effort in this direction.

Reviewer 5:

The reviewer would like to know how this project work correlated with the advanced ignition studies being proposed at SNL by Ekoto and Sjoberg.

Question 4: Proposed future research – the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate 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 complimented that this proposed future research seemed like an excellent plan. The corona ignition and the optical work are of great interest.

Reviewer 2:

The reviewer commented that the proposed future work would address a critical barrier for an important LD engine technology. The potential impact is high.

Reviewer 3:

The reviewer found that project plans seemed reasonable to continue program progress.

Reviewer 4:

The reviewer summarized that the project proposes to continue to determine applicability of RANS-based 3D simulation approach for flame propagation and combustion stability under dilute (lean/EGR) operating conditions and finalize assessment of laser ignition potential. The reviewer suggested that authors need to tie in the overall goals with the specific work performed, which will require maintaining visibility on the performance targets sought for the improved performance.

Reviewer 5:

The reviewer suggested that the PIs consider running additional cycles to test their modeling approach.

Reviewer 6:

The reviewer expressed concern that the laser ignition data provided was very scant. More data and understanding of ignition with the free-air laser should be provided (e.g., how did the system respond to laser output energy). The reviewer suggested that the actual nature of the laser beam and its location in the cylinder should be provided. The reviewer commented that achieving a 20% EGR tolerance is nothing noteworthy. The reviewer would like to know what the plans are to achieve 30% EGR tolerance and with what kind of an ignition system.

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

Reviewer 1:
The reviewer remarked that boosted EGR engines were critical for manufacturers to achieve future efficiency goals cost-effectively, and this work may significantly impact the technology.

Reviewer 2:
The reviewer stated that the project had very relevant for dilute combustion SI engines, which may be the mainline engines of the future.

Reviewer 3:
The reviewer stated that exploring engine concepts such as lean, boosted GDI that can potentially improve FE and reduce emissions is consistent with DOE objectives.

Reviewer 4:
The reviewer remarked that advanced ignition is a key to igniting lean, highly dilute mixtures.

Reviewer 5:
The reviewer commented that the project promotes improved tools that will help in the overall fuel efficiency roadmap. Dilute combustion in SI engines offers the potential for decreasing petroleum consumption.

Reviewer 6:
The reviewer found the project to be relevant, but the impact this project might have was going to be very minimal.

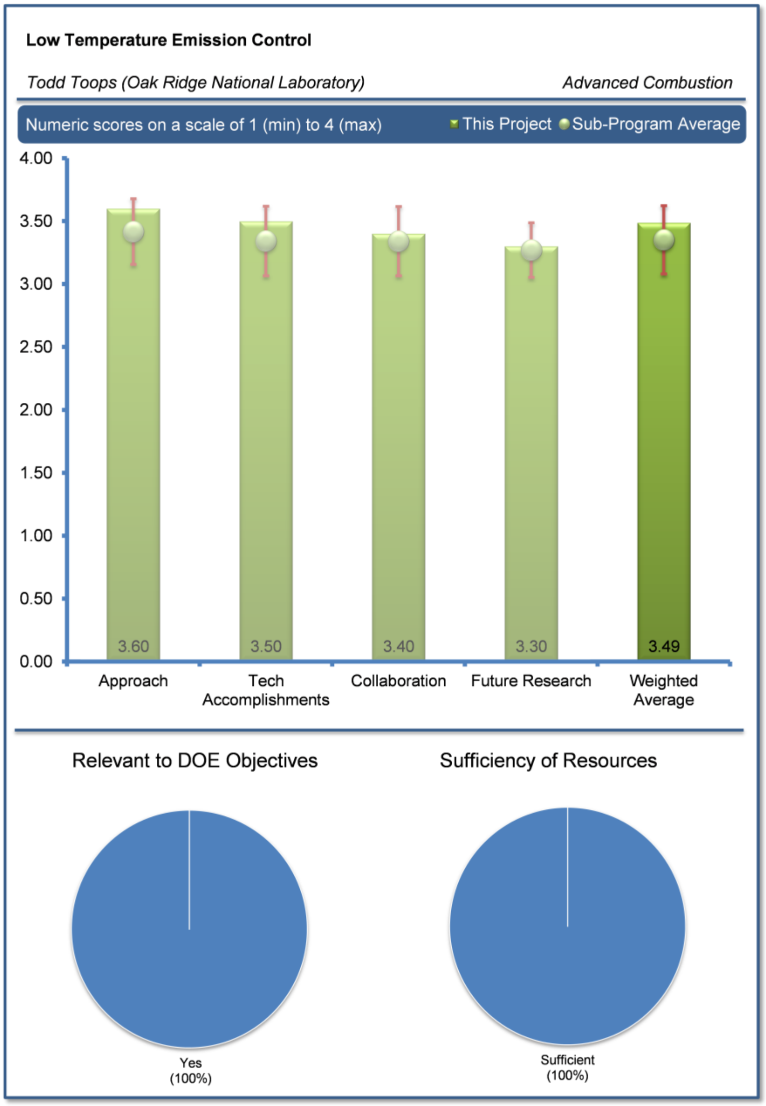
Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that greater resources were needed to accelerate development in this project area, to maintain pace with industry efforts.

Reviewer 2:
The reviewer said that the resources seemed sufficient, but the project may need more if the optical work has to be paid from this budget.

Reviewer 3:
The reviewer remarked that the project's resources were sufficient.

Low Temperature Emission Control: Todd Toops (Oak Ridge National Laboratory) - ace085



Reviewer Sample Size

A total of five reviewers evaluated this project.

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

Reviewer 1:

The reviewer indicated that the range of materials and range of techniques used is excellent.

Reviewer 2:

The reviewer found that the project has a fair approach to characterizing what needs to be done. Considering that this project is mostly about catalyst development and investigation, is the reviewer said it was good to see PNNL is on-board to capitalize on their strengths and know-how in this regard.

Reviewer 3:

The reviewer found that in general, this was a very good approach and consistent with the ACEC roadmaps for uncovering new materials that function at 150°C. However, according to this reviewer, demonstrating the performance of the novel materials under more realistic conditions earlier in the discovery process would minimize the amount of time characterizing a formulation that will not function in vehicle exhaust.

Reviewer 4:

The reviewer detailed that the project was investigating catalysts with good CO conversion without interference from HC or NO_x was a good first step toward developing catalysts that also light-off at low temperatures for HC and NO_x, as the exothermic release from CO oxidation provides extra heat for the HC and NO_x conversion. The reviewer commented that the project was investigating the individual and combined effects of HC and NO_x on CO light-off on Slide 13 is a great approach. The reviewer added that investigating the thermal durability of the new catalysts would be critical. The reviewer clarified that if the catalyst was intended for gasoline engines, the durability needed to be assessed under lean, stoichiometric, and rich conditions.

Reviewer 5:

This project is one of the efforts that harmonizes low-temperature combustion technologies. This is the second year since this project was migrated from the basic energy science (BES) side of program; however, according to the reviewer it still has not addressed potential challenges enough to be considered for the real-world application, such as sulfur poisoning and thermal stability.

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

Reviewer 1:
The reviewer found that the results from the new co-precipitated CuO_x, CoOy, and CeO_2 (CCC) catalyst formulation and on CeO_2-Zr O_2 formulation appeared interesting.

Reviewer 2:
The reviewer observed very novel approaches to developing new materials. Sulfur and HC tolerance should be demonstrated early in the selection process. The reviewer pointed out that thermal durability was also a major concern that was being investigated. According to the reviewer, low temperature activity is essential for new combustion approaches.

Reviewer 3:
The reviewer observed the project team's great progress in developing non-PGM catalysts including the Au/Cu catalyst and CCC catalyst. The reviewer also observed good work on washcoat modifications with zirconium (Zr) as well.

Reviewer 4:
This reviewer opined that advances in finding ways of improving low temperature performance are broad, and suggested that even more effort in aging and response to poisons would be useful.

Reviewer 5:
The reviewer said the project has screened many materials; however, the project needs a more systematic approach to look into new materials with some rationale behind.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer commented that incorporating a supplier to provide guidance and advice was essential for these materials. The reviewer observed a good use of supplier and other resources in this project. The reviewer also thought the CLEERS connection is a benefit.

Reviewer 2:
The reviewer observed that the project had active collaboration with BES researchers, CLEERS, USCAR and U.S. DRIVE.

Reviewer 3:
The reviewer observed project team's good collaboration with Johnson Matthey and University of Tennessee.

Reviewer 4:
The reviewer noted that the team included collaborators from two universities, PNNL, Johnson Matthey, and BES. The reviewer commented that collaboration did not however seem to include a strong role from Johnson Matthey, and the reviewer did not know exactly how the outcome was to be shared with other catalyst outlets on a pre-competitive basis.

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

Reviewer 1:
The reviewer affirmed that the proposed future work was clear and consistent with the remaining challenges and the overall target path.

Reviewer 2:
The reviewer observed that the proposed future research was a fairly sound technical path forward.

Reviewer 3:
The reviewer thought the project needed a more systematic plan and deliverables.

Reviewer 4:
The reviewer commented that for catalysts planned for gasoline applications, the project needs to assess the effect of high temperature rich operation on the catalyst. The reviewer noted that some catalysts look good after lean aging but degrade after rich aging (e.g., SCR catalysts).

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

Reviewer 1:
The reviewer said improved combustion systems that reduce fuel consumption will produce lower exhaust temperatures. The reviewer affirmed that this low-temperature catalyst project would be extremely important to enable such improved combustion systems.

Reviewer 2:
This reviewer commented that improvements in this temperature range are very helpful.

Reviewer 3:
The reviewer said that this project supported USCAR/U.S. DRIVE initiatives to address the need for low temperature aftertreatment to produce viable solutions for emerging, higher efficiency combustion strategies.

Reviewer 4:
The reviewer said yes, the project did support overall DOE's objectives.

Reviewer 5:
The reviewer noted that new combustion strategies produce higher FE while also driving exhaust temperature lower. Hence, synergistically this project supports DOE's charter.

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

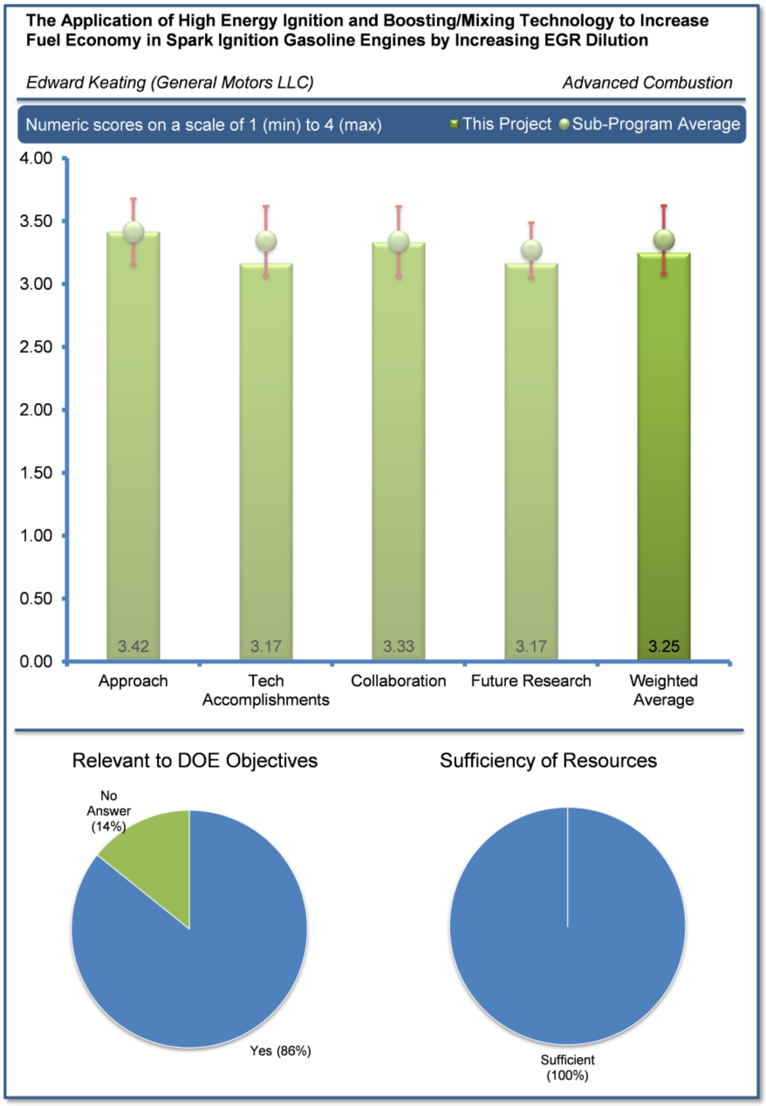
Reviewer 1:
The reviewer concluded that this project was appropriately funded and staffed with researchers with the required knowledge base.

Reviewer 2:
The reviewer said that the funding seemed sufficient for the project.

Reviewer 3:
The reviewer found that the funding level and resources applied to this project were consistent.

Reviewer 4:
The reviewer described that the catalyst technology emerging from this project would be an industry game-changer. The reviewer recommended that the project should have integrated major involvement from key catalyst suppliers (in a pre-competitive set-up) and/or a strong integration of a university catalysis R&D in the project (the role of the University of Tennessee is said to be a graduate student, but no explanation was provided on what exactly the graduate student contributed to the project.)

The Application of High Energy Ignition and Boosting/Mixing Technology to Increase Fuel Economy in Spark Ignition Gasoline Engines by Increasing EGR Dilution Capability: Edward Keating (General Motors LLC) - ace086



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 found that the team's approach was balanced to address the barriers and technical challenges.

Reviewer 2:

The reviewer detailed that the project was looking at all the levers to increase gasoline engine efficiency, and specifically highlighted combustion stability (mixing and hydrogen via D-EGR, spark), thermal losses, and pumping losses. The reviewer noted that much of this work had likely been done by SwRI in the HEDGE consortium, but this group is building on that on a likely future platform base.

The reviewer liked the baseline comparison low pressure loop (LPL) EGR as a real current engine baseline. The reviewer would have liked to see what D-EGR and all the bells and whistles could bring incrementally. The reviewer observed a very impressive approach with much interest.

Reviewer 3:

The reviewer commented that with the push towards engine downsizing, almost all of the companies had adopted the technology mix of turbocharging with increased EGR dilution, improved ignition, and high CR. Moreover, this technology mix offered significant improvements in engine thermal efficiency.

The current project by GM plans to build upon the technologies developed previously under the HEDGE consortium at SwRI. The two new technologies brought to the table in this project in addition to the ones mentioned above are dedicated EGR, and low surface area to volume ratio combustion chamber. While these two technologies introduce novelty, it remains to be seen whether they offer any additional performance improvements without any detrimental implications.

Reviewer 4:

The reviewer remarked nice work to demonstrate an interesting advanced concept and sort out the issues. This reviewer expressed surprise at the low fuel consumption gain target of 12% versus a naturally aspirated (NA) engine base. The reviewer commented that most people say boosted/downsized engines get 15-20%; the reviewer would like to know why this advanced technology gains less. SwRI claims very low BSFC for dedicated EGR.

Reviewer 5:

The reviewer observed an excellent approach to apply HEDGE consortium-developed dedicated EGR cylinder technology to a four cylinder GM engine for potential productive application for full value proposition analysis on midsized vehicle. The reviewer thought that it was good to baseline low-pressure EGR downsized boosted 2.0 liter (L) compared to 2.4L normally aspirated engine. The reviewer noted that the next steps are to test the proposed concept with high energy ignition. The reviewer suggested that a possible improvement is to clarify the performance (power and engine out emissions) target of the R&D engine operating on three power cylinders and one EGR cylinder and how this relates to the vehicle needs and TP emission targets. The reviewer noted that baseline engines are both more powerful than the dedicated EGR engine.

Reviewer 6:

The reviewer said that the project addressed ignition issues and barriers that can enable more advanced combustion techniques, such as higher EGR dilution and/or D-EGR. These ignition technologies should be transferable to other combustion approaches as well. There is some concern about the relative focus between the low-pressure EGR and D-EGR approaches. The reviewer was unclear how the two strategies would be compared.

Reviewer 7:

The reviewer said EGR quality (SwRI) H_2 content produced, HEDGE system, and that all dedicated EGR gets circulated in the intake. The reviewer indicated that VGT is diesel like, and that bypass system designed and implemented during the project.

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

Reviewer 1:

The reviewer commented project team's solid work toward the objectives.

Reviewer 2:

The reviewer observed a good establishment of baseline and putting in infrastructure. The last year was essentially base-building with no major surprises or developments. The reviewer concluded that the next six months will be very interesting.

Reviewer 3:

The reviewer said that the GM team has determined a well thought-out plan of execution for the project. The project team has performed 1D modeling of the system in Phase 2 that was followed by dynamometer testing of the engine to establish a baseline in Phase 3. In Phase 4 the project team plans to build and test an engine equipped with D-EGR and low S/V ratio combustion chambers. The reviewer requested that the project team please correct the heading in Slides 3 and 4 from "RELEVENCE" to "RELEVANCE".

Reviewer 4:

The reviewer noted good progress to prepare state of the art baseline data and modeling data. The reviewer observed that the dedicated EGR engine test data was not available after two years of project and 60% of budget is getting tight. Especially emissions issues can present significant challenges and dedicated EGR engine emissions may be difficult to manage particularly on cold start. The reviewer noted that dilution bypass was an interesting approach with some very good possibilities to enhance catalyst light-off if managed well. The EGR cylinder can provide excess O_2 to and heat to light-off the catalyst more quickly. The reviewer said that other schemes may be possible such as cylinder deactivation on the EGR cylinder.

Reviewer 5:

The reviewer said that the technical accomplishments were impressive. The reviewer noted that there seems to be lack of plan to address the role of various models and designs of vehicles. The reviewer noted that EGR performance was a system issue, and improvement in one specific vehicle may not directly translate to other vehicles. The reviewer recommended that the limitation needs to be addressed.

Reviewer 6:

The reviewer said that good progress was made on the engine design and build. A modest improvement in FE was demonstrated with the low-pressure EGR approach. The reviewer noted that a major limitation with the project was the lack of information on the D-EGR approach. A lot of the D-EGR research was performed under a SwRI consortium (HEDGE) that is not public, but this project is public. The reviewer suggested that it would be better if this project produced publications on the activities related to D-EGR because this is a public project (no publications or presentations listed to date for the project).

Reviewer 7:
The reviewer commented low-pressure EGR loop added in Phase three, and a 3.2% improvement to baseline FE but performance not equal. The reviewer noted two spark plugs per cylinder. The reviewer described the EGR bypass valve as "innovative."

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that SwRI was the lead organization on the base approach–dilution of SI engines with EGR and all the auxiliaries. The reviewer complimented that having SwRI as an engaged partner with a leading OEM on combustion will ensure success. The reviewer cannot recommend any additional collaboration.

Reviewer 2:
The reviewer noted that GM has partnered with SwRI, who bring to the table expertise gained through previous HEDGE consortium efforts.

Reviewer 3:
The reviewer observed project team’s close relations with SwRI to take advantage of their prior work.

Reviewer 4:
The reviewer said that the project’s necessary partners are engaged and seemed to be working well.

Reviewer 5:
The reviewer said that the project’s role of the sole collaborator is clear.

Reviewer 6:
The reviewer observed that the project team had only SwRI as a partner.

Reviewer 7:
The reviewer acknowledged the project team’s collaboration with SwRI, but said no university or national laboratory collaborations.

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

Reviewer 1:
The reviewer found that the plan looked excellent. The reviewer noted that the rubber hits the road this year, and observed the following approach to be very logical: run the engine; analyze the results; fix the deficiencies; and repeat.

Reviewer 2:
The reviewer observed a solid plan for future research.

Reviewer 3:
The reviewer noted that the project’s future work will focus on D-EGR approach.

Reviewer 4:
The reviewer commented that the project was on track to complete the planned tasks.

Reviewer 5:

The reviewer commented that a four-valve single plug is the path of the future, and low pressure EGR loop added.

Reviewer 6:

The reviewer remarked that some additional projections of power and emissions from modeling may improve forward of barriers and directions for future work. The reviewer suggested that exhaust aftertreatment possibilities should be outlined based on projections from modeling, planned control schemes and the HEDGE data.

Reviewer 7:

The reviewer commented that D-EGR appeared to be a technology that introduces new challenges for engine control across all speed-load conditions. The current method of using an 11-point steady-state operation as the test matrix might hide the technical challenges that one would face in transient operation of the engine. The reviewer said that it might be well worth the effort to finally demonstrate the operation of the engine using one of the transient cycles.

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

Reviewer 1:

The reviewer said that the project aims to achieve 12% fuel efficiency improvement while meeting the EPA emission regulations. The reviewer acknowledged that the project is already through Phase-1 work, and the GM team has demonstrated an approximately 3% FE improvement. According to the reviewer, should the technology mix to be tested in latter phases result in further FE improvements, the project team could significantly reduce the nation’s petroleum fuel consumption. The reviewer noted that an added benefit is reduced GHG emissions.

Reviewer 2:

The reviewer said that this project’s technology may enable significant FE gain.

Reviewer 3:

The reviewer commented that potential OEM production pathway for HEDGE Consortium dedicated EGR concept being evaluated for performance and value for potential savings of 12% FE.

Reviewer 4:

The reviewer confirmed that improvement in FE through new EGR design will have direct impact on DOE's petroleum displacement objectives.

Reviewer 5:

The reviewer found that this project supported the petroleum displacement goals of DOE and specifically that this project addressed barriers associated with more fuel efficient engines that utilize dilute gasoline combustion.

Reviewer 6:

The reviewer commented that diluted charges enabled highly-efficient gasoline engines. High energy ignition is a leading approach to enable these engines. The reviewer said that compression ignition was another way, and both need to be evaluated.

Reviewer 7:

The reviewer said that global barriers were not identified by the project team.

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

Reviewer 1:

The reviewer said that project’s resources seemed to be appropriate to the work level.

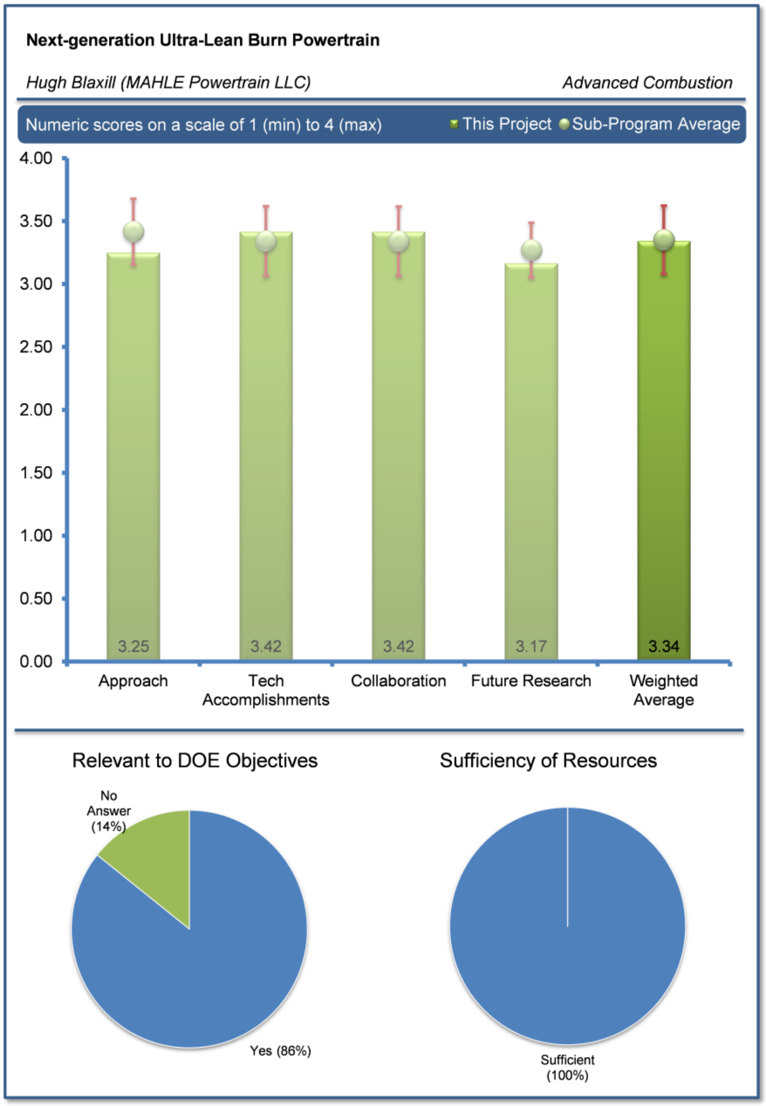
Reviewer 2:

The reviewer found that it looked like there was plenty of money left for the project team to run and optimize the engine.

Reviewer 3:

The reviewer concluded that project team's allocated funds are sufficient, and recommended inclusion of a transient engine test.

Next-generation Ultra-Lean Burn Powertrain: Hugh Blaxill (MAHLE Powertrain LLC) - ace087



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 detailed that Mahle proposes to develop a fueled pre-chamber sparkplug that can serve as an improved igniter under ultra-lean engine operational conditions. This in turn will significantly improve the engine efficiency and further reduce the aftertreatment burden to reduce emissions.

Reviewer 2:

The reviewer said that the approach was impressive, and that early publications looked quite optimistic. The reviewer was delighted to see this work progress, and commented that the technical plan looked good. The reviewer noted a nice mix of single cylinder, simulation, multi-cylinder, and simulation.

Reviewer 3:

The reviewer found that the team had a balanced approach to addresses the technical barriers and challenges.

Reviewer 4:

The reviewer detailed that PFI was the main fueling mechanism, and that design optimization was in Phase 1, and that Phase 2 is design validation with 3D simulations.

Reviewer 5:

This reviewer expressed skepticism about pre-chamber designs because they tend to increase heat transfer losses and require an internal pumping work. The reviewer commented that perhaps the analysis would show how these issues could be overcome.

Reviewer 6:

The reviewer acknowledged that the goals were appropriate, and noted the following: achieve 45% thermal efficiency with comparable or lower emissions on a light-duty SI engine; achieve 30% drive cycle FE improvement over comparable gasoline engine on a light-duty SI engine; and achieve a cost effective system with minimal changes to existing engine. The reviewer observed that the testing approach was good and typically employed for effective combustion projects (i.e., optical engine, single cylinder metal engine, simulations, multi-cylinder engine, and mini-map to project cycle efficiency and emissions). The reviewer found that the technology approach (turbulent jet ignition [TJI]) shows good initial promise to achieve goals.

Reviewer 7:

The reviewer noted that this project addressed barriers associated with enabling lean gasoline combustion. The project addresses ignition and emissions aspects of lean gasoline. The reviewer remarked that the approach to utilize pre-chamber combustion with resulting jet ignition to the cylinder charge is not new but is nonetheless worth pursuing.

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 observed single cylinder work yielding good results and direction, and an impressive extraction of information. The reviewer also noted interesting nozzle diameter results and analyses, and excellent incremental efficiency improvements. The reviewer observed CFD modeling and blowback to pre-chamber.

Reviewer 2:

The reviewer detailed that Mahle has developed a fueled prechamber igniter and further optimized its operation through computer simulations and tests performed on a single-cylinder engine. The net result is the demonstration of an overall efficiency of 46% that surpasses the DOE goal of 45%. Also, the project team demonstrated extension of lean ignition limit to a Lambda value of 2.0 with a NO_x emission level as low as 20 ppm. The reviewer found that these were very impressive achievements that point to the fact that the present development can enable a true lean-burn gasoline engine in the very near future. Referencing Slide 22, the reviewer inquired about why indolene and propane were used as pre-chamber fuel, and how the TJI concept compared with other fueled pre-chamber concepts pursued elsewhere.

Reviewer 3:

The reviewer observed good data so far. The reviewer noted that HC goes up when lean enough for NO_x. The reviewer asked if the project team could control it at such a low exhaust temperature. The reviewer asked if the NO_x was low enough to meet SULEV30 without a NO_x catalyst. The reviewer pointed out that it was essential to consider realistic losses for the boost system, and that a low exhaust temperature may require a difficult boost system and may lose a lot of the apparent efficiency gains.

Reviewer 4:

The reviewer observed an excellent result to meet the goal of 45% thermal efficiency on light-duty SI engine at some test points with NO_x emissions comparable to or below existing SI engines. The reviewer had some question about limited data points presented at 45% being possible across the map, and how the turbocharger emulation was included in thermal efficiency. In some TJI design cases lower NO_x was also accompanied by somewhat higher HC emissions than SI engine for some design configurations. The reviewer remarked excellent work to characterize pre-chamber activity and performance through testing and modeling. The reviewer noted that 30% predicted drive cycle FE improvement over comparable gasoline engine vehicle still needed to be done. The reviewer noted that value analysis to confirm claimed cost effectiveness of the system, and still to do relative to base and competing concepts. The reviewer commented that the system required a head, piston, combustion chamber modification and two sets of injection systems/controls. The reviewer pointed out that some DI only concepts (without PFI) achieving similar results.

Reviewer 5:

The reviewer observed very good progress shown on the understanding and modeling of the TJI system. The explanation of jet penetration into the cylinder was nice and demonstrated significant accomplishments in the understanding of the process. The reviewer observed that low NO_x emissions were demonstrated and clearly showed a benefit of this approach; however, HCs increased at those AFRs. Efficiency improvements were noted, but it was difficult to ascertain the efficiency of this approach relative to other lean gasoline combustion approaches. The reviewer suggested that the efficiency metrics/goals in the U.S. DRIVE ACEC Tech Team Roadmap needed to be adopted by this project to better show results compared with other combustion approaches. The reviewer pointed out that a lot of industry input went into those goals/metrics; so, it was best to use them. The reviewer observed that the major limitations associated with this approach that had not been addressed by the project included durability (to coking/clogging) and transient operation/control (especially with respect to NO_x and HC emissions). The reviewer recommended that the project needed to address these issues in the next stages, and also that PM emissions data were needed.

Reviewer 6:

The reviewer would like to know if initiated CFD model correlation. The reviewer noted that orifice optimization was the key to good flame front generation; over penetrate results in quench at the wall. The reviewer pointed out that NO_x in ppm made the lambda effect more exaggerated.

Reviewer 7:

The reviewer acknowledged that the technical accomplishments of the team were very significant. There seemed to be a slight lack of balance between modeling and testing. The reviewer mentioned that some of the testing results shown were clearly off-scale. The reviewer thought that a balanced approach should be using various filters to capture both low temperature initial injection and the combustion process.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that the project team and collaboration were well coordinated.

Reviewer 2:

The reviewer acknowledged that Mahle is partnering with Delphi to leverage their expertise on ignition systems and fuel injection systems. Moreover, Mahle is using a Ford engine as the platform for testing. The reviewer concluded that the partnerships are ideally suited for the proposed development.

Reviewer 3:

The reviewer pointed out a solid relationship with Ford and the project team.

Reviewer 4:

The reviewer noted that the project had an excellent demonstration of interest and support from Tier 1 and an OEM through direct support, or materials/work in kind.

Reviewer 5:

The reviewer commented that this was clearly a Mahle project with what appeared to be little technical input from Ford. CFD modeling from Delphi plus hardware and direction is probably sufficient collaboration to ensure success to access commercial feasibility.

Reviewer 6:

The reviewer noted the collaborations with Ford and Delphi, but it appeared to this reviewer that most the resources and work was being done at Mahle.

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

Reviewer 1:

The reviewer concluded that the project team’s plans for future work were good, and that the project was on track to achieve the original goals.

Reviewer 2:

The reviewer indicated that the proposed future work entailed further optimization through modeling and further tests. This would be followed through tests on a multi-cylinder engine. The reviewer remarked that these were logical extensions of the current developmental program.

Reviewer 3:

The reviewer observed a logical plan given the overall technical approach. The multi-cylinder engine (MCE) results will certainly be interesting. The reviewer noted that new challenges were anticipated and that the team seemed well-equipped to manage upsets.

Reviewer 4:

As previously mentioned, the reviewer encouraged the project to look closely at heat losses and internal pumping work, and also at after-treatment capability and booting needs.

Reviewer 5:

The reviewer noted a good plan to prepare optimized design and evaluate capabilities on MCE across several test points. All criteria and non-criteria emissions are of interest. This reviewer specifically highlighted HC, CO, NO_x, PM, as well as CO_2/MPG exhaust temperatures for after-treatment considerations, and engine performance to compare to baseline and other combustion concepts. The reviewer suggested that although out of scope for the current project to perform cold work, some potential cold start strategies and concepts to address other possible vehicle system level challenges such as transients, idle, and torque/power performance.

Reviewer 6:

The reviewer suggested that the project's next steps needed to address durability (to coking/clogging) and transient operation/control (especially with respect to NO_x and HC emissions).

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

Reviewer 1:

The reviewer said that the TJI igniter developed in the current program was likely to serve as an enabler for lean-burn combustion in transportation engines. This mode of combustion not only improves the engine efficiency but also reduces the pollutant emissions to very low levels so that aftertreatment may not be necessary. The reviewer concluded that the improved efficiency was in line with DOE's goal to reduce U.S. petroleum consumption.

Reviewer 2:

The reviewer remarked that ultra-lean burn was an attractive approach to deliver high gasoline efficiency with low NO_x emissions. Certainly, work in this field was important and attractive.

Reviewer 3:

The reviewer commented that the project was relevant to FE needs and thus petroleum reduction.

Reviewer 4:

The reviewer commented that potential new combustion technology to provide 30% FE improvement for light-duty applications can significantly reduce petroleum use.

Reviewer 5:

The reviewer stated that improvement of FE via fuel injection system improvement would have a direct impact on DOE's petroleum displacement objectives.

Reviewer 6:

The reviewer said that the project could potentially enable lean gasoline engines which, if commercialized, could significantly reduce U.S. gasoline/petroleum consumption.

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

Reviewer 1:

The reviewer concluded that the team adequately leveraged complementary capabilities.

Reviewer 2:

The reviewer said the project's resources seemed to be appropriate.

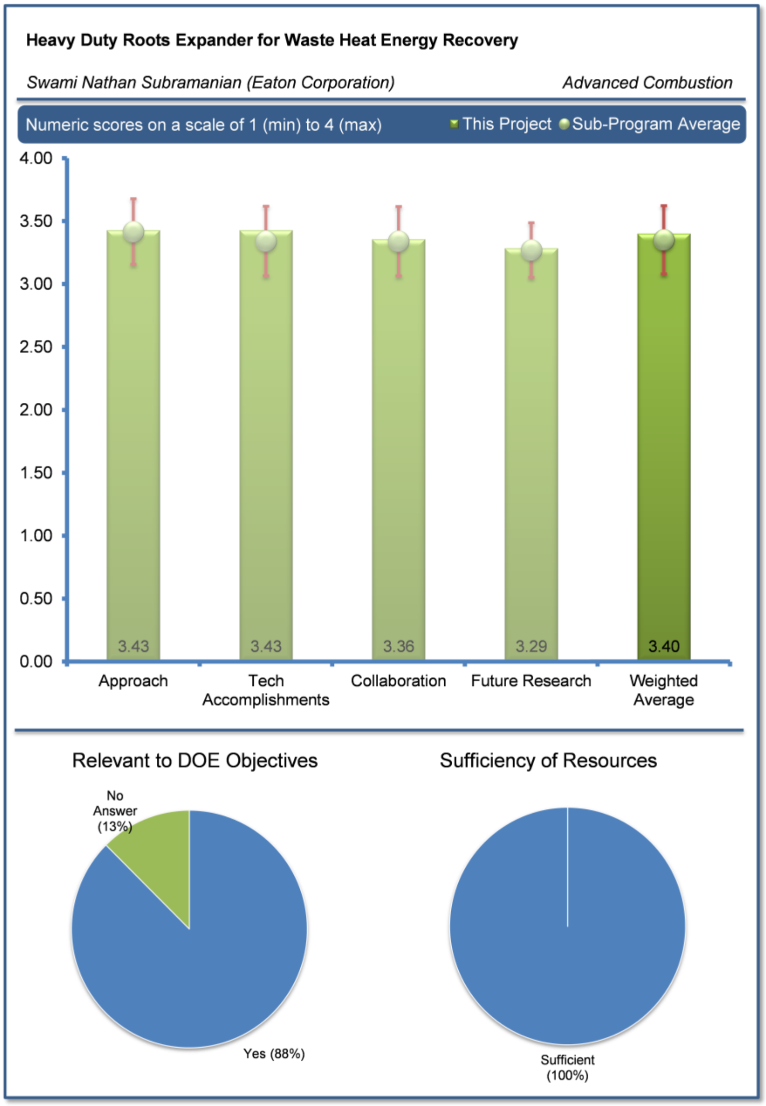
Reviewer 3:

The reviewer commented that the big money spending was coming and that the team built the basic knowledge with relatively low spending on the single-cylinder engine to address issues and keep within budget.

Reviewer 4:

The reviewer commented that resources were sufficient; however, it was unclear why Mahle was only contributing 20% of the total project funding. Most other industry-led projects had a 50/50 government/industry funding model. The reviewer asked if Mahle was committed to this approach, and if so, inquired about matching DOE's funding level.

Heavy Duty Roots Expander for Waste Heat Energy Recovery: Swami Nathan Subramanian (Eaton Corporation) - ace088



Reviewer Sample Size

A total of eight reviewers evaluated this project.

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

Reviewer 1:

The reviewer commented that the approach followed by Eaton to develop a Roots expander for WHR followed a well-thought out plan based on sound engineering principles. This system, once it came to fruition, offered fuel efficiency improvement up to 6% with minimal penalty elsewhere (i.e., cost, durability or emissions impact). Moreover, the roots expander being developed offers low impeller speed, and improved resistance to dual phase working fluids that may result from improper working fluid expansion. The reviewer pointed out that though there were other efforts in the industry to develop WHR systems for on-highway trucks (that by Cummins, for example) the present development was primarily focused on developing one using the unique Roots expander.

Reviewer 2:

The reviewer observed that Organic Rankine Cycle (ORC) WHR was a hot topic and that this program directly addressed many of the issues and opportunities. It was well conceived to build and demonstrate a system for HD trucks.

Reviewer 3:

The reviewer commented that this project addressed barriers with the recovery of waste heat from engine systems to improve overall system fuel efficiency.

Reviewer 4:

The reviewer applauded excellent detailed requirements to design approach for a potential new product from SuperTruck activity. The project is a well-defined spin-off from SuperTruck activity with current goals to improve HD engine efficiency (improvement >5 %) through WHR systems without NO_x and PM penalty. The reviewer noted that the specific focus is a productive design for cost effective, highly durable waste heat recovery system ORC system by roots expander.

Reviewer 5:

The reviewer said the project approach involved ORC to improve expander efficiency in water-based ORC system.

Reviewer 6:

The reviewer observed a typical approach of modeling and bench testing using engine inputs, design and optimization on the bench, and installation on the engine.

Reviewer 7:

The reviewer remarked that the approach to use root extender for waste heat recovery was good. The team seemed to be unaware of the pros and cons of other waste heat recovery option for vehicles.

Reviewer 8:

The reviewer remarked that the approach was technically sound. However, the reviewer was not sure why a John Deere engine was selected with 13 mode cycle to prove the benefits. The reviewer pointed out that the John Deere engine was mainly for off-highway application, while 13 mode cycles were only used for on-highway application for certification cycle. There is disconnection here. The reviewer suggested that the program should be clear where the WHR system would be mainly applied–off-highway or on-highway, where these two applications could have different characteristics with different types of engine calibrations and hardware requirement. The reviewer concluded that due to the high cost of this system, one stone just could not hit two birds.

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 observed the project team's solid results to date. Good analyses seemed to have considered the major issues and identified likely solutions.

Reviewer 2:

The reviewer commented that the team had shown excellent progress in designing a three-stage Roots expander, a test bed to measure its performance, and has further developed an appropriate control scheme and a plan for integration on a HD John Deer engine. The analysis is based on a nine-point mode estimates approximately a 5% fuel efficiency improvement. The reviewer concluded that all along the project, various barriers regarding materials, material compatibility, sealing, and etc. were addressed appropriately. Though the system was overly designed and might lead to a higher cost, it easily lends itself for future optimization through the use of a fewer number of stages.

The reviewer found that other than the physical hardware that has resulted, the knowledge base that resulted from the project – fluid properties of the working fluid, choice of working fluid, control schemes, and etc. – are of long term value. The reviewer noted that a notable exception in this program are inclusion of metrics for added cost and weight resulting from this WHR system. These are factors that have a bearing on transformation of technology to practice.

Reviewer 3:

The reviewer commented on the project team's impressive analyses and optimization. The team was preparing nicely for engine testing with design, procurement, and packaging. The reviewer added that 2014 progress was key to the project.

Reviewer 4:

The reviewer detailed that the project demonstrated with water as working fluid. This worked, but not as good as ethanol. The reviewer added that flow paths were optimized.

Reviewer 5:

The reviewer observed outstanding progress to develop a first prototype productive design for truck OEMs with 6% FE improvement projected, a flexible design for effective use on multiple applications, and cost effectiveness. The reviewer specified a less than 2-3 year payback projected, and consideration for safety of working fluid, which had been a concern. The reviewer detailed that the project evaluated different roots expander ORC WHR system architectures theoretically for optimized system considering heat exchanger layouts on system performance and leading to specifications of roots expander and other required WHR system components. The reviewer added that the project prototyped optimized expander with CFD analysis, bench testing, calibration, and validation durability. The reviewer also noted that valid metrics were presented to demonstrate activity and results, and that the first tests should also focus on road, Class 8.

Reviewer 6:

The reviewer commented that the project demonstrated good progress and was on track. The design and experimental results looked good to date. Furthermore, according to the reviewer the working fluid research is important not just for Eaton but the community in general. More results are needed on system evaluation under transient conditions. The reviewer recommended not only drive cycles, but other simulated transients that may show the optimal and non-optimal conditions where the heat recovery could be performed. More information on cost was also needed; even if exact costs cannot be listed, approximate the percent of engine cost metrics that could be shared. The reviewer pointed out that the control model did not appear to be very sophisticated. The reviewer would like to know if there were plans to develop a model on another platform besides Excel/Visual Basic. The reviewer preferred more appropriate engine control platforms.

Reviewer 7:

The reviewer found that the team had demonstrated the feasibility of recovering heat using the Root extender approach. However, there seemed to be a lack of understanding of how big the system should be in order to achieve the 5% FE improvement. The reviewer noted that the system shown was too small, and that the cost benefit of a large system and the effect of added weight were not addressed.

Reviewer 8:

The reviewer observed that analytical results showed great benefits in Slide 12, which was overly optimistic, and specifically at C speeds. The reviewer would like to know what assumptions were used. The reviewer noted that the expander efficiency at 60% shown in Slide 23 seemed high. The reviewer wondered if the John Deere engine mainly used at C speeds. The reviewer pointed out that for on-highway applications, the engine was hardly seen at such high speed. The reviewer asked how the 6% net FE in Slide 12 was calculated. The reviewer detailed that final FE should be calculated over weighted modes rather than averaged modes.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer judged that the team and collaborators were well organized.

Reviewer 2:

The reviewer said that Eaton had teamed with a number of component manufacturers whose expertise was required for integration of the overall system. The project team had used an off-highway HD engine as the platform to demonstrate the operation of the system being developed. The reviewer pointed out that though this test engine was not an on-highway HD engine, the technology was being tested lends easily for adaptation for on-highway applications. Per the presenter, adaptation for on-highway applications was being pursued outside of this project by Eaton.

Reviewer 3:

The reviewer observed a strong connection with an engine manufacturer, although the reviewer thought it would be nice to also have an on-highway OEM involved.

Reviewer 4:

The reviewer commented that Eaton and AVL were the main partners with what appeared to be good collaboration. The reviewer found that having the “loose” collaboration with Deere (engine only) was troubling, and that the team should try to partner with them or others more involved in engine issues.

Reviewer 5:

The reviewer observed that the project team had a good list of collaborators, although mostly industry.

Reviewer 6:

The reviewer judged the project team’s collaboration to be very good, and asked that the project team please add on-road application partner or on-road test application.

Reviewer 7:
The reviewer remarked that the project team working with John Deere was excellent. However, the reviewer guessed that applications with this WHR system should be for on-highway applications. According to the reviewer, it was hard to justify investment in this kind of expensive system toward off-highway application.

Reviewer 8:
The reviewer pointed out that the project had collaborated with John Deere, and inquired about OEM and off-highway collaboration.

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

Reviewer 1:
The reviewer said that the project's future work plan was good.

Reviewer 2:
The reviewer remarked that there was a solid plan to complete the analysis, build, and demonstration by the project team.

Reviewer 3:
The reviewer concluded that the team was well-poised to move forward. The future work was going to be the key to the program's success.

Reviewer 4:
The reviewer said that the tasks proposed for future research to be conducted in 2014 and 2015 were logical extensions of the developmental effort pursued so far. The reviewer commented that though not included in the promised scope of work, if possible, demonstration and testing of the WHR system on an on-highway truck engine using a transient cycle would be beneficial to correctly assess the net fuel efficiency benefit. The reviewer commented that a long-term operation of the system, say a 200-500 hour continuous operation, would yield information about the long-term durability of the system.

Reviewer 5:
The reviewer remarked that an on-road application by the project team would demonstrate flexibility and performance of design and confirm emission impact.

Reviewer 6:
The reviewer judged project's future work to be good, and suggested that transient operation needs be included in the experimental plan with a focus on defining what how different time scales of engine load changes affect the heat recovery efficiency gains.

Reviewer 7:
The reviewer remarked that the technical direction was clear and that the path to make further improvement was clear too. However, it was not clear what kinds of cycles were to be used for the program. The reviewer wondered if it was a 13-mode, if a John Deere engine would be the best choice.

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

Reviewer 1:
The reviewer noted that project's improvement of engine efficiency supports the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer observed a strong FE impact by the project.

Reviewer 3:

The reviewer stated a potential new product from SuperTruck R&D activity with possibility for 6% fuel savings using waste heat.

Reviewer 4:

The reviewer commented that the proposed development, though aimed towards on-highway trucks, has ramifications towards off-highway and other transportation sectors as well. The reviewer added that the 5-6% FE benefit resulting from this system can easily lead to significant petroleum derived fuel savings. The reduced U.S. GHG emissions resulting from this technology are an added bonus.

Reviewer 5:

The reviewer remarked that ORC WHR is on the 55% BTE roadmaps of all the major HD OEMs. The reviewer added that work is needed and the project will move the application forward.

Reviewer 6:

The reviewer stated that improving heat recovery can improve system efficiency and reduce petroleum reduction, so this project was potentially enabling that approach.

Reviewer 7:

The reviewer remarked that WHR is a solution to improve FE and directly related to engine efficiency. Improving the overall engine efficiency certainly supports DOE's objectives of petroleum displacement.

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

Reviewer 1:

The reviewer concluded that the allocated budget was commensurate with the activities proposed in this project. However, if funding were the limitation, the reviewer asked to please look into adding additional funds to conduct transient tests using an on-highway HD engine. The reviewer remarked that such tests would help determine the true potential of this technology.

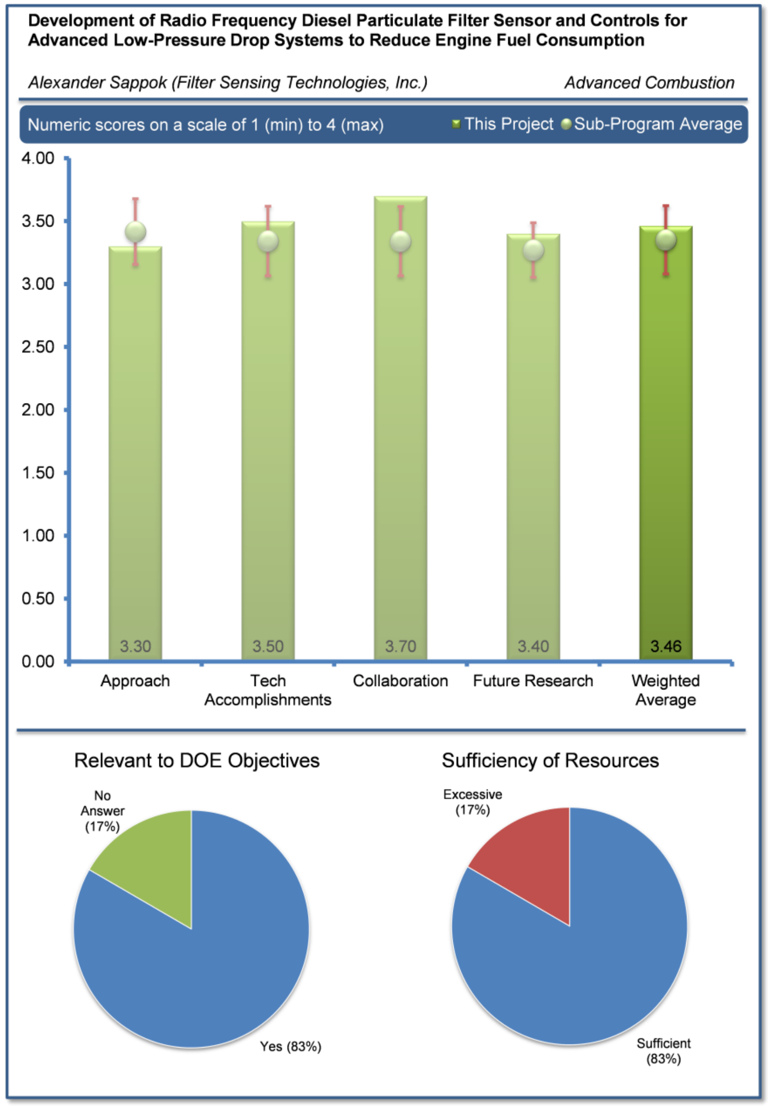
Reviewer 2:

The reviewer commented that the project seemed to be appropriately funded.

Reviewer 3:

The reviewer said that there seemed to be plenty of money available for the project team to move forward.

Development of Radio Frequency Diesel Particulate Filter Sensor and Controls for Advanced Low-Pressure Drop Systems to Reduce Engine Fuel Consumption: Alexander Sappok (Filter Sensing Technologies, Inc.) - ace089



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 a very well laid out program with great collaboration by the project.

Reviewer 2:

The reviewer applauded the outstanding approach to leverage basic, inexpensive radio frequency (RF) technology, including management of key challenges to demonstrate sensor and controls, Proof of Concept, identify and implement a commercially viable sensor package, and define and simplify controls based on first target application use considering the end user application value proposition.

Reviewer 3:

The reviewer remarked that this project was a very interesting concept, and that the program plan was a solid approach to development and toward commercialization.

Reviewer 4:

The reviewer commented that in a typical diesel engine as the DPF soot loading increases the back pressure increases, leading to low engine efficiency. Currently, by measuring the back pressure (heating) regeneration cycles are initiated to burn off the deposited soot. Filter Sensing Technologies (FST) proposes to develop an advanced system based on radio waves that accurately measures in situ soot loading. However, the reviewer opined that FST fails to show that the current system of backpressure measurement is inadequate so that one needs to develop the advanced system. In practical engines, simplicity, low cost and robustness are of prime importance.

Reviewer 5:

The reviewer inquired about a radio frequency sensor for DPF control. This person further reported measurement of PM and ash as well as changes in dielectric properties on the filter measurement, and one-year payback.

Reviewer 6:

The reviewer commented that the overall layout of this project was well thought-out and technically sound, in terms of RF sensor development. RF sensors seemed to provide more information on soot loading than the pressure drop signal typically used in production vehicles, such as uneven soot distribution in the filter as shown in Slide 24. The reviewer said that localized high concentration soot may cause damage to filter so that today's engine regenerates more frequency than appears to be needed as indicated by the pressure drop. However, the reviewer was not clear if this extra information was used as part of the control strategy.

The reviewer described that as the method has been presented, RF sensor signals appeared to be used to measure the overall soot loading on the filter. The reviewer said that it could be more accurate or direct measurement of soot loading. However, it was essentially providing the same information as the pressure drop signal. This reviewer was interested in knowing if the soot distribution information can be reliably derived from the RF sensor and used as a feedback control signal.

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 the project team's comprehensive presentation demonstrating very good progress.

Reviewer 2:

The reviewer applauded that a system development into a miniature unit that could be readily deployed on commercial trucks was commendable. Also, the project demonstrated the operation of this unit on various engine platforms. However, according to this reviewer, the benefits accruing from the use of this advanced unit over a system where back pressure measurement is used in tandem with model based control would strengthen the case for the current development.

Reviewer 3:

The reviewer commented very nice project work, and elaborated that the progress in the design and application was very impressive, especially for a small company.

Reviewer 4:

The reviewer applauded outstanding results. Sensor and controls concept demonstrated, testing facility commissioned, commercially viable sensing element and controls package developed with sensor element integrated in existing exhaust temperature sensor application. The reviewer noted that simplified controls with initial calibration scan provided by device that was developed and tested in a laboratory and fleet environment.

Reviewer 5:

The reviewer remarked that it appeared an impressive team had been assembled to perform the tasks. Significant progress had been made with sensor related development, integration and measurement. With two-thirds of the time used and 58% of the work completed, the project was behind schedule time wise.

The reviewer opined that fleet test fuel saving (Slides 13-14) were not as convincing as it was presented. The reviewer commented that it was not clearly demonstrated that reduced regeneration frequency was the direct result of using RF signals. It could be that the control model was more aggressive. The reviewer wondered if the pressure drop signal in combination with the control model produced the same regeneration event. When claiming improvement over the current technology, it is more convincing if a direct comparison is made. The baseline used for comparison (refuse truck with 2009 Volvo/Mack engine) does not represent the state of art.

Reviewer 6:

The reviewer observed that the ash loading performance was up to 40 gram (G)/LT, the tip in transient tests response was slow, and the correlation with ash-loading measurement was excellent. The reviewer inquired about addressing soot and ash together, thus reducing regeneration events on DPF to save fuel-payback in one year.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that FST had collaborated with various partners in developing and modularizing their system. The project team had shown the performance of their system on a number of partner platforms.

Reviewer 2:

The reviewer observed a good summary of the project team's collaborators and their specific contributions. The reviewer pointed out Detroit Diesel, and the New York City Sanitation Department.

Reviewer 3:

The reviewer observed an outstanding example of collaboration to insure requirements are properly gathered and reviewed from potential end-user and OEMs, hardware manufacture and controls are user friendly/cost effective. The reviewer remarked that the project team enlisted and clearly defined partner roles according to expertise. The project leveraged sensor manufacturer, OEM vehicle manufacturer, fleet, controls specialist and sensor specialist companies.

Reviewer 4:

The reviewer commented that several key relationships had been developed leading to good program progress by the project team.

Reviewer 5:

The reviewer remarked that collaboration and coordination with the industry partner or subcontractors has been good. The reviewer suggested that for the future tasks, it would be valuable to work closely with the engine manufacturers. The reviewer expressed uncertainty if the manufactures listed on Slide 19 will be partners of this project.

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

Reviewer 1:

The reviewer commented that the project was properly focusing on developing optimized calibrations and controls to quantify performance relative to baseline (ΔP + Model) in a wide range of engine and vehicle applications. The clear focus on first most valuable application and durability performance is excellent.

Reviewer 2:

The reviewer commented that it would be interesting to see if there is a fuel savings through more effective scheduling and control of regeneration relative to a situation where manufacturers have done more work optimizing their regeneration algorithms. But this is an important question to answer and this project should be able to do that. The reviewer guessed that this technology would be beneficial.

Reviewer 3:

The reviewer detailed that the proposed work intends to demonstrate the sensor on a variety of vehicle platforms. Possibly the benefits associated with the advanced sensor would become apparent.

Reviewer 4:

The reviewer commented that the project team needed more trucks/manufacturers.

Reviewer 5:

The reviewer observed a very good project plan given the funding scale. According to the reviewer, it would be nice in the future work to see more fleet testing in a wider range of applications, including light-duty diesels.

Reviewer 6:

The reviewer remarked that the proposed future works were sound only because the project had reached this stage. The system level evaluation provides an opportunity to quantify the actual savings, which could validate the technology. The reviewer also noted that a more careful proof of concept should have been done at an early stage of the project.

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

Reviewer 1:

The reviewer detailed that this project aimed to develop a sensor to measure the soot loading of a DPF on a diesel engine. This facilitates a more intelligent and optimized way to regenerate DPF, thereby avoiding unnecessary regeneration cycles. The reviewer concluded that as approximately 6% of total fuel is spent on DPF regeneration, the fuel penalty associated with regeneration could be reduced.

Reviewer 2:

The reviewer acknowledged that the ability to regenerate the DPF reliably is key for a number of diesel applications. This could be very useful to many retrofit programs.

Reviewer 3:

The reviewer recounted a low-cost production sensor that can be easily calibrated and applied to a DPF application can ensure optimized regeneration cycles. DPF filling predictive models and pressure drop measures can be enhanced to insure the fuel consumed on regeneration events is minimized.

Reviewer 4:

The reviewer stated that this is a yes with a question mark. The reviewer said that it was not quantified how much extra fuel was used for the purpose of regeneration. While reduced regeneration frequency does reduce fuel usage, it was not clear that reduced regeneration frequency was the direct result of using RF sensor. The reviewer found that it was questionable to what extent this project supported DOE objectives.

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

Reviewer 1:

The reviewer commented that the project’s resources seemed to be about the right funding.

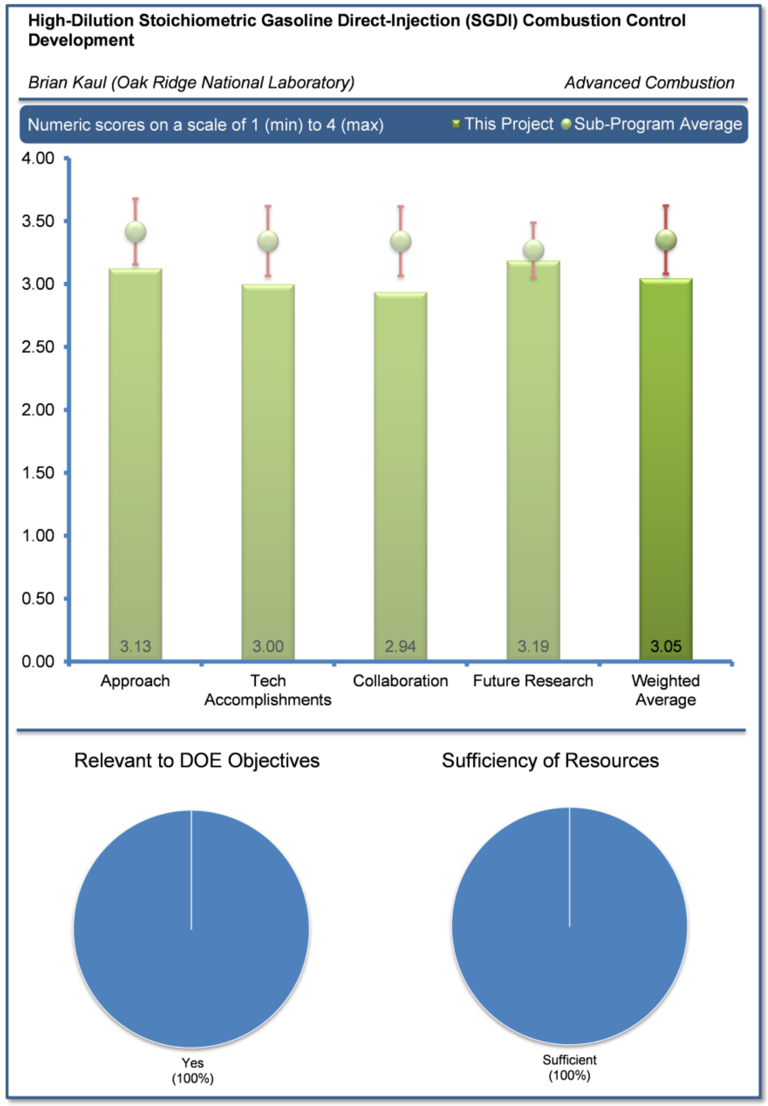
Reviewer 2:

The reviewer found that project funding seemed to be adequate for the remaining tasks.

Reviewer 3:

The reviewer commented that it appeared that FST had been awarded projects from other sources for the same effort.

High-Dilution Stoichiometric Gasoline Direct-Injection (SGDI) Combustion Control Development: Brian Kaul (Oak Ridge National Laboratory) - ace090



Reviewer Sample Size

A total of eight reviewers evaluated this project.

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

Reviewer 1:

The reviewer exclaimed that it was about time someone did this work. The reviewer remarked that it was an exciting chance to do something about the stability limit.

Reviewer 2:

The reviewer commented that the project addresses a specific, critical barrier for dilute SI combustion in a focused manner. The importance of advanced controls is often overlooked, but is of equal importance to (and is an essential to the success of) combustion system development.

Reviewer 3:

The reviewer remarked that the approach of symbolization of chaotic time series to discretize the data and identify trends should enable development of better control systems for dilute SI systems.

Reviewer 4:

The reviewer observed that this was the first time this program had been reviewed. The reviewer remarked that the investigators were addressing an important problem and the project team was learning a lot about addressing the problem as they proceed. The reviewer fully expected that their approach would take on a sharper focus as the project moves forward. For example, the project team might be able to specifically identify and rank the phenomena that the deterministic causes of cyclic variability. This could have broad implications, from control system development to design changes in the engine.

Reviewer 5:

The reviewer remarked that stability limits directly impacted the FE effectiveness of dilution strategies. Being able to operate closer to the limit is beneficial. The reviewer asked if cylinder pressure was required for optimal control, and inquired if crankshaft speed or some other feedback mechanism could be used.

Reviewer 6:

The reviewer said that the project sought to characterize cyclic variability for external EGR operation. The project will evaluate effects of varying engine control inputs with the goal to develop next-cycle control methodology to reduce cyclic variability and implement next-cycle controls on engine. The reviewer noted that the project could give more clear indications on the roadmap control strategy pursued. The task is rather challenging and for this reviewer, it is unclear if the technical barriers leading to predictability will be overcome.

Reviewer 7:

The reviewer commented that the second bullet under Project Objective was not clear. The reviewer asked how downsizing and boosting had made the part-load effects of EGR (viz., increased efficiency) important, and wondered if it should be the other way around. This is because a large fraction of the part-load losses have been recovered via downsizing and boosting. The reviewer acknowledged that the approach addresses the combustion instability problem of high dilution engines, which needs to be successfully developed to increase engine efficiency and reduce petroleum usage. However, the approach seeks to only manage and minimize the combustion variability of an existing engine design, by adjusting fueling level of a cycle that is anticipated to suffer from the harmful effects of a previous cycle. The reviewer remarked that it remained to be seen if in the net a thermal efficiency gain is achieved. The reviewer noted that very precise experiments would be needed to verify the effect.

The reviewer commented that having said that, this project is still useful for controlling the engine in such a way so as to operate at the "edge of stability," and the concept of next-cycle controls can have applicability over the entire engine operating range irrespective of whether or not EGR is used.

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

Reviewer 1:

The reviewer observed good progress by the project team on milestones.

Reviewer 2:

The reviewer commented good project progress for a first year review.

Reviewer 3:

The reviewer commented that the formulation of the strategy and analysis is an important first step in demonstrating improved controls. Although in the relatively early stages, the indicators showed promise for the future work.

Reviewer 4:

The reviewer noted good progress by the project team on a difficult problem. The project team has created a good test bed and the necessary infrastructure to do some great work.

Reviewer 5:

The reviewer commented that the project is in the initial phase of development and has limited progress reported. The project evaluated analysis methods for identifying deterministic components of variations. The reviewer said that symbol-sequence statistics were used to identify recurring non-random trajectory of events. The results showed a decrease of COV at 11% and 17% of EGR. The reviewer commented that the benchmarks however, remove the bad cycles to recalculate the statistics. This does not appear meaningful. The reviewer observed that high EGR leading to longer time-constant instabilities were reported. These results are what would be expected.

Reviewer 6:

The reviewer commented that the project's framework that has been established to identify and affect a control strategy seemed to be sound. It remains to be seen the extent to which the project team's control approach will demonstrate benefits in performance.

Reviewer 7:

The reviewer found that the ability to discern patterns in the seemingly random data with the symbolic analysis was very interesting. The reviewer noted that the correlation of combustion instability to the EGR path-length was also very interesting. However, it seemed like that correlation would be strong when operating in a misfire-type situation and therefore easy to discern. However, according to the reviewer, when operating at a COV of about 3% the correlation may not be as strong and the usefulness of the technique may be severely diminished. The reviewer pointed out that Slide 4 stated that cylinder balancing was completed, but these results were not included in this review. The reviewer inquired if this was because these results were available too late to be included in the AMR presentation and meet the deadline.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer observed solid collaborations by the project team with Ford and National Instruments. The reviewer expected opportunity for more as more people realized the possibilities.

Reviewer 2:
The reviewer noted that some industry collaborations with Bosch and Drivven were mentioned by the project team.

Reviewer 3:
The reviewer commented that the project was collaborating with Bosch and National Instruments on a high-EGR control system development but no details were given showing their contribution, except in a generic way.

Reviewer 4:
The reviewer commented that the project team's collaboration with Bosch and National Instruments is strategically important, but a stronger connection to industry controls expertise would link this project more closely with technology development efforts leading to commercialization and avoid wasted or redundant effort.

Reviewer 5:
The reviewer would like to see more collaborators involved in the project (e.g., an OEM).

Reviewer 6:
The reviewer commented that sufficient project collaboration exists with Bosch, a Tier I supplier and National Instruments. The reviewer added that the project may benefit from collaboration, or at least input, from an OEM's controls experts.

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

Reviewer 1:
The reviewer observed a well laid-out plan for future work by the project team.

Reviewer 2:
The reviewer commented that the project plans to demonstrate a next-cycle control of the engine, having impact over limiting COV. The reviewer continued that it will address differing dynamics of lean-burn versus external EGR.

Reviewer 3:
The reviewer remarked that the future research is targeted at addressing an appropriate barrier to dilute SI combustion. Ensuring that the engine hardware (i.e., combustion chamber, injectors and ignition system) is capable of demonstrating of the efficacy of the control strategy will also be important to the success of the project.

Reviewer 4:
The reviewer said that it will be interesting to see the final answer from the project team on whether a net gain in thermal efficiency can be gained during a relevant experiment.

Reviewer 5:
The reviewer complimented excellent start. As the project addresses these issues, you will want to extend to transient and cold start operation. The reviewer asked if the project team could only make awful combustion into bad combustion, or if the project could also make bad combustion into good combustion. And, asked the reviewer, if doing so allows the project to run in significantly better regions than one could without this methodology.

Reviewer 6:

The reviewer commented that the proposed work was good, but the reviewer was a little skeptical as to the size of benefit that would be realizable. Clearly from a condition with multiple misfires, this approach would show an improvement. However, production engines are not calibrated to misfire. The reviewer asked how much closer 'to the edge of stability' could engines be pushed, without miss-fire, but having a recognizable pattern to recognize. This reviewer was not sure. Again, according to the reviewer, this is a worthy endeavor, and the data will speak for itself. The reviewer hoped there was something here.

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

Reviewer 1:

The reviewer acknowledged that many engines are stability limited under some conditions. Any ability to move those limits back should be helpful.

Reviewer 2:

The reviewer said that the control systems are important to pushing the limits of dilute/lean SI combustion, improving the efficiency of these systems.

Reviewer 3:

The reviewer said that the development of advanced control strategies to extend SI dilution limits should make this approach more feasible for commercialization of this technology.

Reviewer 4:

The reviewer commented that combustion instabilities at the dilution limit have a deterministic structure combined with stochastic noise. Cooled EGR enables fuel efficiency gains with boosted downsizing, but is limited by cyclic variability.

Reviewer 5:

The reviewer said that high dilution engines, either lean or EGR, are part of the strategy to increase engine efficiency and reduce petroleum usage.

Reviewer 6:

The reviewer remarked that EGR and stability are limiting factors to engine efficiency.

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

Reviewer 1:

The reviewer found that the project's resources were sufficient. However, the reviewer said that the resources may need to be increased in fiscal year 2015 to ensure that the combustion hardware is suitable for the controls demonstration.

Reviewer 2:

The reviewer said that the project's resources were sufficient.

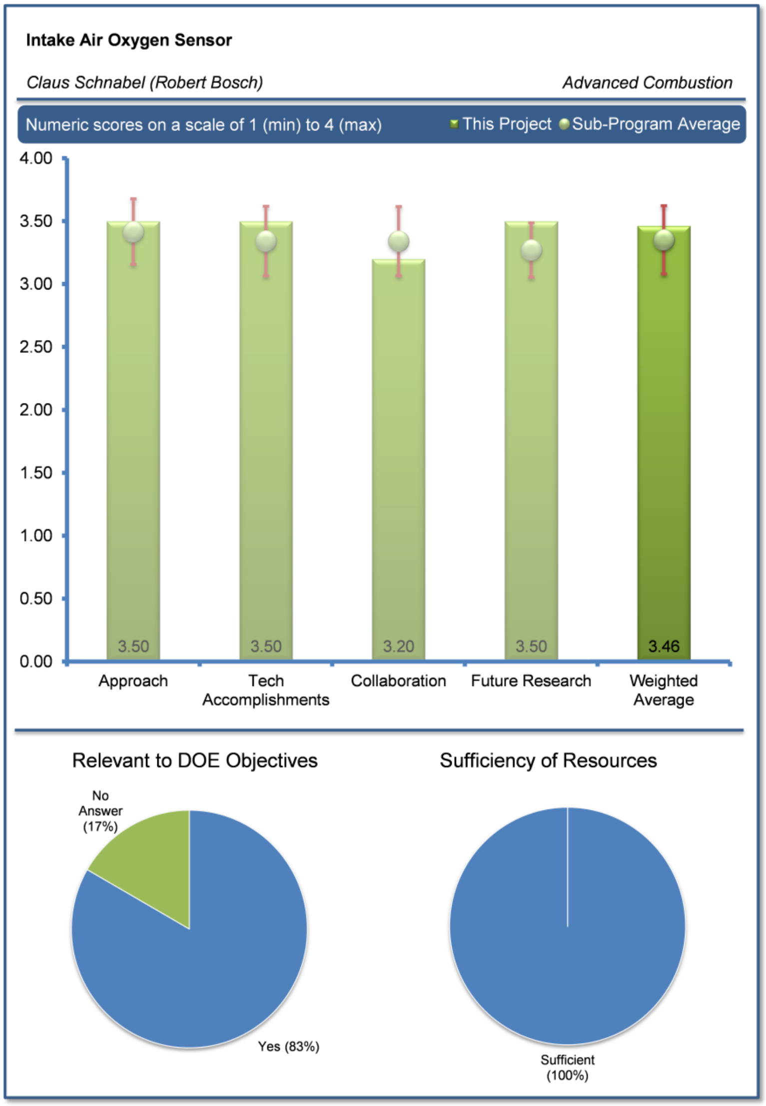
Reviewer 3:

The reviewer found that funding seemed appropriate for the planned project work.

Reviewer 4:

The reviewer remarked that project resources were sufficient provided planned work could be completed in the next fiscal year.

Intake Air Oxygen Sensor: Claus Schnabel (Robert Bosch) - ace091



Reviewer Sample Size

A total of six reviewers evaluated this project.

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

Reviewer 1:

The reviewer noted a well-thought out process for identifying the needs, and identifying critical performance criteria

Reviewer 2:

The reviewer noted a very solid approach reflecting Bosch's long experience in automotive sensor development.

Reviewer 3:

The reviewer said that the approach was reasonable with staged development and distribution of responsibilities. Proper starting point, gaps analyses, adaption, testing, scale-up, and controls all logical and proven approaches.

Reviewer 4:

The reviewer commented that in this project, Bosch intended to develop an oxygen sensor that could be deployed in the engine intake air duct. Such a sensor would facilitate accurate measurement of EGR fraction, especially under low-load and low-speed conditions. The reviewer noted that this in turn would facilitate high efficiency engine operational modes that use EGR. The reviewer observed that a cooled EGR estimation algorithm had been developed as a part of this project. The reviewer remarked that it would have been nice to share this information in the form of a publication.

Reviewer 5:

The reviewer said that this project was well designed in terms of oxygen sensor development, installation on the engine as well as integration with cooled EGR control. The target set for the accuracy of the sensor is quite high, which may be difficult to meet or verify in actual engine operation.

The reviewer pointed out that as internal EGR or residual gas fraction varies from cycle to cycle and cylinder to cylinder, at some point, more precise knowledge on external EGR rate does not offer added benefit for final in-cylinder EGR prediction. The reviewer concluded that it is therefore sensible to work with cooled EGR partners, Clemson and ORNL, to define the accuracy of EGR rate needed for the modeling and control, which in turn defines the accuracy of the intake O_2 sensors. The reviewer remarked that once a realistic accuracy is defined, more efforts could be put in to make the sensor durable and low cost.

Reviewer 6:

The reviewer said cooled EGR application was needed for this O_2 sensor, and noted an EGR estimation algorithm. The EGR control is based on the O_2 feedback, and models GT power. Water effects/pressure effects/O_2 level are sensitive. The reviewer noted the potential to ignite with HC vapors in exhaust.

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 remarked that the project team nicely designed tests and analyses given solid results leading toward production.

Reviewer 2:

The reviewer said that the project followed a well-defined pathway for the development of the intake O_2 sensor. With the intension of developing the sensor for all potential diesel and gasoline applications, the team had considered all elements that could potentially affect its performance.

Reviewer 3:

The reviewer observed an excellent identification of issues and risks, and several accuracy challenges. The reviewer commented engine sensitivity to control strategy to determine needs. The reviewer observed a nice assessment of manufacturing feasibility, impressive prototype development, and impressive progress on failure modes, seals, protection tubes, etc.

Reviewer 4:

The reviewer pointed out that Bosch has plenty of expertise in O_2 sensors, which has been well applied in this project. The technical accomplishments presented fit well with the project and DOE goals. The reviewer noted that the team was about halfway through the project, and all major issues had been touched on. The reviewer said that what was not very clearly defined was how the progress on certain matrices was measured, such as those in Technical Risk Assessment (Slide 11).

Reviewer 5:

The reviewer noted very good progress. However, it was not clear to this reviewer what was new in this development. It seemed like the project team was developing an expanded range of sensor capabilities by using technologies that already exist within the company. Clarification of what is new would have helped this reviewer make an assessment of whether it is appropriate for the federal government to support this work.

Reviewer 6:

The reviewer expressed concern that the risk of fire seemed major. The reviewer commented that this is for SI, not diesel, but it could be adapted to diesel.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer said that Bosch had formed an excellent team and was leveraging complementary capabilities very well.

Reviewer 2:

The reviewer pointed out that the project team had excellent partnerships and assignment of tasks, and that each member was dealing with strengths.

Reviewer 3:

The reviewer pointed out Clemson and ORNL as collaborators with the project team.

Reviewer 4:

The reviewer commented that Bosch was presumably working with a number of customers even though it was not shown in this talk.

Reviewer 5:

The reviewer remarked that project's collaboration and coordination with partners seemed to be lacking or not shown. Hopefully, this situation will change for the future tasks.

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

Reviewer 1:

The reviewer said there was a high probability of project success leading to production.

Reviewer 2:

The reviewer said that, so far, the proposed future work was a logical progression of the developmental work performed.

Reviewer 3:

The reviewer commented that the project's future work plan seemed achievable, focused on risk areas, and will achieve project objectives.

Reviewer 4:

The reviewer remarked that the proposed future works were sound and logical. The system level evaluation provided opportunity to quantify the benefit of technology. The reviewer remarked that hopefully, more close collaboration with cooled EGR partners would occur during this phase of the project.

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

Reviewer 1:

The reviewer said that relatively accurate information on intake oxygen could potentially improve cooled EGR control strategy, and thus improve the FE which supports the DOE objective.

Reviewer 2:

The reviewer commented an important tool for high EGR levels, which in turn are necessary for low emissions with high efficiency.

Reviewer 3:

The reviewer commented that advanced controls were essential to efficient engine operation. This project gets to the heart of a key one – air and EGR control.

Reviewer 4:

The reviewer detailed that the proposed development of intake oxygen sensor facilitates the metering of EGR under low-load and low-speed conditions, which are primarily used under typical driving conditions. This in turn would lead to the development of highly efficient downsized engines that use turbocharging and EGR.

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

Reviewer 1:

The reviewer said that the team leveraged complementary capabilities excellently.

Reviewer 2:

The reviewer found that project's resources seemed to be properly funded.

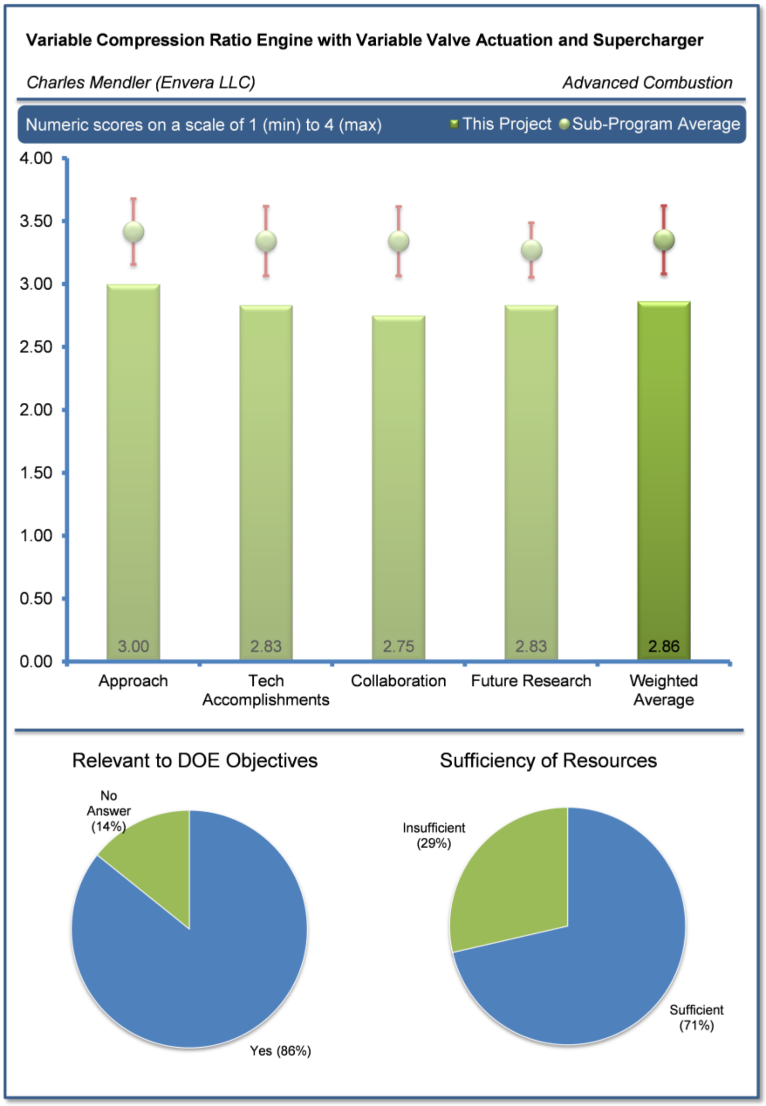
Reviewer 3:

The reviewer said that project's funding seemed to be adequate for the remaining tasks.

Reviewer 4:

The reviewer remarked that the project partner funding seemed low, but Bosch funding and capability seems quite adequate to help out if needed.

Variable Compression Ratio Engine with Variable Valve Actuation and Supercharger: Charles Mendler (Envera LLC) - ace092



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 found that the project team's approach to address the technical barriers was well planned and balanced.

Reviewer 2:

The reviewer commented that combining with VVA was interesting; and observed the Atkinson cycle enabled with VVA, a 40% improvement in pickup truck, and GT power modeling to match supercharger.

Reviewer 3:

The reviewer said that this was a very interesting concept for VCR. The reviewer did not see how the project would convincingly demonstrate 40% FE benefit without more effort on system integration. The reviewer remarked that controls, after-treatment, vehicle implication like shift schedule, were all important and did not seem to be addressed. Perhaps the objective should have been more component or subsystem oriented.

Reviewer 4:

The reviewer remarked that VCR combined with VVA and supercharging was an interesting combination much discussed in the literature. The reviewer found that goals seemed achievable given the expected flexibility of the system. The feasibility, design, and build approach was quite standard. However, according to the reviewer, the system seemed quite complex so there will be significant challenges.

Reviewer 5:

The reviewer detailed that pressured by the requirement for improved mileage, most of the engine manufacturers have adopted a combination of turbocharging, plus GDI and high levels of dilution, for knock mitigation. Usually, the high levels of dilution have been instituted via increased levels of EGR. The reviewer detailed that the present project proposes an alternate pathway for knock mitigation – that of using variable compression ratio (VCR), which allows one to use low CR at high loads and high CR at low loads, thereby improving the engine efficiency overall. The reviewer noted that the other technology that is proposed is VVA to institute Atkinson/Miller cycle, is somewhat proven.

The reviewer commented that while the technology to vary CR is innovative and commendable, it relied on moving the crankshaft position vertically. This introduces new difficulties of sealing oil containment while allowing for crankshaft traverse, reliably transmitting the shaft power to transmission, having the needed time response for transient engine operation, and added cost and weight.

The reviewer noted that the benefits from the proposed VCR technology must surpass those from EGR or lean-burn technologies to be viable. The reviewer remarked that maybe the present project will shed some light as progress is made.

Reviewer 6:

The reviewer remarked that VCR device with Atkinson cycle is possible to meet targets of the project (i.e., part-load brake thermal efficiency of 31%, over 25% FE improvement on SI engines without sacrifice to power and emissions, and enhanced alternative fuel capability with regard to R&D).

However, according to the reviewer, there is some data in the literature indicating real FE improvements of 7% with Atkinson cycle (Honda 2009 SAE)[1] and system development of certain VCR systems is mature and on the shelf for manufacturers to implement as needed (MCE-5 in Europe)[2].

The reviewer noted that mature MCE-5 technology, similar to the current project, has not been adopted in Europe beyond demonstration vehicles at PSA in 2010. The reviewer noted that the R&D approach for this project could be improved by taking a look into the potential mechanisms which are either available now (and full complete ready systems like MCE-5) or more practical devices which do not require as significant base engine changes, such as the Honda system, FEV, Hyundai patents, Ford patents for Connecting Rod/Piston based devices, and implementing one of these devices in the test program, therefore avoiding a long and expensive engine development and providing a clearer pathway to production.

The reviewer suggested an additional recommendation for improvement is to identify an OEM or Tier 1 with interest to partner to develop a VCR technology. Because base engine changes are required and are one of the largest barriers to production use of this technology, the OEM/Tier 1 integration partner interest will demonstrate the need/interest in the marketplace and expedite integration to a base engine design. Additionally, the OEM partner with interest can provide leverage with their existing engine controls for more practical controls integration of a very complex activity.

The reviewer said that VVA 2-step mechanisms are in production, and tailoring the device to the Atkinson application is a valuable exercise for enabling fuel saving technologies.

The reviewer noted that a cost effective variable speed supercharger was the original option for this project and may be highly desirable for other fuel saving projects.

Reviewer 7:

The reviewer noted that combining three advanced technologies, VCR/VVT/supercharging, into one system sounded very attractive. However, how the market could accept such an expensive system was not clear at all. The reviewer found that more challengingly, the engine system control remained a daunting task with so many unexpected hurdles to overcome.

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[1] SAE 2009-01-106; testing in an otherwise conventional production 2.0L, 4-cylinder engine, the Honda dual piston mechanism was able to adjust the engine from a CR of 9.6 to 14.2 and back again. Combining the high compression ratio with the Atkinson cycle, the engineering team demonstrated a 7.4% improvement in FE in operation over the Japanese 10-15 cycle. As part of the study, the team also demonstrated switching durability of the dual piston mechanism of more than one million cycles.

[2] The VCRi engine principle. The MCE-5 engine provides continuous and reactive compression ratio control with a range between 7:1 and 20:1 to each cylinder of the engine. The MCE-5 engine block integrates power transmission and compression ratio control through a combination of a rod-crank mechanism, long-life gears and exclusive actuators. The result of 12 years of intensive R&D, MCE-5 VCRi is a technology with extremely low residual functional or industrial risks. The MCE-5 VCRi engines exist in single-cylinder, in four-cylinder with two-stage turbocharging and in direct gasoline injection versions. MCE-5 VCRi demo cars are currently running. http://www.mce-5.com/english/pop_up/atouts_strategiques/It_s_ready.html.

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 good progress by the project team on the build of the engine –, stress analysis on VVA, and that the supercharger appeared to be developed already – but that it must be matched to the engine design needs.

Reviewer 2:
The reviewer said that the project team had good results so far--mainly selecting options and getting hardware together as planned.

Reviewer 3:
The reviewer commented that the technical accomplishments of the team are significant. The added weight and volume seemed to be a concern and the benefits may need to be addressed at the vehicle level. The reviewer found that the answer was positive but less convincing. Technical data and analysis are lacking and needed to support the claims.

Reviewer 4:
The reviewer remarked that the project work has had some setbacks, but fundamental structural issues were being addressed. VVA improvements seemed to be within Eaton's normal commercial responsibility given the commercial status of the technology. The reviewer commented that the delay in crankcase casting delivery was troubling. Troubleshooting seemed to be causing delays, but we are early in the project with time to recover.

Reviewer 5:
The reviewer said that the integration of the device on a production engine was a good accomplishment. However, OEM support would improve the prospects of the project's success and the integration of the technology in an engine should it prove effective. The reviewer acknowledged good progress on new VVA lost motion Atkinson application, and little activity on supercharger except gathering requirements.

Reviewer 6:
The reviewer summarized that following a predetermined scope of work, the Envera/Eaton team has shown excellent progress in Phase 1 of this project. Specifically, the project team has developed a conceptual design to incorporate VCR, been working to improve their VVT mechanism to incorporate late intake valve closing, and planned to use GT power modeling to guide the selection of boosting hardware. However, according to the reviewer, the main envisioned impediment to this VCR technology is reliable transmission of shaft power from a shaft that translates vertically. The reviewer commented that the presenter had not revealed details claiming it (VCR power takeoff coupling) to be proprietary. The reviewer concluded that in absence of its details it is difficult to judge the feasibility of this concept.

Reviewer 7:
The reviewer commented that not too much progress was reported except some preliminary analytical and design findings. The reviewer would like to know why, in Slide 32, the conventional V8 engine had better BSFC at high loads starting at 240Nm. With such an expensive investment, BSFC should be better over entire operating range.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The reviewer said that the team leveraged complementary capabilities to ensure progress of the project.

Reviewer 2:
The reviewer found that the project team’s collaboration with Eaton was well managed.

Reviewer 3:
The reviewer observed solid interaction with Eaton. The reviewer suggested that a partner would be needed for controls and vehicle integration most likely.

Reviewer 4:
The reviewer noted that the collaboration between the two partners was certainly impressive and can address the expected mechanical troubleshooting. The reviewer expressed concern about the team's ability to calibrate such a complex system. The reviewer suggested that the project team consider bringing in calibration expertise, at least to help guild the large number of variables to address here.

Reviewer 5:
The reviewer pointed out that for this level of engine integration, OEM interest and high level controls support is warranted, but not in the team.

Reviewer 6:
The reviewer commented that working with Eaton was good, but it was concerning if no OEM was involved, at least from a technical advisor point of view. The reviewer expressed concern that the system may be developed in such a way that nobody would accept it due to the high cost and a highly complicated system.

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

Reviewer 1:
The reviewer found that the project was on track to achieve the planned goals.

Reviewer 2:
The reviewer commented that the project's proposed future work was a logical extension of the program followed so far.

Reviewer 3:
The reviewer observed that the team was plugging away at the complex issues. The project plan seemed reasonable, but the reviewer suggested that contingencies were needed to manage any slippage.

Reviewer 4:
The reviewer remarked a good plan by the project team for hardware build and test, but seemed weak on system integration and ultimately a FE demonstration.

Reviewer 5:
The reviewer suggested that the focus on the current device should be re-evaluated for best pathway. Other devices are more appealing to manufacturers because they do not require base engine block changes or have been fully developed and could be purchased for testing. The reviewer suggested that one of these pathways should be considered for the device selection to simplify the hardware aspect to get into the performance demonstration phase more quickly, and to ensure OEM interest for the selected approach.

The reviewer recommended that other research, such as the Honda paper and MCE-5 work, should be summarized to ensure that the state of the art is considered in the R&D approach going forward.

Reviewer 6:
The reviewer was hopeful that a "go/no-go" decision could be really used. The reviewer views that this could be a very high risk project with no clear return path of investment.

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

Reviewer 1:
The reviewer said that improvement of engine efficiency supported the overall DOE objectives of petroleum displacement.

Reviewer 2:
The reviewer said that improvement of engine performance had direct impact on fuel consumption and FE. It supports DOE's objectives of petroleum displacement.

Reviewer 3:
The reviewer commented that high FE for petroleum reduction supports DOE’s objectives.

Reviewer 4:
The reviewer commented that the project team projects a 40% FE improvement which surpasses that of the DOE goal of 25% improvement. While FE improvements are certain, due to various factors, they might not be as high as the project team projected. However, the reviewer found that the present project supports DOE's mission of petroleum displacement and GHG emission reduction.

Reviewer 5:
The reviewer noted that VCR devices applied to engines with Atkinson have high projected benefits. The reviewer said that VCR device development (or integration) and associated valvetrain/supercharging and controls are important steps to achieve projected gains.

Reviewer 6:
The reviewer said that the three technologies are often discussed as attractive means to drop FC. The reviewer said that we need to get a better peak in the box.

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

Reviewer 1:
The reviewer said the project’s resources were sufficient.

Reviewer 2:
The reviewer said that no provision by the project team for the significant effort of system integration, control system, and calibration to support the system demonstration FE objectives.

Reviewer 3:
The reviewer said that project’s resources were insufficient to implement a system with the hardware and controls complexity involved. The base engine development and integration and the controls efforts require significant budgets assuming a baseline control system and calibration data/approach are available. The reviewer recommended that additional partners and funding could improve risk.

Acronyms and Abbreviations

Acronym	Definition
1D	One Dimensional
3D	Three Dimensional
ACEC	Advanced Combustion and Emissions Control
AEC	Advanced Engine Combustion
AFCI	Advanced Fuel Cycle Initiative
AFR	Air to Fuel Ratio
AKI	Anti-Knock Index
ANL	Argonne National Laboratory
APS	Advanced photon source
AMR	Annual Merit Review
Au	Gold
AVFL	Advanced Vehicle/Fuel/Lubricants
BES	DOE Basic Energy Sciences
BMEP	Brake Mean Effective Pressure
BP	Bandpass
BSFC	Brake-specific fuel consumption
BSG	Belt-Driven Starter-Generator
BTE	Brake Thermal Efficiency
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CCC	Co-precipitated CuO_X, CoO_y, and Ceo_2 catalyst
CFD	Computational Fluid Dynamics
CI	Compression Ignition
CLEERS	Cross-Cut Lean Exhaust Emissions Reduction Simulations
CNT	Carbon Nanotubes
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COV	Coefficient of variance
CPU	Central processing unit
CR	Compression Ratio
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
CSC	Cold Start Concept
CT	Computed tomography
Cu	Copper
CZ	Ceria-zirconia
D-EGR	Dedicated-Exhaust Gas Recirculation
DC	Direct current
DI	Direct Injection

Acronym	Definition
DISI	Direct Injection Spark Ignited
DOC	Diesel oxidation catalyst
DOD	U.S. Department of Defense
DOE	Department of Energy
DPF	Diesel particulate filter
DSNY	City of New York Department of Sanitation
DTBP	Di-t-butyl peroxide
E85	85 percent Ethanol blend with gasoline
ECN	Engine Collaboration Network
ECU	Engine control unit
EGR	Exhaust Gas Recirculation
EHN	2-ethylhexyl nitrate
EHR	Exhaust heat recovery
EPA	U.S. Environmental Protection Agency
ERC	Engine Research Center
FACE	Fuels for Advanced Combustion Engines
FE	Fuel Economy
FGM	Flamelet generated manifold
FMEP	Friction mean effective pressure
FST	Filter sensing technologies
FTP	Federal Test Procedure
FTIR	Fourier Transform Infrared Spectroscopy
FY	Fiscal year
GDI	Gasoline Direct-injected
GDCI	Gasoline Direct Compression Engine
GFR	Glomerular filtration rate
GHG	Greenhouse gas
GM	General Motors Corporation
GPF	Gasoline Particulate Filter
GPU	Graphics Processing Unit
GSA	Advanced probing technique
GTDI	Gasoline Turbocharged Direct Injection
H_2	Hydrogen
HC	Hydrocarbon
HCCI	Homogeneous Charge Compression Ignition
HD	Heavy-Duty
HECC	High efficiency clean combustion
HEDGE	High-Efficiency Dilute Gasoline Engine
HPC	High Performance Computing
HV	High voltage
ICE	Internal Combustion Engine
ICT	Institute of Chemical Technology
IMEP	Indicated Mean Effective Pressure

Acronym	Definition
IP	Intellectual property
ISFC	Indicated Specific Fuel Consumption
ITE	Indicated Thermal Efficiency
K	Potassium
Kn	Knudsen Number
L	Liter
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LD	Light-Duty
LES	Large Eddy Simulation
LEV	Low Emission Vehicle
LIF	Laser-induced fluorescence
LLNL	Lawrence Livermore National Laboratory
LNT	Lean NO_x Trap
LPL	Low-pressure loop
LTC	Low Temperature Combustion
LTGC	Low Temperature Gasoline Combustion
MBC	Model based controls
MCE	Multi-cylinder engine
MD	Medium-Duty
Mg	Magnesium
MIT	Massachusetts Institute of Technology
mJ	Milijoule
Mn	Manganese
MOU	Memorandum of Understanding
MPG	Miles Per Gallon
ms	Milliseconds
MSU	Michigan State University
MTU	Michigan Technological University
N_2	Nitrogen
N_2O	Nitrous Oxide
NA	Naturally aspirated
NH_3	Ammonia
NIST	National Institute of Standards and Technology
NMOG	Non-methane organic gases
NO	Nitric Oxide
NO_x	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
NREL	National Renewable Energy Laboratory
NSC	NO_x Storage Catalyst
NSF	National Science Foundation
NSR	NO_x Storage Reduction
NVO	Negative Valve Overlap

Acronym	Definition
O_2	Oxygen
OBD	On-Board Diagnostics
OEM	Original Equipment Manufacturer
OH	Hydroxide
ORC	Organic Rankine Cycle
ORNL	Oak Ridge National Laboratory
OSC	Oxygen storage capacity
OSU	Ohio State University
PAH	Polycyclic aromatic hydrocarbon
PCCI	Premixed Charge Compression Ignition
PDT	Pulse discharge technique
PFI	Port Fuel Injection
PFS	Partial fuel stratification
PGM	Platinum group metal
PI	Principal Investigator
PM	Particulate matter
PN	Particulate number
PNA	Passive NO_x adsorber
PNNL	Pacific Northwest National Laboratory
POD	Proper orthogonal decomposition
PPC	Partially Premixed Combustion
ppm	Part per million
Pt	Platinum
PWM	Pulse width modulation
R&D	Research and development
RANS	Reynolds-Averaged Navier Strokes
RCCI	Reactivity Controlled Compression Ignition
RCM	Rapid compression machines
RF	Radio frequency
SACI	Spark assisted compression ignition
SAE	Society of Automotive Engineers
SCR	Selective Catalytic Reduction
SCRF	Selective catalytic reduction on filters
SEM	Scanning electron microscope
SI	Spark-ignition
SIDI	Spark-ignition direct-injection
SNL	Sandia National Laboratories
SULEV	Super Low-Emission Vehicle
SUV	Sport utility vehicle
TARDEC	U.S. Army Tank and Automotive Research, Development and Engineering Center
TCR	Thermochemical recuperation
TDC	Top dead center
TE	Thermoelectric

Acronym	Definition
TEG	Thermoelectric Generator
TRD	Transmission radiation detector
TWC	Three-Way Catalyst
UC	University of California
UConn	University of Connecticut
UHC	Unburned hydrocarbons
UM	University of Michigan
USCAR	U.S. Council for Automotive Research
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle Efficiency and Energy sustainability
UW	University of Wisconsin
UWM	University of Wisconsin-Milwaukee
VCR	Variable compression ratio
VCT	Variable camshaft timing
VTO	Vehicle Technologies Office
VUV	Vacuum ultraviolet
VVA	Variable Valve Actuation
WHR	Waste Heat Recovery
WSU	Washington State University
XAFS	X-ray absorption fine structure
XPS	X-ray photoelectron spectroscopy
Zr	Zirconium
ZT	Thermoelectric Figure of Merit