4. ADVANCED COMBUSTION ENGINE TECHNOLOGIES

The Advanced Combustion Engine subprogram of the U.S. Department of Energy's Vehicle Technologies Program (VTP) is improving the fuel economy of passenger vehicles (cars and light trucks) and commercial vehicles (medium-duty and commercial trucks) by increasing the efficiency of the engines that power them. Work is done in collaboration with industry, national laboratories, and universities, as well as in conjunction with the FreedomCAR and Fuels Partnership for passenger vehicle applications and the 21st Century Truck Partnership for commercial vehicle applications. Research and development (R&D) efforts focus on improving engine efficiency while meeting future federal and state emissions regulations through a combination of: combustion technologies that minimize in-cylinder formation of emissions; aftertreatment technologies that further reduce exhaust emissions; and understanding fuel property impacts on combustion and emissions. Technologies that improve the overall engine performance are also pursued.

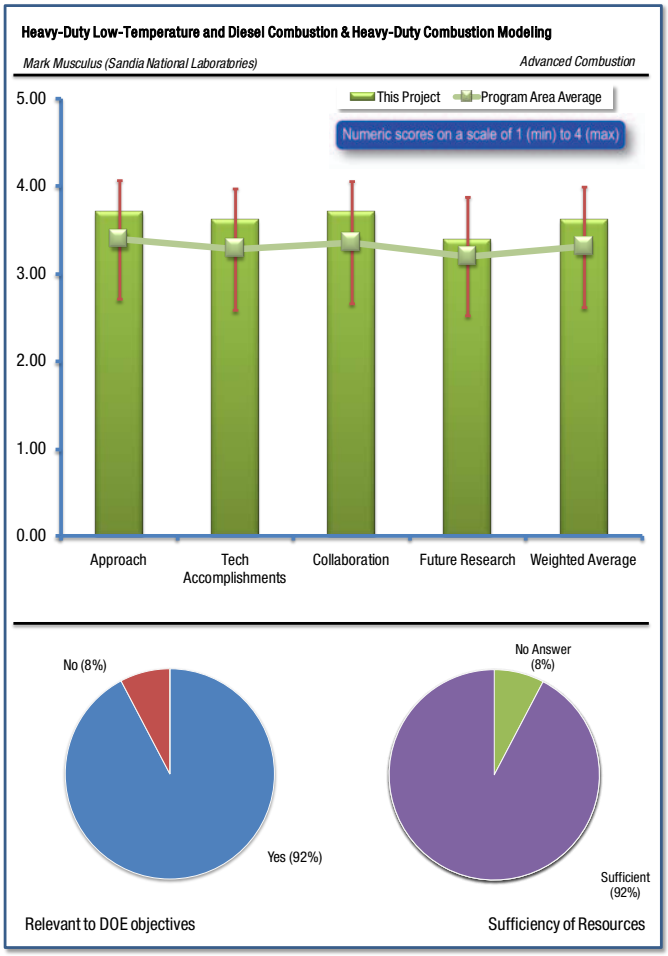
In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses *(on a scale of 1 to 4)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A 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)	4-4	3.69	3.62	3.69	3.38	3.62
Low-Temperature Automotive Diesel Combustion	Paul Miles (Sandia National Laboratories)	4-7	3.46	3.08	3.58	3.31	3.27
Sandia Optical Hydrogen-fueled Engine	Sebastian Kaiser (Sandia National Laboratories)	4-10	2.80	2.40	2.80	2.70	2.59
HCCI and Stratified-Charge CI Engine Combustion Research	John Dec (Sandia National Laboratories)	4-13	3.92	3.69	3.85	3.38	3.73
Low-Temperature Diesel Combustion Cross-Cut Research	Lyle Pickett (Sandia National Laboratories)	4-16	3.67	3.50	3.67	3.17	3.52
Automotive HCCI Engine Research	Richard Steeper (Sandia National Laboratories)	4-19	3.27	3.55	3.27	2.90	3.36
Large Eddy Simulation (LES) Applied to LTC/Diesel/Hydrogen Engine Combustion Research	Joe Oefelein (Sandia National Laboratories)	4-21	3.33	3.00	3.25	3.08	3.13
Free-Piston Engine	Peter Van Blarigan (Sandia National Laboratories)	4-24	2.67	2.25	2.25	2.75	2.42
Optimization of Direct-Injection H2 Combustion Engine Performance, Efficiency, and Emissions	Thomas Wallner (Argonne National Laboratory)	4-27	3.11	3.00	2.89	2.78	2.99
Fuel Spray Research on Light-Duty Injection Systems	Christopher Powell (Argonne National Laboratory)	4-30	3.67	3.33	3.42	3.00	3.39
Visualization of In-Cylinder Combustion R&D	Stephen Ciatti (Argonne National Laboratory)	4-32	2.92	2.92	2.91	3.00	2.93
Computationally Efficient Modeling of High-Efficiency Clean Combustion Engines	Salvador Aceves (Lawrence Livermore National Laboratory)	4-35	3.36	3.42	3.45	3.36	3.40
Chemical Kinetic Research on HCCI & Diesel Fuels	William Pitz (Lawrence Livermore National Laboratory)	4-37	3.69	3.92	3.85	3.54	3.81
KIVA-4 Development	David Carrington (Los Alamos National Laboratory)	4-39	3.29	3.50	3.50	3.29	3.42

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Stuart Daw (Oak Ridge National Laboratory)	4-43	3.27	3.00	3.18	2.82	3.07
High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Diesel Engines	Robert Wagner (Oak Ridge National Laboratory)	4-46	3.38	3.38	3.46	3.15	3.37
Achieving and Demonstrating Vehicle Technologies Engine Fuel Efficiency Milestones	Robert Wagner (Oak Ridge National Laboratory)	4-49	3.58	3.55	3.42	3.25	3.50
Emissions Control for Lean Gasoline Engines	Jim Parks (Oak Ridge National Laboratory)	4-52	3.38	3.38	3.13	3.25	3.33
A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines	Dennis Assanis (University of Michigan)	4-54	3.08	3.08	3.67	3.27	3.18
Optimization of Advanced Diesel Engine Combustion Strategies	Rolf Reitz (University of Wisconsin)	4-57	3.71	3.79	3.64	3.57	3.72
Flex Fuel Optimized SI and HCCI Engine	Gouming Zhu (Michigan State University)	4-61	3.10	2.67	2.55	3.00	2.80
CLEERS Coordination & Joint Development of Benchmark Kinetics for LNT & SCR	Stuart Daw (Oak Ridge National Laboratory)	4-64	3.83	3.33	4.00	3.50	3.56
CLEERS: Aftertreatment Modeling and Analysis	Darrell Herling (Pacific Northwest National Laboratory)	4-67	3.43	3.57	3.71	3.71	3.57
Development of Advanced Diesel Particulate Filtration (DPF) Systems	Kyeong Lee (Argonne National Laboratory)	4-70	2.86	3.00	3.14	2.86	2.96
Combination and Integration of DPF-SCR Aftertreatment Technologies	Kenneth Rappe (Pacific Northwest National Laboratory)	4-73	2.86	2.86	2.83	2.86	2.85
Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials	Chuck Peden (Pacific Northwest National Laboratory)	4-76	3.50	3.33	3.71	3.29	3.42
Degradation Mechanisms of Urea Selective Catalytic Reduction Technology	Chuck Peden (Pacific Northwest National Laboratory)	4-79	3.71	3.33	3.57	3.29	3.45
Experimental Studies for DPF and SCR Model, Control System, and OBD Development for Engines Using Diesel and Biodiesel Fuels	John Johnson (Michigan Technological University)	4-82	3.43	3.14	3.71	3.57	3.34
Development of Optimal Catalyst Designs and Operating Strategies for Lean NOx Reduction in Coupled LNT-SCR Systems	Michael Harold (University of Houston)	4-84	3.60	3.33	3.67	3.33	3.44
Three-Dimensional Composite Nanostructures for Lean NOx Emission Control	Pu-Xian Gao (University of Connecticut)	4-87	2.67	2.86	2.43	2.57	2.72
Efficient Emissions Control for Multi-Mode Lean DI Engines	Jim Parks (Oak Ridge National Laboratory)	4-90	3.50	3.00	3.57	3.00	3.20
Cummins/ORNL-FEERC CRADA: NOx Control & Measurement Technology for Heavy-Duty Diesel Engines	William Partridge (Oak Ridge National Laboratory)	4-92	3.50	3.43	3.57	3.29	3.45
Pre-Competitive Catalysis Research: Fundamental Sulfation/Desulfation Studies of Lean NOx Traps	Todd Toops (Oak Ridge National Laboratory)	4-95	3.33	3.33	3.33	2.83	3.27
Advanced Engine/Aftertreatment System R&D CRADA with Navistar, Inc.	Josh Pihl (Oak Ridge National Laboratory)	4-97	3.50	3.33	3.50	3.67	3.44

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Development of Chemical Kinetic Models for Lean NOx Traps	Richard Larson (Sandia National Laboratories)	4-99	3.20	3.20	2.80	3.00	3.13
Development of High-Efficiency Clean Combustion Engines Designs for SI and CI Engines	Kenneth Patton (General Motors)	4-101	3.83	3.67	3.33	3.83	3.69
Advanced Boost System Development for Diesel HCCI/LTC Application	Harold Sun (Ford Motor Company)	4-103	3.00	3.20	3.00	3.00	3.10
Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines	Scott Fiveland (Caterpillar)	4-105	3.60	3.80	3.40	3.60	3.68
An Engine System Approach to Exhaust Waste Heat Recovery	Richard Kruiswyk (Caterpillar)	4-107	3.40	3.20	3.20	3.20	3.25
Advanced Diesel Engine Technology Development for HECC	Donald Stanton (Cummins)	4-109	3.60	3.60	3.80	3.20	3.58
Exhaust Energy Recovery	Chris Nelson (Cummins)	4-111	3.80	3.80	2.80	3.40	3.63
High Efficiency Combustion and Controls	Kevin Sisken (Detroit Diesel)	4-113	4.00	3.33	3.33	3.33	3.50
Low-Temperature Combustion Demonstrator for High-Efficiency Clean Combustion	William de Ojeda (Navistar International Corp.)	4-115	3.67	3.67	3.67	3.00	3.58
Advanced Collaborative Emissions Study (ACES)	Dan Greenbaum (Health Effects Institute)	4-117	4.00	3.50	3.75	4.00	3.72
Measurement and Characterization of Unregulated Emissions from Advanced Technologies	John Storey (Oak Ridge National Laboratory)	4-119	3.75	3.75	3.67	4.00	3.77
Collaborative Lubricating Oil Study on Emissions (CLOSE Project)	Douglas Lawson (National Renewable Energy Laboratory)	4-121	3.50	3.25	4.00	3.25	3.41
Thermoelectric HVAC for Light-Duty Vehicle Applications	Clay Maranville (Ford Motor Company)	4-123	3.25	3.33	3.75	3.50	3.39
Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling	Gregory Meisner (General Motors)	4-125	2.75	2.75	2.50	2.75	2.72
Thermoelectric Conversion of Waste Heat to Electricity in an IC Engine Powered Vehicle	Harold Schock (Michigan State University)	4-128	3.75	3.50	3.75	3.50	3.59
Develop Thermoelectric Technology for Automotive Waste Heat Recovery	Gregory Meisner (General Motors)	4-131	3.25	2.75	3.00	2.75	2.91
Automotive Waste Heat Conversion to Power Program	John LaGrandeur (BSST LLC)	4-134	3.50	3.50	3.50	3.25	3.47
OVERALL AVERAGE			**3.39**	**3.28**	**3.36**	**3.20**	**3.31**

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



Reviewer Sample Size

This project had a total of 13 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Comments were generally positive in this section. The first reviewer said very fundamental analyses are required for the more advanced demonstration and implementation of LTC for commercial applications. Project goals are being modified and changed on an expedient basis - shifting from purely an emissions focus to more of a focus on fuel efficiency. A second reviewer said minimizing engine-out emissions addresses a key roadblock for improved efficiency, while another added that fundamental understanding of heavy-duty diesel combustion processes is necessary for future engine developments. A fourth reviewer said the data being generated leads to improved understanding, and is very relevant. We need to ensure this understanding is captured and translated into a tool that aids the industry. Another commented that, to the extent that LTC can be utilized at light load to control emissions, it can reduce the need for fuel to maintain adequate aftertreatment temperatures. If we can control LTC at high load with optimal timing, engine efficiency can be increased. A sixth reviewer said that this enables the construction of low emission, high efficiency diesel engines. This work will help with the development of CFD models to match engine results. This is an understanding necessary for the construction of high efficiency clean engines. The team could show a better picture of how this ties into higher efficiency engine work.

Another reviewer said the work addresses soot, HC and CO emissions problems with low temperature combustion. The work also addresses the lack of understanding multiple injection processes in advanced combustion systems, which have the potential of reducing soot and HC emissions. One reviewer said this project does support the DOE objective of developing a fundamental understanding of low temperature combustion that will enable the use of less engine aftertreatment and thus potentially increase engine thermal efficiency. At this point in time it is unclear what type of indicated fuel consumption improvement is possible with this approach versus other more conventional approaches that may include additional aftertreatment technology.

Another reviewer said that there are certainly a lot of efforts that are focused on improving fundamental understanding of diesel combustion and this information is being well shared with a large diverse industry group. The final reviewer said a shift is needed from emissions formation to reducing fuel consumption and CO_2. Two objectives are related to soot formation and oxidation. Another is on HC+CO oxidation. Fourth is flame propagation. This reviewer submits that given the emerging tight CO_2 regulations, which will be much more difficult to meet in the future than reducing criteria pollutants, the emphasis shifts to efficiency with little emphasis on emissions formation. Movement into GDI and efficiency is right on target.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

Comments were generally positive in this section. The first reviewer said this is a useful merge between modeling and experimentation. Another said this team has done a great job of identifying key technical issues, and applying "best in the world

capabilities" to study those issues. A third reviewer said the team has made good measurements showing effects of post injections and good measurements showing difference of LTC and conventional operation. Another reviewer noted the excellent overall focus on the forefront of LTC investigation. The combined core competency of SNL and UWM researchers offers unique opportunity to advance the state-of-the-art. A fifth reviewer said the combination of modeling and state-of-art measurement is superb. This reviewer added: ability to adapt to new needs; use of new tools is cutting edge and critical for public programs like this; apply this approach to efficiency gains.

Another reviewer commented that planar laser imaging diagnostics are applied to a single cylinder optical engine with very good optical access. Data and knowledge is combined with modeling efforts at the University of Wisconsin. One reviewer said, scientifically, this is a great project. The PI is developing PM formation and oxidation understanding in free jets that currently doesn't exist today for real world direct injection combustion devices. The only possible improvement in this project is the current lack of quantification of any possible fuel consumption improvement versus more conventional combustion approaches. Another reviewer said the team had pursued excellent technique development, but still the main focus is on emissions rather than efficiency. The final commenter asked if these techniques can be applied to GDI cold engine soot formation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Comments were generally positive in this section. One reviewer said good results were shown on reduction of UHC and promising methods were presented, while another reviewer said the results shared are interesting and with good explanation and understanding given to the optical data. A third reviewer said, once again, new findings in LTC are discovered. The dual laser approach and the dual injection investigations have uncovered new characteristics of the LTC. A fourth reviewer said this group is ahead of the world in understanding the combustion process in ways relevant to engine design and development. Another commented "nice work on new methods." The soot formation comparison of LTC with conventional engines is enlightening. The impact of post injection on main injection soot is a new finding and important. This is a good plan on GDI, according to this reviewer, who also suggested that the team remain flexible as knowledge develops, focusing on improved efficiency rather than emissions.

Another reviewer said, scientifically, this project is aiding in the community's understanding of in-cylinder soot formation/oxidization. The optical aspects of this project are truly outstanding. Again, it would be nice to see some type of experiment or simulation that shows how this combustion approach would impact fuel consumption. One reviewer said very interesting insight is being discovered on the rate of formation of soot in LTC combustion with the use of two different laser wavelengths. Also, post injection has been verified to reduce soot from the main injection. The exact reason for this is still being probed. For now the formation of OH late in the cycle is thought to oxidize the soot. This reviewer added that progress has been made to understand post injection's potential to reduce UHC. One final reviewer commented on the good incremental improvement and advancement that is necessary to lay the groundwork for industry's application of these technologies. Areas of investigation are closely related, but this reviewer queried to what extent this is a scattershot approach.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. One reviewer said that SNL is a key part of a large team that includes other labs, industry, and academia. This integration results in first-class transfer of new learning to those who need it. Another reviewer said this project has been well coordinated with industry and the University of Wisconsin through AEC working group meetings that includes input from key engine OEM partners. A third commenter noted that the team is dealing with a large working group, and this reviewer cannot imagine a program that could do better on collaboration, specifically with pulling together a large group to share the output and lessons of both this program and similar at the universities. Another reviewer said the collaboration with the University of Wisconsin is outstanding. This reviewer added that there is also a solid connection with the Advanced Engine Combustion Working group.

One reviewer sees more sync between SNL and UWM this year and a good team, and recommended that the team not add to the MOU membership. This reviewer felt the project's membership is already large enough to barely reach a consensus. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony. Another reviewer said this is a very well-established multidisciplinary project that has extensive industry backing. This reviewer added that closer

interaction with modeling partner (UW) would be more advantageous to the project. The final reviewer said the work is very broad and cross-functional. Lund and the University of Wisconsin bring in more academic inputs. This reviewer didn't see evidence of bringing in industry researchers, and added that this is critical for rapid communication and implementation of latest results.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

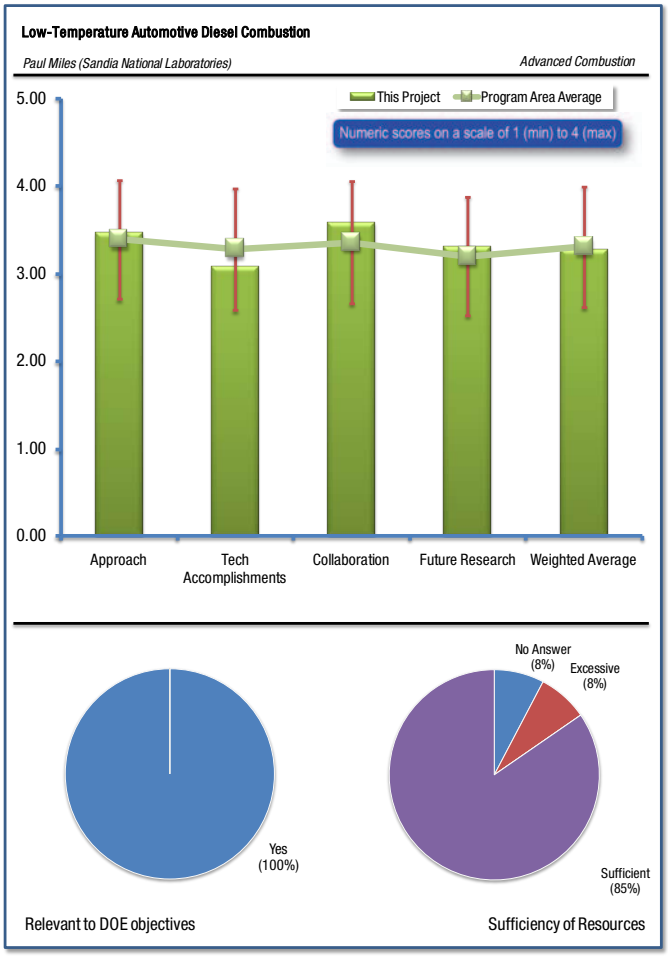
Comments were mixed in this section. The first reviewer observed good steady progress. Project goals are updated as experimental results and modeling results shape the future directions to lead to further efficiency improvements. A second reviewer noted a good plan, while another said keep going; there is more to do and to learn. A fourth reviewer said future work is very relevant. It will be focused on dual fuel concepts proposed by University of Wisconsin for high efficiency. Work will also continue on the reduction of HC emissions with multiple injections.

A fifth commented that the team mentioned an intent to evaluate a dual fueled engine, but there is no clear plan for what to look at. Another reviewer said that it would be interesting to broaden the range of speed / load cases investigated, especially as the area of research extends into multiple injections, and dual fuel. One commenter thinks that the program needs to shift emphasis from emissions to efficiency. The work on LTC is interesting and by reducing emissions the team may indirectly impact fuel consumption. However, the investigators need a mind-shift into how to improve combustion processes to reduce CO_2 emissions. The move into dual fuels and GDI is right on target. Explain experimental results from Wisconsin and use the fundamental understanding to improve efficiency. The final reviewer commented that overall, the approach is sound scientifically, if focused on continually seeking fundamental understanding of PM formation in free jets. As mentioned above, it would be beneficial to include some type of consideration for fuel consumption impact with LTC strategies.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer said there is an appropriate level of effort, while another said overall this is a good project with promising techniques and useful results. The final reviewer commented that too many publications can be a distraction.

Low-Temperature Automotive Diesel Combustion: Paul Miles (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 13 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

The first reviewer said LTC has promise to reduce efficiency losses due to emissions control and provide high efficiency combustion if well controlled. Another said fundamental understanding of advanced combustion modes helps drive engine design of the future. A third reviewer said improved emissions measurement techniques in cylinder can confirm modeling. These models are needed for future engine designs. Another added that the team is gaining fundamental understanding of the combustion process in question, which should help in optimizing the system to our advantage. A fifth commenter said this project applies optical diagnostics to understand the processes due to which combustion in diesel engines is inefficient, and how exhaust pollutants are formed, which offers insight into reducing combustion inefficiency by changes in engine design.

One reviewer said LTC is critical to engine efficiencies because LT emissions are costly to light-duty diesels. This reviewer would like to see a closer tie directly to improving combustion efficiency. The reviewer doesn't see many domestic OEMs moving into diesel. Benefits would be valuable to Germans and Japanese, for domestic and international sales. This reviewer supposes this is OK. Another commenter said this project partially supports DOE objectives–it addresses combustion schemes that may reduce engine-out emissions, but doesn't seem to include an element that addresses the impact of such combustion schemes on fuel consumption. The final reviewer said improving diagnostic techniques will be required for the further development and understanding of fundamental combustion processes in light-duty engines, in addition to heavy-duty engines. This reviewer added that this project needs to enunciate exactly why the processes studied are different from HD.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer noted the significant work on developing techniques to evaluate combustion, while another commented on the top-quality work with leading-edge facilities. A third reviewer said this is a great combination of optical and metal engines, and CFD/kinetics modeling to address CO and unburned hydrocarbon formation. It methodically develops an understanding of the impact of spray targeting and bowl design on CO and unburned hydrocarbon that may be of value in designing next generation small bore diesel combustion systems. Another reviewer said using optical engine, modeling and metal engine work for feedback loop is impressive and valuable. The approach is well-refined over the years. The team needs to emphasize developing new analytic tools to cover deficiencies.

Another reviewer commented that in-cylinder optical measurements are the focus of this work. The results provide knowledge for model improvements and developments at the U of W. The engine is similar to the metal engine at the U of W. Care has been taken in the details of the optical engine design to mimic that of the metal engine. Emissions and cylinder pressure measurements are also used in the overall analysis. One commenter said that, to use a predictive model, the team will need to establish confidence that it is robust.

Hopefully when the discrepancy between model and testing is resolved, it results in a model improvement that increases robustness for other conditions and engine geometries. Another reviewer said the project is reactive in its objectives, which is not a bad thing, but the motivations for changing directions and goals needs to be better motivated.

The final reviewer said that a balance is probably needed in the time/effort spent on "improving the techniques" versus running investigation experiments. This reviewer suggests less of the former and more of the latter. Is running a "broad range of operating conditions" with this hardware set a good choice? Should the work focus on a selection of high priority points? This reviewer is recommending a deeper and narrower forward planning, instead of the broad and necessarily shallow testing. This reviewer suggested that the team should consider limiting the time and resources spent on developing a "library of data" and run focused tests to iteratively validate simulations. The reviewer suggested that the team run statistically designed test matrices.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the new diagnostics seem to be very useful and help clarify the processes. Another commented on the nice matrices. The team is looking at operating conditions, and impact of changes. There was good correlation with results and nice development of theory. The team is getting an understanding of deficiencies on measurement and model. A third reviewer said the experimental database that is being developed for CO and unburned hydrocarbon formation as a function of targeting is of value to modelers for designing future small bore combustion systems. Again, the missing element is fuel consumption impact. Another commenter said the results and progress shared were of good interest and showed helpful understanding of some of the contributors to combustion inefficiency. It would help to have a design matrix of some combustion system parameters that are being studied so that the output could be of more direct help in the designing of real life combustion systems ... injector tips, bowls, swirl, etc.

The fifth reviewer would like to see more results that can be applied to engine development, while another said the presentation did not really show a $1 million accomplishments level, especially on the experimental side. Another said that the project highlights that the 'marriage' between fundamental engine measurements and computational modeling is a tricky one - how can differences between the results seen be ascribed to problems with either one of the techniques? For example, it is possible to "see" something in the model results that is not seen in the physical results–is it a modeling problem, or a failure of the diagnostic technique? The benefits of modeling are known and are obvious, but we need to admit that we will never see truly fully predictive modeling capability.

The final reviewer said a wide array of experiments sweeping several relevant parameters has been completed. Deep-UV laser diagnostics have been developed to measure CO, C2 and PAH fields. There is no evidence seen of CO or unburned hydrocarbons leaving the bowl, as the modeling has predicted in the past. The mixture leaving the bowl is clean. Thus it looks like the modeling is incorrect. The modeling has been exercised to check the sensitivities of various parameters, but none so far explain the discrepancy between model and experiments. It seems more likely that the problem is with simulating the mixing processes rather than chemical kinetics or grid size issues. This reviewer added that experiments have also been conducted that verify that CO and unburned hydrocarbon emissions can be decreased by reducing squish height and targeting the spray deeper within the bowl.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were generally positive in this section. The first reviewer said collaborations are well established and productive, while another observed great integration with academia, industry, and other labs. This reviewer added that this was a good example of collaborative research. Another reviewer said the UW and GM collaboration is important. It is nice to see industry (GM) so intimately involved. A fourth reviewer noted that the PI is collaborating with GM, the Lund Institute, and UW-ERC. That brings together optical engine measurements, metal engine measurements, and kinetics/mixing simulation–outstanding collaborative team. Another reviewer commented that very close ties with the modeling efforts exist with the University of Wisconsin. Indirect ties also exist with several industrial companies and national labs via the Advanced Engine Combustion group. A final reviewer said the list of the collaborating groups is impressive, as is the case with all the SNL projects under the MOU. This reviewer added that the team should capitalize more on it. Is this work coordinated with other related efforts within the SNL Combustion Facility? How so? This reviewer recommended not adding to the MOU membership. The team's membership is large enough to barely reach a consensus now. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

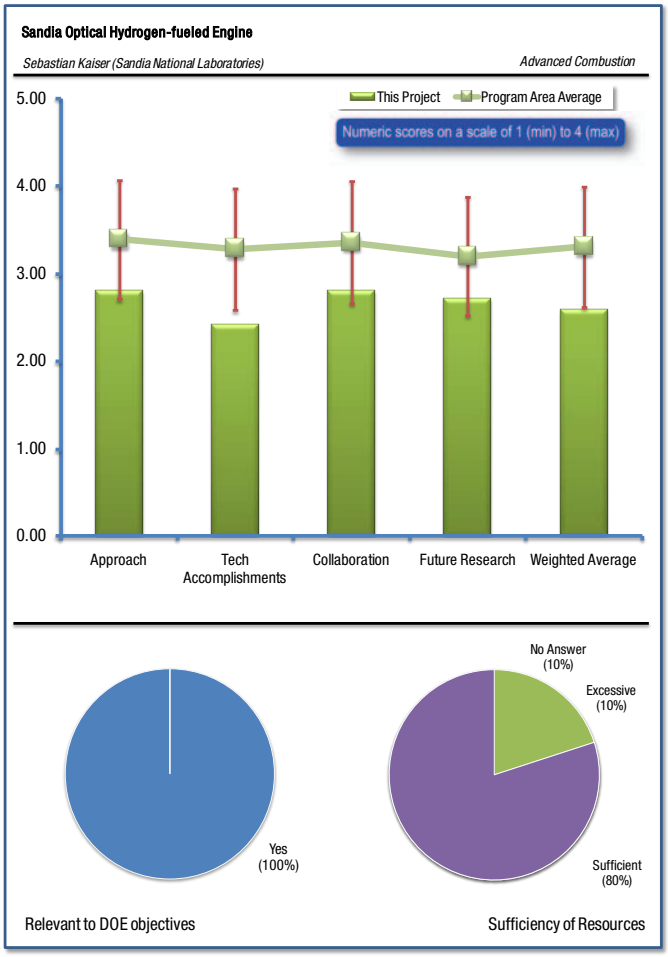
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer said keep up the good work. Another said there was nice movement into changing geometry given current understanding, and added that the team will be able to corroborate model and check hypotheses. Another commenter offered no comments–logical future plan for next year. A reviewer stated that the future plans are somewhat ad-hoc, perhaps by necessity in order to respond to changes or modifications in the industry's research directions. The final reviewer said the search for the model's shortcomings will be pursued by doing more experiments that increase understanding of mixing processes by varying injection pressures, swirl ratio and injector hole sizes. This reviewer added that multiple injections will also be investigated.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said seems like an appropriate effort level, while the other commenter said funding seems to have been a bit on the high side for this year's result. This reviewer added that too many publications can be a distraction.

Sandia Optical Hydrogen-fueled Engine: Sebastian Kaiser (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 10 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Comments were mixed in this section. The first reviewer said this work has a conceivable use should H_2 ever become viable as a fuel. Another commented that the overall efficiency gains justify the work. Longer term perspectives provide balance with shorter term vision of other projects: we need to understand fundamentals. A third reviewer commented that it uses H_2 instead of hydrocarbons, and added that this assumes the H_2 is not coming from oil. One reviewer said hydrogen-fueled IC engines have promise for very large increases in vehicle fuel economy. Modeling results at Argonne National Labs has recently shown this benefit. Other benefits are high power density and low NOx. This reviewer added that one significant concern is the hydrogen fuel infrastructure, without which this project ultimately cannot be successful.

Another reviewer asked where hydrogen currently fits in the DOE's energy mix. The industry is receiving mixed signals about whether hydrogen is being considered for the future or not. This project is quite esoteric–investigating a single jet flow in a cylinder for DI of H_2 is quite far removed from our current emphasis on fuel efficiency for diesel and gasoline engines. Another reviewer commented that this project was more relevant in prior years when the H_2 "hype" was at its peak. The final reviewer stated this project weakly supports the DOE objectives of understanding fundamental combustion phenomenon toward improving engine fuel consumption. This reviewer added that the latter portion of the objective is being weakly addressed in this project.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer said the combination of optical, metal engines and modeling is the correct approach. Another agrees with the need to increase the understanding of the combustion, fuel, air and combustion chamber. This reviewer added that fundamental investigations of interactions are important and well worth investigating, and the method used in this program to try and isolate these effects does seem like a logical approach. A third reviewer said the early emphasis on modeling is key, but added that it seems like time to move on and get more correlations. Modeling needs to push beyond hardware limitations and recommend best configurations.

A fourth commenter said, to date, optical engine measurements have been informative and the limited CFD has shown that mixing issues still require quite a bit of attention. The presentation did not include metal engine measurements, which are critical in this type of research project. An integration of optical engine, modeling, and metal engine results is necessary to develop continual understanding of hydrogen DI engine combustion behavior. Another reviewer said an optical engine is used to measure in-cylinder processes of H_2 fuel injection, mixing and combustion. These are combined with results from the metal engine at Argonne and numerical simulations at three different national labs to get the total understanding. Technical barriers related to engine performance should be spelled out and the plan to address those barriers should be clearly outlined.

Another reviewer commented that the greater focus on simulation is good, but added that the quality of simulation leaves much to be desired. The same "quantity" of simulation will yield significantly better results if (and only if) it is done by a national lab or an academic partner who has an already-established core competency in engine simulations. A few of the experimental results slides are repeats from last year's work. The focus on the single-hole injector is a step in the right direction. Another reviewer said there was good use of measurement and simulation. However, the reviewer thinks the team should have partnered with Fluent for the Fluent CFD. The CFD results are more a result of the individual doing the work than the code itself. This reviewer doesn't know how much interaction there was with the Fluent CFD writers. Another reviewer said, again, the use or relevance of H_2 needs to be better motivated. Isn't ethanol use in DI engines more relevant, or the direct injection of CNG, for example? The final reviewer said the team needs to consider more than one speed-load condition as part of the injector evaluation process, and subsequent combustion work.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer said the models are developing well. There is not much correlation, but information flow is just beginning. Models should contemplate the impact of lube oil, as this reviewer would expect this to be a significant practical issue that will emerge–more related to ash and PM/PN emissions than HC emissions. A second reviewer said there was good progress with the data and model, but there was not full agreement so far. Covering a broad-based investigation domain from fundamentals all the way to the Ford metal engine is a tall order. It requires critical competencies and multi-faceted teaming that are not available to this project. This is reflected in the quality of results. A fourth reviewer said the team needs to address the discrepancy between simulation and experiment. Another reviewer said it is unclear that there were significant advancements made in the testing last year that improved our fundamental understanding of the combustion process and that would give some good insight into better methods to optimize the combustion process for improved engine performance. Clearly efforts were made in the testing and simulation, this reviewer added, but it was not clear what fundamental advancements were made.

Another reviewer said progress is slow and the results scattered. Results purport to show the inadequacies of KIVA versus FLUENT. Shouldn't the KIVA modelers be told? Better description of the "time to complete injection" versus in-cylinder bulk flow motion should be more fully described. One commenter was suspicious of the CFD results and curious if an expert Fluent user could have done better. This reviewer thought a good KIVA user would have done better. With the coarse grid, it makes this reviewer wonder if there was a computer resource issue. Another reviewer said limited combustion understanding has been generated to date. For example, it would be nice to see more study on injector targeting, wall effects, and bowl design on mixing and combustion. Metal engine results would help address these shortcomings. The final reviewer said only one operating condition and three injection timings have been studied this year. When integrated over a three year period, the amount and scope of knowledge generated from this work seems to fall below expectations. This reviewer added that the motivation for the selection of hardware (like the single-hole injector), the selection of operating conditions, and the selection of flows should be based on improving engine performance, not necessarily on what is easy to model with numerical simulations.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Comments were mixed in this section. The first reviewer said it is encouraging to see that collaborations with simulation and metal engine researchers have improved this past year. Another said industry involvement from Ford and connection with the MOU group is good. A third commenter said collaboration seems okay at this early stage: ANL and LLNL. This reviewer would like to see more industry involvement later in the project.

Another reviewer didn't know what the mixing objective was, and queried if the team was trying to achieve a homogeneous mixture at TDC. A fifth commenter said that, though the presentation suggested a collaboration element with Ford, there was no data shown for metal engine experiments. This reviewer added that the collaboration with LLNL and ANL is obviously very good, given their recent CFD modeling results. Another asked why there is no mention of Cummins Westport, who has done a fair amount of work in the area of direct injection of H_2 in HD engines. The final reviewer said, if not already done, this work should be compared with the (robust) NG fundamental investigations, nationally and abroad, and similarly for H_2 work. (H_2 and NG have many similarities and differences too.) This reviewer also suggested increasing the level of experience and core competency of the collaborators who are carrying out DOE-funded activities.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

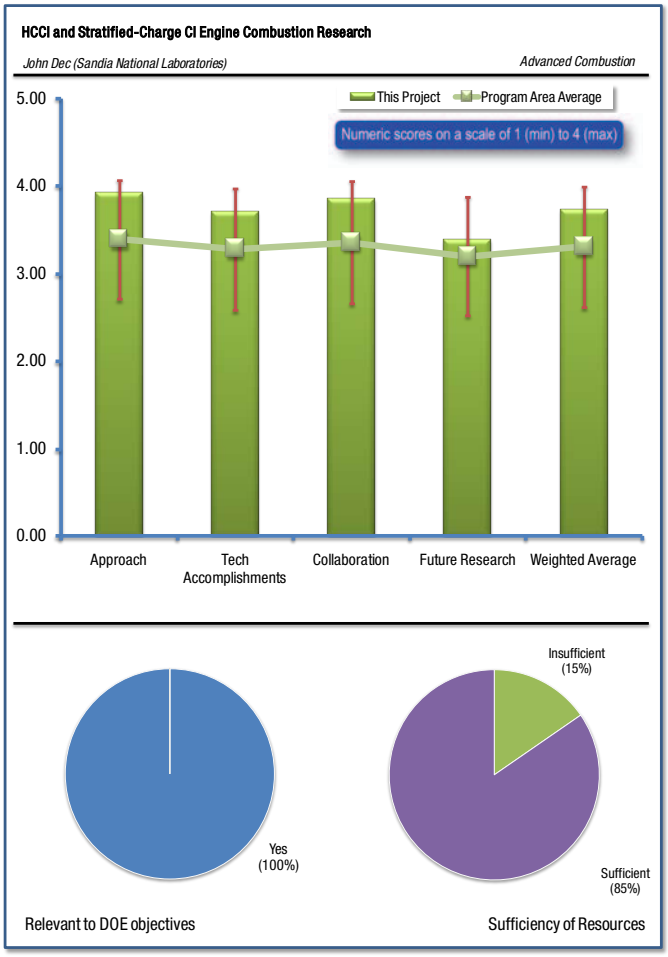
Comments were mixed in this section. One reviewer said the work is worth continuing, and added the team should perhaps consider potential future fuel sources; will H_2 come from a reformer and thus perhaps be mixed with CO and/or CH_4? If so, what are the implications to this work? Another reviewer said that they need to push the envelope on injection and parameters. This is a very different fuel and the investigators need to model the various independent variables and recommend hardware directions. A good example would be low pressure and large nozzle diameters, or using different cone angles (impingement on crown seems like a non-issue). A third reviewer said the focus should be on in-cylinder emissions formation, understanding and identifying ways to reduce, then on power density. Another commented that it would be nice to see more spray targeting elements included in future work, including more metal engine work to address mixing issues seen to date.

One reviewer stated that it is imperative that the metal engine work at Argonne is the driving force for this work at Sandia. Design issues, injector selection, and efficiency and emissions performance issue generated at Argonne (with advice from the OEM partner involved) on their metal engine should drive investigations on this optical engine work. This reviewer added that validation of the simulation, while very necessary and important, should not be the sole focus of this work. Another reviewer commented that the future plans are somewhat random–why the emphasis on single jet injection? At some point with single-hole injection, single injection and low pressure, we would be better off with port injection. The final reviewer said Fluent simulation at ANL should be stopped. It is an exercise that a junior engineer at an industrial partner can do well. The value of running a simulation at LLNL is TBD. Model tuning is elementary. This reviewer added that the work needs to rise to be on par with a national lab-type research activity.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that, given the relatively low likelihood of H_2 ever being a major transport fuel, this is an appropriate and perhaps generous funding level. Another reviewer asked if we should find a source for the fuel first. It would make more sense to this reviewer if the team used methane; we know how to get that, both out of the ground and renewable. The final reviewer asked, has the team surveyed the ICE H_2 work done in Germany, Europe (especially TNO), and Japan? This reviewer added that it may be worthwhile for the PI to spend a couple man-months on this, then re-examine the future plans. Should the project be scaled down, considering the emerging “realities” of the H_2-based transportation value proposition?

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



Reviewer Sample Size

This project had a total of 13 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that HCCI/LTC efficiency improvements are "right-on," and that improving range can lead to improved CO_2 if gasoline is used. A reviewer commented that the focus on extending range and efficiency of HCCI directly supports goals. Similarly, a reviewer said the increased load range of LTC addresses a key barrier to implementation.

A reviewer said this is a very good fundamental project aimed at advancing the understanding of HCCI while pushing up IMEP and exploring possible ISFC improvements. The fundamental understanding of these combustion systems will drive future engine design. A reviewer noted that the project seeks to provide fundamental understanding of LTC combustion. Very specific issues like thermal stratification, and the potential of intake boost to extend the high load limit of HCCI combustion is being investigated.

A reviewer observed that higher load levels of HCCI engine operation will be critical to allowing the widespread implementation of HCCI in real-world commercial applications. Expanding HCCI to alternative fuel usage (ethanol and other biofuels) will serve to allow for conventional petroleum-based fuel displacement. A final reviewer said this supports efforts for higher efficiency at usable loads on a light duty diesel; also showed how to improve thermal efficiency by a significant margin.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer said there was excellent work at using the measured results in cylinder to lead the LES simulation work: good job of using boost and EGR to get higher BMEP levels for HCCI. A reviewer said that the PI has further expanded last year's very good fundamental work to address both high load operation and impact of HCCI strategy on ISFC. The team is uniquely suited to tackle a difficult problem. John Dec has chosen TS and methanol HCCI as the focus of his current studies. This is endorsed by the MOU members and others, so this reviewer took it as a "best-in-class approach." A reviewer said this work is leading the world in understanding quasi-homogenous combustion systems, and this group has defined the opportunities for control through stratification.

A commenter observed this is a good, comprehensive approach with well-motivated goals and modifications to the project on the fly. Another reviewer also noted this is a comprehensive approach–optical, models, metal, and said it was nice to see good transfer of information to industry (GM); the modeling of stratification and in-depth variable is impressive. A reviewer also noted the combination of data from metal and optical engines. The metal engine is allowed to set the agenda for the optical engine. This is a very sound approach. Also, CFD models are applied to gain further understanding that experiments cannot provide. A reviewer felt this approach is using the best available tools to focus on key HCCI issues.

The final reviewer would like to see a clear summary of the assumptions for the engine testing, and would like an assessment if any of these assumptions present future roadblocks to implementation of these techniques.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer noted there is good progress on a wide front, and increased boost for HCCI and the use of ethanol in HCCI engines are both very useful project goals. Another said there was a good deal of high quality progress made over the last year, including enough detailed work to understand the causes and give good insight to the value and reasons for the behavior observed with HCCI. The work on thermal stratification was very helpful and directly relevant to HCCI understanding. Further comments were that important findings/confirmations were made on showing the importance of thermal stratification on progression of auto-ignition: this is an important discovery on early ignition impacts from boost on combustion stability. This is nice work as are the results on improving efficiency via boost and reduced EGR. A commenter noted the team is gaining good fundamental understanding of thermal stratification plus other interesting results, plus interesting data on boosting. The presenter demonstrated the importance of TS, but they now need to determine how to impact it. This reviewer also had questions on the impact of thermal versus concentration stratification, as well as TS correlation with concentration gradients.

A reviewer observed that more details on thermal stratification in the bulk gas and the near wall region have been obtained. Thermal stratification reduces the maximum heat release rate, which reduced knock. The correlation with combustion is excellent and now provides confidence in our understanding of the effect of thermal stratification. In addition: the effect of residuals on thermal stratification in a low residual situation has been shown to be not significant; the effect of intake boost in extending the high load HCCI limit has been observed for a range of speeds; the loss in maximum IMEP is not a huge issue.

A reviewer commented on the very good results on the impact of increasing BMEP on engine pressure rise rate limits and peak firing pressure limits based on fundamental thermal stratification optical engine measurements and modeling. However, more work still needs to occur addressing further increasing load and qualifying ISFC impact, and also addressing control issues for transitioning from one steady-state to another steady-state operation point.

Final comments were that everyone waits to read the papers coming from this work, and that the PI has achieved the objectives set down and added to them as the project proceeded.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first comment was that this is very important work that has resulted in a breakthrough - impact of boost on extended HCCI range. It is nice to get this moving into industry through closer collaboration. Another recommended keeping up the great collaboration. A reviewer said everything seems to be working together to achieve the project objectives. The third reviewer said that the presenter is dealing with a wide range of participants and John does an excellent job sharing his work across a broad range of the diesel engine community.

A reviewer noted a wide range of collaborations with industry, national labs and universities. Similarly, a commenter stated that they are working with many key universities and industry partners. This project has a good collaboration of strengths of optical and metal engine work at SNL and Stanford, and HCCI kinetics modeling work at UM and GM. A reviewer highlighted the close integration of academia, labs, industry, and sets an example for other research programs.

Good coordination with other institutions was noted by a reviewer, who further commented on a good, real-time technology transfer to GM. In addition the sixth reviewer stated, “Do not add to the MOU membership. You have large enough membership to barely reach a consensus now. Sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.”

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said "keep going." Another observed that expanding future research to biofuels, high efficiency boosted HCCI and closer integration with computational modeling are all useful areas. Future direction modifications are an expedient approach and a good use of DOE funding. Plans are appropriate to address some key HCCI issues.

The fourth reviewer thought the plan moving forward is solid, although it would be good to run some simple transient evaluations (engine load and speed changes) to see how HCCI would perform with changing engine conditions to understand combustion stability and the potential requirements to make this work over a real drive cycle. Another observation was that the future challenge would be to demonstrate this on a multicylinder engine. The PI should do a study of the work to show how variability effects would be a challenge on a multi cylinder: the PI should also study transient effects for a multi cylinder.

A reviewer noted the direction on improving TS and major impacts. There is a need to move towards impacting TS to improved performance: how will this be accomplished? The PI may need to move into interplay with concentration gradients. The final reviewer asked if the PI has considered the effect of air motion and the gas total kinetic energy on TS.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Funding level was generally judged to be appropriate. A comment was offered that this project appears to support post-docs and other personal at SNL and LLNL. The funding seems reasonable. A reviewer would like to see more resources being spent on this project: these are excellent results that are well-aligned with DOE and industry objectives, and are a good investment. The last commenter would fund this more and put in multi-cylinder work and transient operation work.

Low-Temperature Diesel Combustion Cross-Cut Research: Lyle Pickett (Sandia National Laboratories)

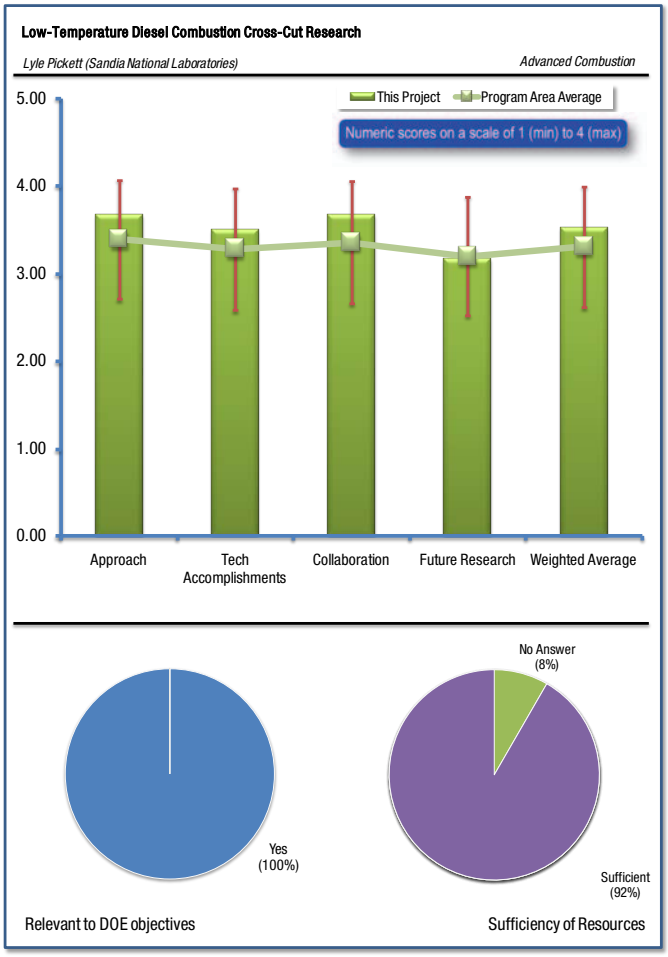
Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer noted that the project included fundamental studies of spray mechanics, spray combustion and soot models for conventional and alternative fuels which are important areas of research for fossil fuel displacement. A separate reviewer noted that the Engine Combustion Network is quite important for transmission of data and to develop common understandings with non-DOE researchers. The reviewer added that this was a central tool for propagating information and that cross-cuts like this develop broadened understanding and corroboration. A separate reviewer stated that the project was gaining a fundamental measurement under controlled conditions to advance inputs to better models. One reviewer said that the project provides excellent data for in cylinder modeling calibration and development.

One reviewer said that the project addresses the sources of unburned hydrocarbon and CO emissions, and thereby also addresses efficiency barriers for low temperature combustion processes. The reviewer added that load limit issues for LTC combustion are also addressed.



A reviewer said that this was a multi-faceted project which provides a great baseline fundamental spray formation and combustion database for engine combustion system modelers to calibrate their models to reduce engine-out emissions and addressing spray-targeting issues for DPF regeneration. The reviewer added that fuel consumption improvement is addressed in this project in the form of a method to reduce fueling during DPF regeneration and this is a tie with DOE goals, but a little weak.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that the approach of establishing baseline injection equipment, nozzles, and operating conditions for experimentation at various worldwide labs is wonderful. The reviewer added that with time, the measurements taken by the various partners can be readily compared and used by combustion modelers to improve existing spray/kinetics models in compassion to gathering published data that will include a huge variety of boundary conditions that are difficult to resolve by modelers.

A reviewer described the project approach as well designed and an expedient experimental direction. A separate reviewer stated that it was a unique approach to managing variability while maintaining applicably to real engines. A reviewer stated that the project capitalizes on a long standing SNL experimental setup and core competency.

A reviewer sated that the quantitative optical diagnostics are used in a combustion vessel to generate data useful for the improvement of numerical models of fuel injection processes. The reviewer continued that this is done via the Engine Combustion Network, and the study of a standard injector common to many labs around the world. The reviewer added that the laboratory setup allows for very

careful control of the experiment and boundary conditions adding that the effect of high pressure and temperature on spray character can be studied.

A reviewer thought that the stated objective of this project is good, and having a large group of injectors spread across the world is a great effort for correlation, especially if people are willing to share some of the interesting results, beyond the basics required for collaboration.

A reviewer noted that the project was starting with spray, adding that this was a good start with identical injectors. The reviewer also said that the work on soot understanding is a good application for collaboration, however, future engines will operate at high NOx and low PM and this becomes less critical. The reviewer saw a need to focus on efficiency drivers.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer thinks this is one of the best overall projects, adding that it provided fundamental data to develop combustion, spray, and emissions models for designing engines of the future.

One reviewer said there were good findings on late post injection and biodiesel impact. A reviewer described good applications in spray geometries as well as the biodiesel soot investigations. A separate reviewer observed good systematic progress, adding that the project was pushing the boundary of fundamental engine combustion understanding.

A reviewer noted that the initial test and evaluation of the commonality of spray boundary conditions is promising, though much work still lies ahead of all the involved partners in this study. The reviewer added that the most tangible contribution to date is in the area of spray penetration at very low charge density and high temperatures where DPF regeneration spray targeting has potential over-penetration issues. To date, the reviewer said, there is little demonstration of what type of ISFC improvements could be made during DPF regeneration through more optimal spray targeting, adding that this possibly could be addressed in the future.

A reviewer described the data set from the injection penetration work as fairly impressive, especially the collaboration between lab data and simulation work. The reviewer added that it would be good in the future to have this work expanded to include the other injection parameters, meaning injection pressure, hole diameter (and other injector hole descriptive items, e.g. L/D, radius, etc.) to build an ever larger and potentially more helpful data base to be considered in injector/combustion system design.

A reviewer said there was a very good agreement of boundary conditions and spray penetration data between Sandia and IFP, adding that in the case of combustion, lift-off lengths also were the same between the two institutions. The reviewer continued that liquid penetration for late injection has been studied and this condition is relevant to DPF generation. The same reviewer noted that new information has been generated as follows: biodiesel sprays are shown to penetrate 25% more than standard diesel; and soot morphology as a function of downstream position in the spray has been studied.

A reviewer said that the characterization of injector A shows good correlation with others. The same reviewer also listed jet penetration with biodiesel and ULSD comparisons and soot formation and characteristics as having very interesting results. The reviewers added that these were nice preliminary results and direction.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer described a widespread collaboration with a wide range of stakeholders and investigators. A separate reviewer said there was an excellent cooperative network.

One reviewer said that the Engine Combustion Network is an interesting concept and it needs to be kept pre-competitive. The reviewer added that the quality of work and results will be dependent on where the experiments are carried out, as not all the combustion labs and researchers are equal. The reviewer added that this would affect the overall results, as they rely on others to provide some of the building blocks to supplement project results. The reviewer urged the project not to add to the MOU membership,

suggesting that their membership is large enough to make it difficult to reach a consensus now. The reviewer added that sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

A reviewer described the collaboration as excellent so far, noting there was nice collaboration with IFP, Bosch, etc. and that this is a central objective to make sure a valuable tool is being developed. A separate reviewer stated that the Engine Combustion Network is a great idea.

A reviewer said that this is a huge collaborative effort among numerous global research institutions with outstanding effort by the PI is setting up this huge collaboration.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer noted that the project direction is on a year-to-year basis and is modified as required to investigate new areas of interest. One reviewer described strong focus parameters that can affect HCCI management. A reviewer said that GDI is good addition to portfolio of planned work.

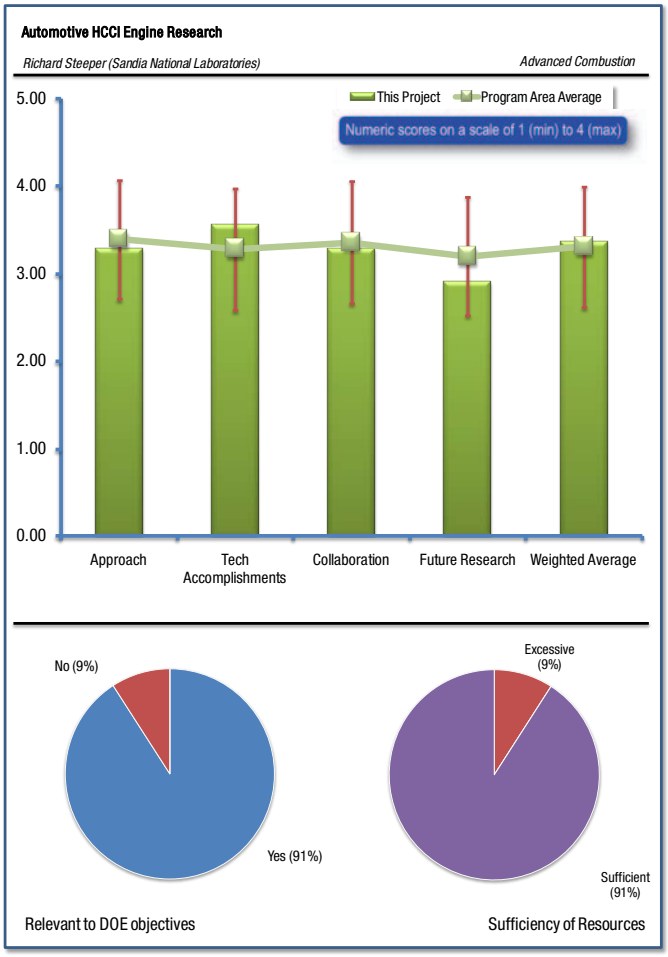
A reviewer stated that the future work is very logical and will be beneficial to modelers and engine development companies. The reviewer added that the only missing piece revolves around quantifying fuel consumption improvements associated with more optimal DPF regeneration spray targeting. A separate reviewer said that several items needed for model development have been put on the list.

A reviewer suggested that the project needs to move towards high-efficiency objectives, giving the example that we are seeing a very strong movement towards high-NOx and low PM operation (low EGR), and very high injection pressures. The reviewer continued that it was also very important to move into LD gasoline DI, adding that these will be the bulk of US engines in the next 5-10 years and we need much more understanding here.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

There were no responses to this question.

Automotive HCCI Engine Research: Richard Steeper (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 11 reviewers. HEYWOOD

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that HCCI combustion, once implemented on a large commercial scale, will have a positive effect on fleet fuel efficiency. A separate reviewer stated that it is very important to advance understanding in efficiency of gasoline DI engines adding that there was a novel approach with high NVO levels.

One reviewer said that the experimental work described is an important bridge between modeling and multi-cylinder engine demonstration of high-efficiency engines. A separate reviewer noted that fundamental knowledge of low temperature combustion is being generated, adding that these include the areas of thermal and residual stratification, ignition, heat transfer and mixing.

A reviewer said they could not make the leap to better efficiency with this one, adding that they need to see a 1-D cycle simulation that shows how this concept of NVO injection for HCCI is going to improve efficiency.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said this was one of a few gasoline combustion based projects and there was a good balance with diesel fuel based combustion. A reviewer said the experiments are performed in an optical engine and new diagnostics are being developed as necessary. The reviewer added that computer models are being exercised for further understanding.

A reviewer commented that investigations of chemical kinetics of early stages of heat release in HCCI combustion are a key to controlling it, continuing that from today forward, gasoline will contain at least 10-15% ethanol. The reviewer suggested that the oxygenate components might have an important effect on CO production, as well as other potentially relevant intermediate species (e.g., aldehydes), and so this might be an important element to consider in the chemical kinetics work. The reviewer would like to see the work include a fuel effects/sensitivity study.

A reviewer stated that the use of NVO is not well motivated other than to drive internal EGR, and wondered why study this particular phenomenon versus any other “interesting” conventional DI, SI or pre-mixed combustion effect. A reviewer suggested that the project team should consider running 1-D global cycle simulation models such as GT Power or WAVE to supplement the detailed KIVA analysis. This would give much insight especially when NVO is the focus of the study. A reviewer said that the optical engine with modeling is impressive, but it needs more metal engine work. The team needs to focus on efficiency gains.

One reviewer missed the fundamental importance of this work and how it will benefit IC engines moving forward. The reviewer understood what was being examined, just not how this really advances the state of the art in system design.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that the experiments to determine the relative influence of thermal and chemical factors on heat release are of critical importance to LTC. A separate reviewer said that the experiments that distinguished between thermal and chemical effects and revealed chemical effects are very valuable.

One reviewer said there were nice correlations of SOI NVO and performance and a good interpretation of observations. The reviewer added that it was an interesting discovery on NVO impact on heat release. The reviewer also commented on the good work done on diagnostics and CO impact and the excellent work on developing new diagnostics and better S/N.

A reviewer said that the accomplishments are good, but that this project does not offer a holistic view of any particular part of HCCI engine operation that is useful, timely or lasting.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was a good collaboration with a range of institutions. A separate reviewer said that the work is well coordinated with modeling efforts, and industry interest is sufficient to maintain technical relevance/significance. One reviewer stated that the collaboration was very impressive with UW, LLNL, Ford and GM and that it was nice to see inputs from OEMs helping to set direction.

One reviewer urged the team not to add to the MOU membership. The reviewer believes the project's membership is large enough to barely reach a consensus now. The reviewer added that sooner or later, the work will be leveled at the least common denominator and SNL may be challenged in maintaining harmony.

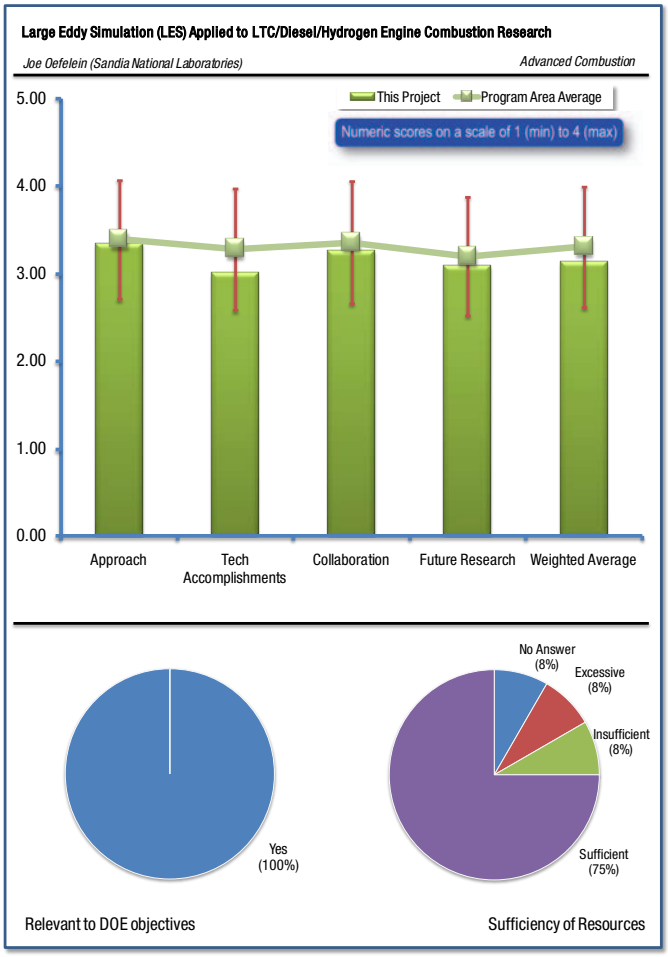
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that while HCCI is important, this project seems to be in better position than some others to shift emphasis toward other types of combustion such as lean burn. This may be more important for light duty in the next 10 years or so. A separate reviewer said that there was a need to continue developing understanding of this operating principle and added that the project should continue getting OEM direction. The reviewer suggested the project needs to move towards advancing efficiency gains. A reviewer made the general comment that the proportion spent on facility upgrades and expansions at SNL appears to be excessive.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer made the general comment that the proportion spent on facility upgrades and expansions at SNL appears to be excessive.

Large Eddy Simulation (LES) Applied to LTC/Diesel/Hydrogen Engine Combustion Research: Joe Oefelein (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

The first reviewer commented that fundamental studies of injector characteristics are important for novel engine concepts to displace conventional fuels and engines. A second reviewer remarked that LES can be a powerful tool for better understanding of combustion and for the helping with the development of the traditional CFD tools. The third reviewer expressed that this project provides simulation capabilities for the development of high efficiency, clean, low temperature combustion engines.

The fourth reviewer stated that the work is an important longer-term step toward including experimentally-observed effects on engine modeling. Similarly, the fifth reviewer opined that it is important to push modeling foundations, and added that models are so critical to understanding.

The sixth reviewer noted that this project indirectly supports DOE goals of advanced combustion development and improve fuel consumption characteristics. This reviewer explained that the net output of this project is essentially the translation from high fidelity CFD analysis of DI combustion into engineering models, and added that it is important that this work continues given the possibility for improved engineering models based on high density computational meshes.

A seventh reviewer responded both positively and negatively to the relevance of this project to overall DOE objectives of petroleum displacement. This reviewer remarked that this project should be totally funded by BES, and it is indeed a fundamental work that falls outside of the VTP charter. Additionally, the "link" should exist without providing VTP funding support.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer stated that the computational power behind this project is very impressive. The second reviewer noted the project's use of cutting edge components, and interesting dissection of effects via the interface envelope choice, and that it was nice to see multiple fuels and engines being modeled to develop common fundamentals. This reviewer added that it is very important to correlate with reality. A third reviewer offered that the project has good use of computer resources, and the focus on modeling and improving this area of expertise is an excellent area in which to focus. Furthermore, this reviewer remarked that obviously, collaboration is hugely important in this project to make sure there is a broad data set that can be used for simulation calibration.

The fourth reviewer opined that this project comes across as a solution looking for a problem, and added that relevance to real engine practicalities is obvious, but needs to be better motivated.

A fifth reviewer commented that the approach is aimed toward a significant improvement in more computationally-intensive methods, and is an important step in bringing this closer to eventual "desktop" calculation. This reviewer warned that the broad scope may be getting ahead of the tool's capabilities, and suggested that stepping back and validating the basic models against experiment would be a better use of time.

The sixth reviewer indicated that the project is fascinating as always, but offered concern that the techniques cannot be employed by only a select few with this computing capability.

A seventh reviewer recommended that an area of improvement is in validation versus experimental measurements. Additionally, to date, there has been little effort in validation against practical engine type measurements, though future work is focused on this validation issue. Otherwise, the approach has been very good.

The eighth reviewer remarked that this is a "nice to do" project.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer noted that the work beginning on HCCI experiments at Sandia will be particularly important and relevant. The initial results are encouraging. The work on modeling liquid HC sprays is also very critical. The second reviewer commented on the nice interface analyses and mixing, and added that it is important to push state-of-art and expanding time on looking at unexplored territories. The third reviewer remarked that this is the frontiers of simulation, and noted that it is fully dependent on the future computing platforms capabilities. Additionally, this reviewer offered that there were too many "nice pictures" reflecting the progress made.

A fourth reviewer queried whether there is more to this than impressive visualization to the layman. This reviewer also pondered how good the visualization is, other than as measured by gross parameters and variables like jet penetration length and large scale structure development.

The fifth reviewer stated that progress is relatively slow in going from base validation cases to "real world cases". This reviewer questioned how the evolving jet simulations in the presentation compare with fundamental experimental measurements of scalar dissipation rates. Additionally, this reviewer offered that the only concern is that the impression given is that validation is done on a macroscopic scale, comparing to parameters such as jet penetration rates and cylinder bulk temperature, and not on a microscopic scale, which is more relevant to accurate prediction of mixing and heat transfer processes. For example, the comparison with HCCI scalar fields seems to suggest that the turbulence length scales are too large. The reviewer also queried whether there is sufficient experimental temperature and/or concentration field data for validation, to give better agreement going forward.

A sixth reviewer expressed that milestones in the presentation are largely "ongoing" projects, and further added that the milestones are not clear. The seventh reviewer commented that this project needs much more validation against experimental measurements in order to aid engine designers.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer opined that the project has an amazing list of collaborators. The second reviewer commented that collaboration both inside Sandia and beyond is well represented. A third reviewer indicated that the project has done excellent work in having an LES working group that involves uses of various CFD codes. This reviewer hoped that the lessons learned are available to these CFD code companies.

The fourth reviewer noted that the CFD side of the equation is very collaborative in nature since it includes a number of groups that are either software developers or researchers who have expertise in engine CFD. This reviewer did explain that more collaboration is necessary with those who have experimental data available for validation, and suggested possibly UW-ERC or GM.

A fifth reviewer commented that collaboration is sufficient to steer the project in the right direction, but recommended that the model needs more validation data. The sixth reviewer stated that more in-depth understanding of the underlying combustion phenomena will help the modeler understand the results.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer recommended continued analysis of the less-well understood cases of highly diffusive gaseous fuels (hydrogen) and liquid fuels, as a means of better identifying the gaps in fundamental understanding that would be required to get to the next level. The second reviewer praised the project as great work, but added that the challenge will be to turn this into a practical tool for industry.

A third reviewer noted that future research needs to have a long-term vision and not merely be reactive to suggestions from existing Sandia research; otherwise the significance of this work will be dilute. For example, the long-term goal of investigating a very high pressure, multiple-injection DI process would be a good basis for ongoing, background work.

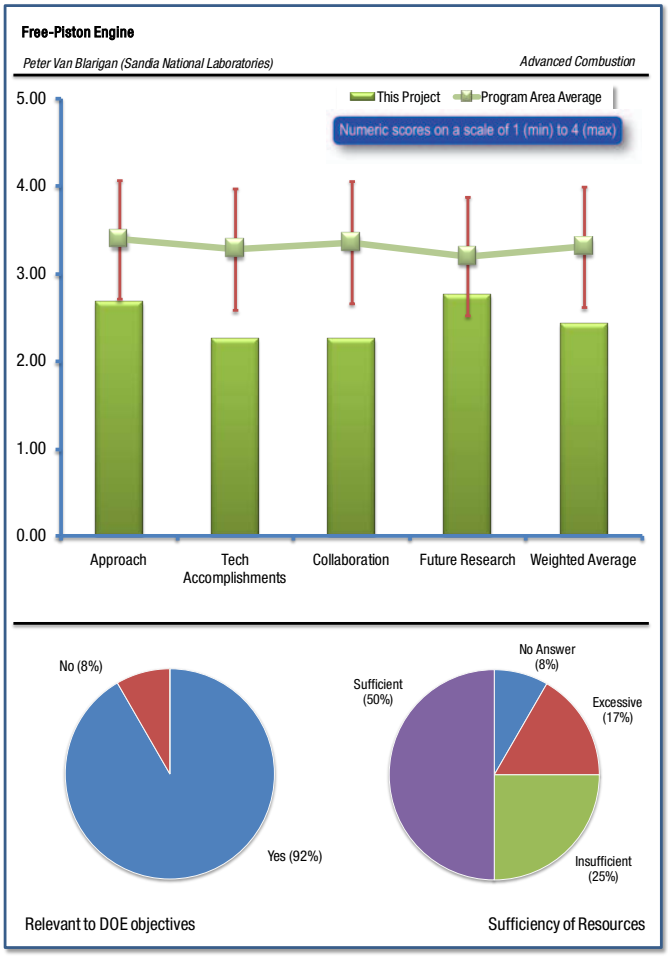
The fourth reviewer commented that the future work does include possible validation against Lyle Pickett's combustion network database, but possibly this effort could also include any experimental data from UW-ERC and/or GM. Additionally, this reviewer stated that the more validation the better chance engine design companies will be able to reap the benefits toward developing less computational intensive engineering models.

The fifth reviewer explained that generating reduced but practical computing capability for common engine designers at the PC and workstation level is required next.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that the gap in investigators is now filled, and added that it is important to get training done and progress. A second reviewer recommended that DOE's BES fund the project.

Free-Piston Engine: Peter Van Blarigan (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

The first reviewer noted that this is an interesting engine concept that deserves to be pursued. Similarly, the second reviewer expressed that this is a good, innovative project that really would advance the state of the art. This reviewer did add that there are some obvious challenges with the variety of new devices being combined, but the reviewer gave good marks for thinking outside the box.

A third reviewer indicated that the FPE program remains an important long-range technology as a cost-effective and efficient powerplant for PHEVs. The fourth reviewer remarked that the free piston has very high efficiency potential and could be an alternative to fuel cell. Furthermore, it can easily adapt to a broad range of fuels. The fifth reviewer supposed that one could "burn a lot of stuff in this thing."

The sixth reviewer explained that, theoretically, this project supports DOE goals for pushing peak engine thermal efficiency above 50% while attempting to meet emission standards in-cylinder. A seventh reviewer noted that the project promises very high efficiency (>50%), via high compression ratios (20-40:1). The eighth reviewer offered that this project is best fit for a SBIR-type program and not VTP funding.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer really liked the innovative ideas behind this free piston engine, and added that this has the potential to generate a lot of very interesting data that could be of great interest as we move forward.

The second reviewer noted the interesting design approach, but commented that there is still a lot of work to get a working device. A third reviewer indicated that much credit is deserved in assembling a functional prototype. The reviewer did query whether the approach taken is meant to prove out the capabilities of the LEG-FPE under fired conditions, or to examine two-stroke, ultra-high CR, lean HCCI with various fuels. Additionally, the reviewer noted that if worked separately, each would be a substantial effort, and that taken together, this is a highly ambitious undertaking for the resources proposed.

A fourth reviewer explained that the major technical barrier is practical implementation, and suggested that this should be addressed via a meaningful prototype. Furthermore, this reviewer expressed that funding has been increased in 2010 to build parts and assemble a prototype.

The fifth reviewer opined that the project seems to have gone backwards rather than forward, although reconsidering a number of previous assumptions and engine features is a good idea.

The sixth reviewer commented that the elusive free-piston, 2-stroke engine has been researched and studied to a great detail by DOD, DOE, Daimler Benz, AVL, FEV and many others. This reviewer felt that this project is "beating a dead horse."

A seventh reviewer expressed doubt that the engine will ever run, adding that the planning is so poor, and that it was built without knowing how to get it started, the reviewer could not begin to imagine all the potential failure modes. If you have HCCI near constant volume combustion, you will "wake all the neighbors for miles" when this engine runs. This reviewer did comment that none of the other researchers care about noise either. This reviewer further noted the need to do a safety review with this, as there are unrestrained pistons (projectiles) and high voltages.

The eighth reviewer indicated that the project seems to be spending a lot of time on the start mechanisms and synchronization routines, and questioned whether mechanically coupled pistons would more quickly allow for combustion development (and concept assessment).

A ninth reviewer said that the steps undertaken in the project during the last couple years have been logical, as the PI has slowly developed a prototype engine. One point of concern was expressed by this reviewer concerning the air system, which must supply a significant amount of pressure (work) to compress the charge. A suggestion was made that possibly more attention should be given to reducing this parasitic loss and improving engine power density.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

The first reviewer indicated that progress is being made toward a working prototype, although it seems that mechanical difficulties such as the lock/release mechanism and bounce chamber design have unnecessarily impeded the progress toward gaining an understanding of the fundamentals (i.e., high CR HCCI combustion, and continuous control of a running engine). A reviewer remarked that too much effort is being expended on nuances to arrive at an operating concept. A reviewer declared that the team has some hardware, but cannot run it. This reviewer questioned whether any time has been spent doing DFMEA's, and whether some experienced engine design people have been looking at this.

A reviewer commented that the project seems to have been re-commenced with a more rigorous approach to the design. This reviewer also noted that the design of the gas bounce chambers (and the required latching mechanism) seems to be a retrograde step, and queried how this may give a better free piston engine. Further, this reviewer questioned what thought has been given to other bounce mechanisms.

A reviewer opined that the project still has a long way to go to get results that might progress development of a free piston engine. While this reviewer explained that fuel fired results will be most critical, they did question whether engine control can be maintained.

A reviewer expressed that the project is an interesting concept, but that it was unfortunate that the controls challenge and effort seem to be on par or greater than the combustion effort. A reviewer acknowledged that there are certainly challenges/obstacles being encountered, which are being addressed, but it does seem that overall progress is moving at a fairly slow pace. The reviewer queried whether it would be good to accelerate the design and troubleshooting phase of this program and get to the longer term testing program. Similarly, the sixth reviewer stated that progress still seems slow, and that, while funding has increased for 2010, full staffing has still not occurred in June of 2010. Further, this reviewer noted that HCCI combustion, promised in last year's review, has still not been tested with other fuels. This reviewer did question whether the high efficiency of the HCCI combustion will be lost in the alternator and in the energy needed for the enabling subsystems.

The final reviewer observed that most of the work to date has been in analysis and design with the former under most ideal conditions. The reviewer added that there are many obstacles in front of the PI, including meeting brake thermal efficiency above 50%. This includes taking into account air system parasitic losses, maintaining a high efficiency linear alternator, addressing in cooling issues with the linear alternator, and properly controlling the effective compression ratio.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the level of collaboration is appropriate for this stage of development. A second reviewer expressed that the list of collaborators is very good, adding that the "subjects" of collaboration are engineering developments, not research. The third reviewer remarked that there should be other collaborations with universities, and offered the European Volvo/Chalmers University collaboration as one to follow. A fourth reviewer recommended that the project work to pull together the small community of free piston developers. The fifth reviewer mentioned that there has been a small modeling collaboration with UM and GM, and that otherwise, this is a standalone project that could benefit from more interaction with GM concerning the real world issues with this engine.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer indicated that plans seem appropriate to determine if the design is feasible. The second reviewer noted that the approach to the future seems clear–to make a free piston engine and to run it on a number of fuels. However, this reviewer remarked that the pathway to get there is not clear.

A third reviewer observed a need to accelerate the troubleshooting phase of this program and move into the testing phase, as a lot of good data could potentially be derived via testing with this unique engine. The fourth reviewer commented that the PI needs to take actual real brake thermal efficiency measurements on this engine before proceeding any further with this project.

The fifth reviewer opined that the scope is very ambitious for a program of this size.

The sixth reviewer does not see a value to this research project. Eventually, this will be realized and the project will be terminated without significant accomplishments.

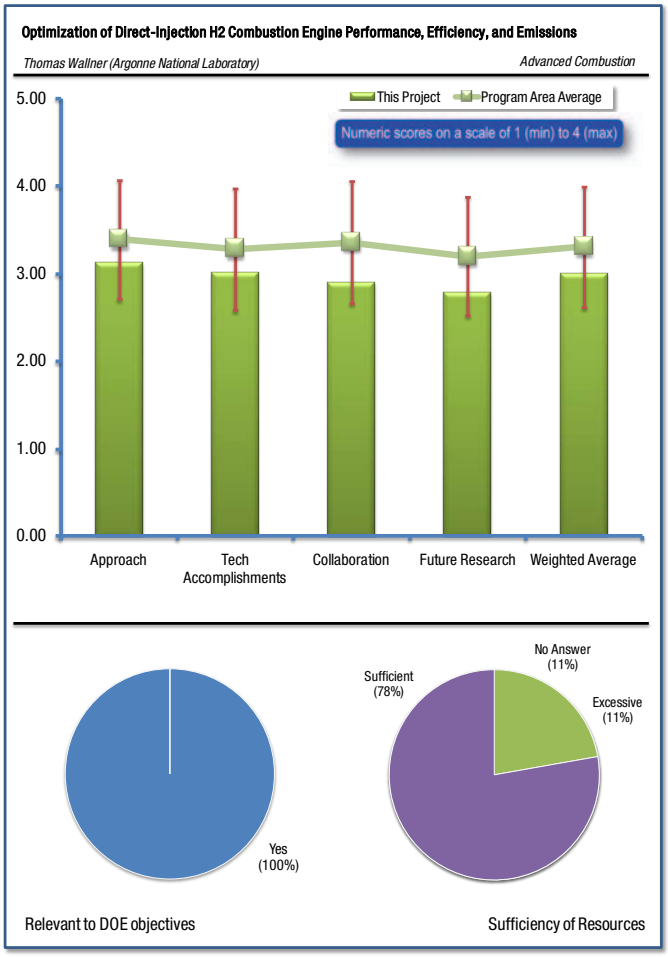
QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer indicated a slow start was seen, but more appropriate effort is shown now. The second reviewer acknowledged the adequate funding, but saw a need for more directed support, as it seems like Peter is a one man show. A third reviewer commented that, given the long-term nature of the research, the level of funding is appropriate. Yet, it appears to be insufficient to cover the outlined project scope.

The fourth reviewer noted the novel engine design is a very expensive enterprise, and that this budget still does not seem adequate. Although budget is increasing, the fifth reviewer remarked that it may not be sufficient to move the technology forward. Further, this reviewer questioned whether spending a small fraction of the effort on free piston (rather than fuel cell) could be a quicker route to high efficiency mobile electricity supply.

The fifth reviewer stated that the PI might be "a few million away from making this work."

Optimization of Direct-Injection H_2 Combustion Engine Performance, Efficiency, and Emissions: Thomas Wallner (Argonne National Laboratory)



Reviewer Sample Size

This project had a total of 9 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

The first reviewer observed that H_2 fuel can displace petroleum. The second reviewer remarked that this project directly addresses DOE goals for improved engine thermal efficiency and while address emission standards.

A third reviewer commented that hydrogen IC engine use will be a useful bridge to a more "hydrogen intense" alternative fuel future. The fourth reviewer indicated that IC engines are at the very least a bridge technology to the long-term vision for use of H_2 in transportation. The fifth reviewer stated that this was more relevant in prior years when the H_2 "hype" was at its peak.

The sixth reviewer explained that hydrogen certainly could have potential to improve the greenhouse gas situation, assuming it can be produced in a manner that is CO_2 free (clearly outside the scope of this project).

A seventh reviewer shared that while hydrogen is a fuel that will provide a pathway to the DOE goal of 45% brake thermal efficiency, the infrastructure for hydrogen production and distribution and onboard storage remain huge issues.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer acknowledged that the project team has been very responsive to previous reviewer comments and criticisms. Additionally, this reviewer noted that project modifications over the past year have been very well thought out, useful and relevant. The second reviewer observed that the project is using single cylinder engine to evaluate realistic conditions.

A third reviewer commented that overall, this is a well thought out, methodically executed project. Further, the only area that is missing is work on any thermal efficiency losses associated with fuel preparation that are considerably higher compared to other engine alternatives.

The fourth reviewer indicated that it is important to be building a base understanding of H_2 combustion in ICEs, but would like the focus of this work to be exclusively on achieving high efficiency with H_2.

The fifth reviewer stated that this is not a fundamental investigation effort but is more like an industrial development work. This reviewer declared that Fluent simulation at ANL should be stopped, adding that ANL carrying this task and reporting on it may reflect negatively on both the Lab and the VTP program. Rather than having a local post-doc do it, this reviewer suggested engaging acknowledged experts that can design an effective simulation plan and carry it out. Examples abound in many other programs reported during this annual AMR. Additionally, this reviewer opined that the model tuning is elementary, and that the work needs to rise to be on par with a national lab-type research activity. This reviewer also commented that experimental investigations of H_2O and EGR

injection for lower NOx are looking at an old technology. The underlying phenomenological explanation is well-studied and has been documented in the public literature for the diesel engine. This reviewer questioned why the researchers expect these "diluents" to behave differently in an H_2-fired engine, and queried whether they have applied Chemkin and KIVA to it. Briefly, this reviewer offered that the studies are experimental hit-and miss. A revamp of the philosophy, approach and strategy of this effort can lead to significant improvements.

The sixth reviewer observed that the project includes single cylinder investigation, as well as a focus on NOx emissions and injector development. The reviewer also noted the effort to trying water injection and EGR to reduce NOx emissions, as well as investigating different injector designs, location and nozzles designs, and multiple injection strategies. This reviewer suggested that the focus should be on more generic issues like increasing efficiency and reducing NOx, rather than local optimizations like trying different nozzle designs.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

The first reviewer remarked that good progress was made and a good assessment of the practicalities and potential of the methods considered was performed. The second reviewer commented that the PI has made much progress in the last year in addressing and improving thermal efficiency at two load points. There is still much more work to be done since this effort has not fully reached DOE thermal efficiency goals, though there is great promise that the next generation combustion system will meet this goal. The third reviewer observed that they did a good job getting this engine up and running and producing data. Additionally, this is much preferred over getting caught up in the many mechanical issues that certainly could have dominated this type of program. The fourth reviewer acknowledged the good progress in addressing engine efficiency and emissions, but noted there are still concerns with overall H_2 cycle efficiency.

The fifth reviewer questioned whether 45% is a good enough efficiency goal. This reviewer also queried whether there should instead be an indicated efficiency goal (since this is likely not a near or mid-term technology) rather than using best-case extrapolations for PMEP, FMEP. Moreover, the uncertainty in NOx requirements for 2030+ and in technological advances in aftertreatment (particularly with regard to H_2, the perfect reductant) makes any focus on NOx seemingly unnecessary. This reviewer questioned what the technical barriers would be if the NOx constraint were the removed (e.g., temperature issues, heat loss).

A sixth reviewer indicated that the work required to compress H_2 to injection pressure is not included. A rough estimate for large scale high pressure H_2 should be provided.

The seventh reviewer commented that the project should have been rated lower but was given "fair" to help with the overall score. Additionally, the reviewer commented that piece wise investigations of selected options yield narrow application results. Finally, this reviewer questioned whether the team has surveyed the ICE H_2 work done in Germany, Europe (especially TNO) and Japan, and suggested that it may be worthwhile for the PI to spend a couple of man-months on this, then compare the program approach and results to prior work.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer commented that the project is a good combination of national lab, industry and academic partners. The second reviewer explained that this project appears to leverage work at both SNL and LLNL in the areas of optical H_2 engine measurements and CFD modeling of the spray formation process. This reviewer noted that it would be interesting to compare any of the metal engine results with any recent work at Ford Motor Company.

A third reviewer recommended that, if not already done, this work should be compared with the (robust) NG fundamental investigations, nationally and abroad, as well as for prior H_2 work. This reviewer stated to increase the level of experience and core competency of the collaborators who are carrying out DOE-funded activities.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer explained that future plans are well thought out and reasonable for the budget and effort reported. A second reviewer commented that there is a good plan as far as engine work, but questions the overall H_2 strategy and where the H_2 engine fits in. The third reviewer noted that, overall, the future work is addressing the current combustion system limitations of the metal engine. This reviewer added that it would be helpful this coming year to collaborate with Ford and compare any experimental measurements available from past Ford H_2 engine research.

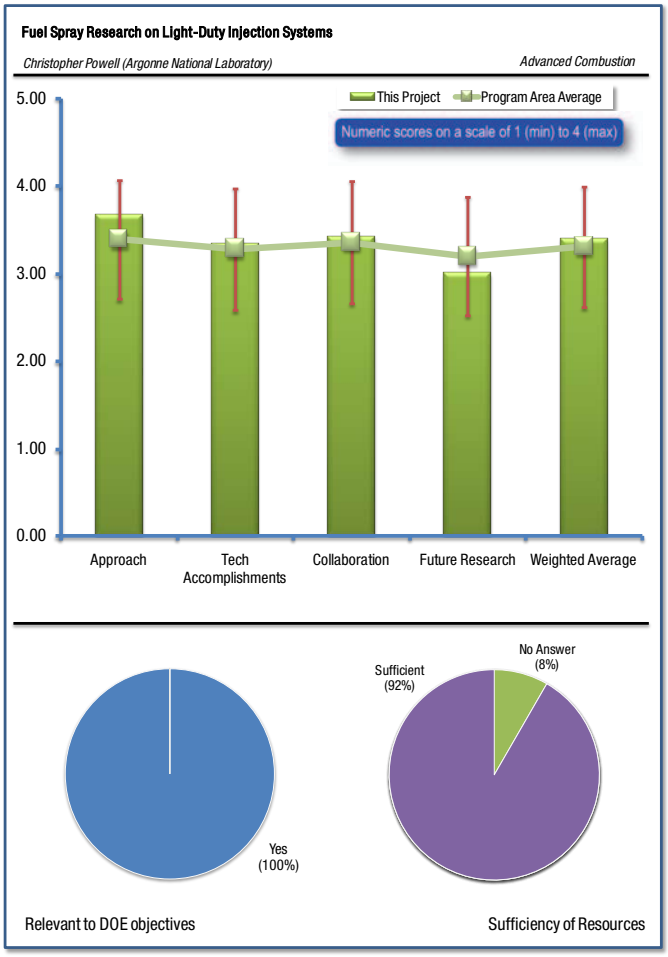
A fourth reviewer recommended that emphasis should be on efficiency alone, and not engine-out emissions controls. Ultimately, the life-cycle efficiency benefits of H_2 ICE's will have to compete against other options (e.g., fuel cells), and placing the focus instead on reducing engine-out NOx may confound future efforts to sort out best technology options for H_2.

The fifth reviewer stated that a significant revamp is highly recommended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The single reviewer whether the project should be scaled down, considering the emerging realities of the H_2-based transportation value proposition. If not, a pragmatic "peer review deep dive" may improve the resource utilization if the involved research staff are open for it.

Fuel Spray Research on Light-Duty Injection Systems: Christopher Powell (Argonne National Laboratory)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Reviewers commented that the project is highly relevant. One reviewer commented that the project's fundamental studies of injector performance and the fluid dynamics of fuel injection are important for a wide range of engine operation. A second reviewer remarked that this project supports LTC and other combustion mode research aimed at improving engine thermal efficiency while meeting emission standards.

Another reviewer said improved injection can increase efficiency and decrease losses to emission control, and a fourth reviewer remarked that the project leads to basic understanding of fuel injector nozzles and their operation which is critical to diesel engine performance and modeling. The fifth reviewer remarked that especially with the dedicated space, focused research to understand fuel sprays can be conducted. Fuel sprays are at the heart of most advanced combustion concepts.

The final reviewer felt that diesels offer reduction in petroleum use, but more emphasis on GDI systems may ultimately be more important to petroleum/CO_2 reduction.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

Reviewers had positive feedback about the use of ANL facilities. One reviewer remarked that the project possesses unique capabilities that capitalize on a specific ANL facility and core competency, and a second reviewer also remarked good use of available facilities and new information produced to help refine injection design. A third reviewer remarked that the approach is rigorous and well thought out, but progress has been slow (possibly due to construction at the Argonne APS).

Another reviewer noted that this project has come a long way since 2005 when vessel boundary conditions were nowhere close to actual engine conditions. After years of patience, this diagnostic is now providing very valuable internal spray measurements. The approach is outstanding and development of the near facility to allow more rapid experimental execution should provide a dramatic increase in the development of knowledge in near injector spray dynamics.

Two reviewers had positive feedback about the use of x-rays. According to one reviewer, x-rays offer unique insight, and opening the beamline to general user proposals will also be important for collaborative efforts with academic institutions. However, this reviewer would like to see more emphasis on high pressure gasoline sprays, including integration with experimental work in this area. Another reviewer remarked that using X-rays to study sprays is certainly an interesting topic, but had questions about using a 2-D method to study what is clearly a 3-D event. However, still a lot of good information can be gained from this type of work. Certainly the ambient conditions in the test chamber are also an item to be strongly considered; potentially up to and including reacting sprays.

The final reviewer commented that this may be the only method for studying needle motion in some common rail injectors where this measurement is extremely difficult. Spray visualization is good stuff but not as important.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw evidence of progress. The first reviewer remarked that technical progress has been good but slow. A second reviewer remarked that the project has created a very useful tool for fuel system makers, one that they could not have done individually on their own. The third reviewer said this looks like a good start, but we did not see very many results. Hopefully, now that the technique is proven, we can see more interest and more results. According to the fourth reviewer, overall, very good progress was made since 2005. It would be nice to more liquid distribution measurements over a larger variety of charge density and temperatures indicative of DI engines. According to another reviewer, certainly a lot of good progress was made relative to the facility and taking of data. High marks were given for this progress, and the results do indicate the potential for learning a good deal about spray development.

The sixth reviewer remarked the validation of other efforts in this field is of fundamental importance, and the seventh reviewer noted that progress is slow due to the commissioning of the new facility. Another reviewer summarized that the team is explaining some of the observed results by others, such as the SNL work. The team is showing some discoveries and confirming other observations via the X-ray approach. They have completed the new fully dedicated facility. They are supporting the GM work.

Remarked the final reviewer, seems like the volume of work being done is low. Can the scope and volume of work done be expected to increase in the future due to the dedicated facility?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers had positive feedback on the collaboration with industry and labs. Said one reviewer, collaboration is good and fairly comprehensive. It will presumably increase in the next project period due to projects that can be conducted at the new beamline facility. A second reviewer remarked collaboration with industry is good, and a third reviewer thought it was good to see the team is working with industry. The reviewer thought the fuel injector makers will continue to be interested. A third reviewer noted that the project is collaborating with two leading fuel injection system companies, and remarked that SNL, GM, and UWM are great stakeholders to engage and to benefit from this work. Another reviewer remarked the project has benefited from collaboration with industry (Bosch and GM) and universities (modeling) throughout the years. The new collaboration with Delphi should provide new insights into post injection spray dynamics. The final reviewer questions if there are any new resource bottlenecks with the new beamline that might limit the potential for expanding cooperative efforts.

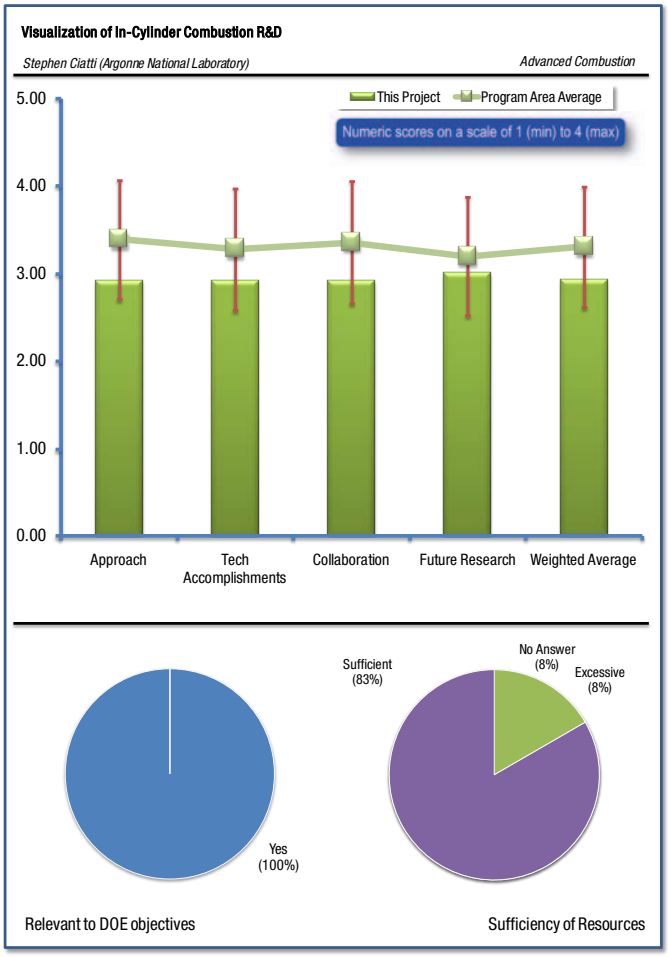
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

Reviewers had suggestions for future work plans. According to the first reviewer, future plans are quite wide open, which is both good and bad. The second reviewer would like to see a more focused plan. Probably this needs more communication of the capability and opportunity to get inputs and ideas. The third reviewer would like to see a high-pressure injection (3000 bar) into a high density charge ($65 kg/m^3$). This is what the modern engines will soon be doing in a few years. The fourth reviewer remarked overall, the proposed research is very good. It would be nice to see a larger database of near injector behavior versus variances in charge density and temperature. The fifth reviewer suggests put the Vehicle Technologies X-Ray beamline to a good use: measure the quality and quantity of its output. Harvest the current capabilities while embarking on adding more. The final reviewer questions if multiple injection events can be studied with this apparatus and technique.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The responding reviewer remarked there was adequate funding, unless cooperative efforts are expanded.

Visualization of In-Cylinder Combustion R&D: Stephen Ciatti (Argonne National Laboratory)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

The first reviewer felt that improved PCCI combustion would allow for the deployment of high efficiency engines in the LD arena. According to the second reviewer, the focus on more practical implementation of LTC in a multicylinder engine is an important part of transferring this technology to industry, and the third reviewer saw significant potential for increased efficiency vs stoichiometric combustion. The fourth reviewer felt the PI made a good case that he can burn gasoline much more efficiently than today's gasoline engine. The fifth reviewer remarked diesel like efficiencies with gasoline like fuels and lower NOx is a worthy goal.

The sixth reviewer would prefer to further explore commercially available fuels, before moving into custom blends. According to another reviewer, the project does support overall DOE objectives of reducing petroleum usage. But there is some uncertainty regarding the focus of the project. It is stated that the barriers addressed are all related to control of low temperature and transient combustion. However, most of the work (except of course for the same-cycle control work) being done is related to combustion and fuels development.

Another reviewer remarked that the project kind of supports DOE's objectives, and elaborated this project is evaluating non-standard fuels under LTC/PCCI operation and it is unclear if any of these fuels are practical as we look out in the future. The hope is that this effort will lead to fundamental understanding in ignition behavior of these various fuels toward helping design LTC/PCCI injection strategies for conventional fuels. The main value of this effort is in assessing the impact of gasoline type fuels on diesel engine performance which is important.

The final reviewer said they partially missed the point on why running a diesel engine on gasoline is desirable, but the data are interesting. Granted, high compression ratio is run and reasonable efficiencies obtained, but the reviewer was not sure there is real value to this.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer saw a good approach to HCCI control with interesting results. The second reviewer felt the approach of testing and evaluating fuels with non-standard diesel or gasoline fuel properties is good toward establishing the effects of ignition quality and evaporation rate on PCCI approaches. It would be nice to eventually translate this work to include production available gasoline fuels. According to the third reviewer, the approach holds good potential for demonstrating the project goals for power density, efficiency and emissions. But if the goal were to help bring the technology closer to commercialization, then more focus should be placed on system cost, with attention to the fuel injection system and combustion controls, and possibly on acceptance factors such as combustion noise. If the engine "runs better with lower injection pressure", then why not resort to a lower-cost fuel injection system?

The fourth reviewer remarked that the approach is somewhat ad-hoc. Exactly what is the final goal, and what are the intermediate results that have to be achieved along the way? "We wanted to see what was possible" seems like an enjoyable voyage of discovery, but this is not the best way to plan or conduct an experimental process or procedure. According to the fifth reviewer, the work is OK, but it seems like a "let's just dive into it and see what happens." This reviewer can see a whole lot of issues on the horizon: sensitivity to things like intake manifold temperature, ambient temperature, fuel cetane variability, etc. This all needs to be considered. Is one of these a show stopper? Then address it from the start, or stop the show and work on something else.

The sixth reviewer remarked that this overall approach is industrial-type development work. The National Lab brings little expertise to bear on the work, with uncertain value-added. Using the Converge code and its application is better suited for a graduate student exercise. What would the simulation approach be if, for example, Rolf Reitz or Dennis Assanis is challenged with the objectives of this project? The effect of the CR variation can be well studied and characterized by a 1-D (GT Power or WAVE) cycle simulation with a KIVA combustion analysis support. Further, introducing the fuel chemistry into the KIVA analysis would yield substantially more robust results and insight that cannot be attained by the prescribed testing. The engine platform can then be used for model validation, etc.

Another reviewer thought the objectives were not clear and could be laid out more clearly. Known roadblocks and approach to overcome need to be laid out more clearly. The final reviewer remarked there seems to be uncertainty regarding the focus of the project. Is it control system or is it combustion system development? Perhaps it is both?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

According to one reviewer, very good progress was made on controlling HCCI combustion, and the project is demonstrating real potential. The second reviewer felt that progress has been relatively modest, but 2010 appears on track. The data provided so far are strictly steady state, but transient performance using this strategy would be interesting and insightful. The third reviewer saw good progress on a number of fronts–increased power density for HCCI is a good goal, but this project needs more direction and oversight.

The fourth reviewer noted that some PCCI data has been generated to date though much work lies ahead of the PI. It would be nice to see more engine speed and load points included in the test matrix. The fifth reviewer remarked that results show much effort and investment went into lab and instrumentation setup, as has been the case in prior reporting periods. This is not "technical accomplishments and progress." The experimental setups at GM, other industry companies (Cummins for example) and academia (UWM & UM for example) are still superior to that described in this project. Why continue investing in a "me too" effort and report the progress on the status of lab construction? The endoscope feature is nice, but not necessary or critically needed. Cut-and-try results were shown. The team should design an experiment and validate the results with a statistical significance. The summary slide reflects the results: it provides generic statements with lack of progress.

According to the sixth reviewer, the approach appears to be a bit haphazard. The final reviewer remarked the presentation does not clearly spell out the progress in emissions reduction or efficiency gain relative to a known baseline. How do we know we are making progress? Some effort should be expended to compare fuel consumption results on a more familiar basis to a PFI gasoline baseline.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers saw good collaboration. According to the first reviewer, good collaboration and apparent buy-in from an OEM (GM) was shown. The second reviewer remarked this appears to be well coordinated project with GM and BP as a fuel supplier. According to the third reviewer, industry collaboration is appropriate for successful technology transfer. However, this reviewer would like to see a more coherent plan for coordination with other labs that will clearly contribute to the project's success.

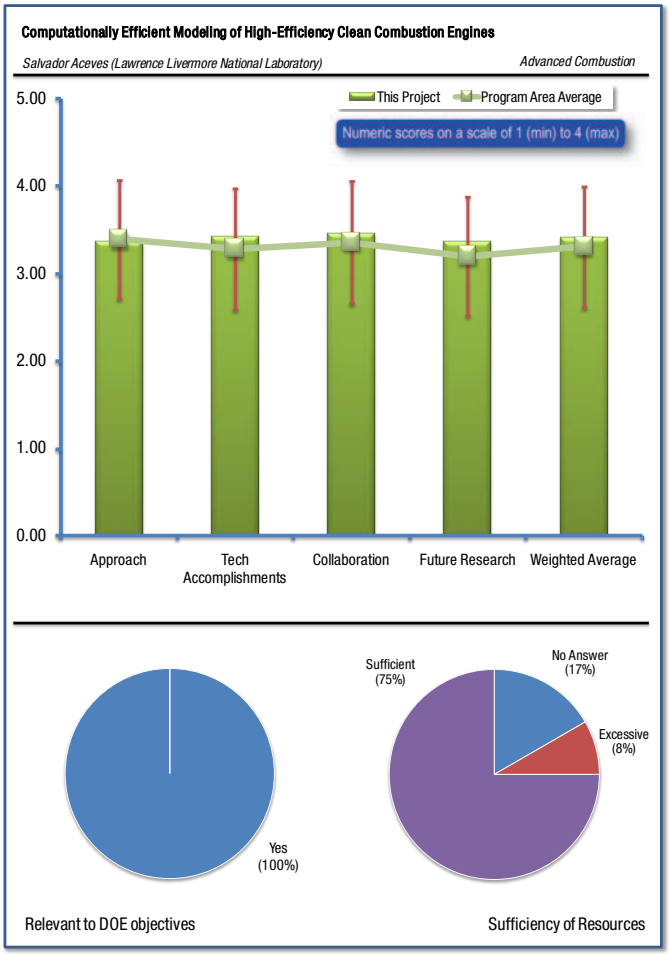
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer felt that the optical work is the most useful part to explain how this works. The reviewer is looking forward to seeing how it works. According to the second reviewer future plans need better consideration. Engine control is a good avenue for further study, but it needs to be well-planned. The third reviewer said that the project goals are worthwhile and feasible, but would like a more clearly defined plan for coordination with other labs that could help this project be even more successful. Another reviewer would like to see a clear plan on how to address key roadblocks. The firth reviewer said that we expect a substantial amount of the progress during the next year including fuel system timing studies, EGR sweeps, and comparison with fundamental spray data from SNL. The final reviewer said that it really needs a review and a major revamp.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

According to one reviewer, too much investment was made in lab setup, hardware, and instrumentation.

Computationally Efficient Modeling of High-Efficiency Clean Combustion Engines: Salvador Aceves (Lawrence Livermore National Laboratory)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Reviewers saw that computation modeling is relevant. According to the first reviewer, computational modeling is important to evaluate and control new combustion regimes, and the second reviewer concurred that modeling is a critical part of relating the single-cylinder testing to eventual multi-cylinder approaches. The third reviewer remarked that computational models that couple fluid mechanics and chemistry are a must if advanced low temperature combustion concepts are going to be brought to fruition. Another reviewer remarked this project indirectly supports DOE engine efficiency goals by providing designer with simplified models that help speed up the development process.

The fifth reviewer noted that advanced modeling is useful to improve engine development for efficiency. Unfortunately, this reviewer did not feel competent to evaluate progress in modeling development at this level. Work should be shared with software developers for commercialization. The final reviewer remarked the work supports objectives indirectly by showing how to create better and faster CFD models for simulating engine combustion.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

According to the first reviewer, this is an outstanding utilization of unique national lab capabilities that is focused on pushing the state-of-the-art of robust simulation. It combines applied math, Chemkin and KIVA into a user friendly package. Using neural net also is a plus. There is a good bridge between BES and VTP. The second reviewer noted that transferring these tools to the public domain is a major step toward future advancement of LTC technology. The third reviewer remarked overall the approach is good; the only lacking element is more detailed validation. The fourth reviewer said simulation work is clearly important as we move forward, and this program will certainly make advancements in the simulations as we move forward, especially the work focused on improving computational speed. According to the fifth reviewer, it is very important that these codes can be run on a desktop PC and thus enable the engine designer to use them effectively.

The sixth reviewer commented that approach seems scattershot, and the team is trying to do many things across many fronts. The final reviewer would like to see more correlation to engine results at various operating conditions. This would include a more conventional diesel operation condition with near TDC injection and diffusion burning. This is how diesels operate today and probably will for a long time.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally saw good progress. According to the first reviewer good progress was made in overcoming barriers to the quasi-real-time calculation of coupled CFD and chemical kinetics on a grid-intensive basis. The second reviewer said continued validation with experiments is helping to build invaluable tools in this area. The third reviewer thought the project pushed the envelope further, and is validating engine data from other labs. Reasonable results were obtained, both correlation and probing of differences from experimental data. A reviewer asked if the team is publishing too many details, to the point that others may get to where the team is today and leapfrog with little investments in money and resources. The fourth reviewer commented that the PI is showing impressive results. Not sure how these get translated to industry. The fifth reviewer also saw very good progress to date. The only shortcoming is lack of experimental validation. The sixth reviewer remarked that results of applications shown are very encouraging.

According to another reviewer, it looks like very good work but this person was not able to evaluate this modeling effort. The final reviewer commented that perhaps it is just difficult to explain the improvement in numerics that is being worked, but it is just not easy to understand the level of progress that was made on this program.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw a wide range of collaborators–this is to be encouraged. The second reviewer also commented outstanding integration with efforts within DOE and universities. The third reviewer remarked that this project historically has included outstanding collaboration between LLNL, other national labs, and various universities–great job.

The fourth reviewer said that it could be outstanding, but asked if the team has too many partners, beyond the point of diminished returns. The team has added new offshore collaborators: how much is gained from this versus what is given away. Does "public release of the code" reflect the best stewardship for DOE and the U.S.-based industry? Should there be a tiered cost to give the code to users and others abroad? It is great that the team is giving a software license to a U.S.-based company, but will they market it as well, or will the team be able to have some control on it? The final reviewer would like to see collaboration with the CFD industry. This is how it could better get into the hands of users.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

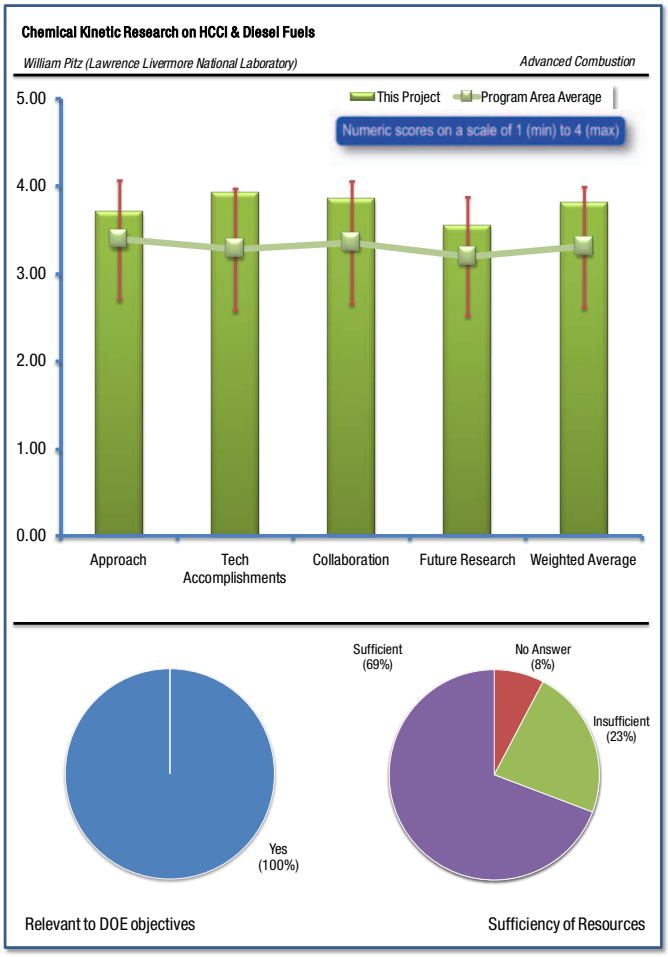
The first reviewer commented Keep up the good work, and suggests consider paring down the "partners" and collaborators: maybe limit it to ORNL, SNL and one or two industry partner(s). The second reviewer said commercialization of the multi-zone model is wonderful. The only recommendation is to continue validation.

According to the third reviewer, future plans are ambitious–the use of teraflop GPUs for example. Is this not just a distraction from what should be the main objectives of this work? The final reviewer commented that continued efforts to make these tools available on the desktop will significantly improve university contributions in this area.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer commented that $1 million is a large sum. What would the team do if you have only $800K? What will the team do if you have $1.2 million? According to the second reviewer, this seems like a lot of funding for the little amount of engine test correlation. If ERC is doing a lot of this, is this just to support ERC KIVA? If the government is funding this, it should go to the whole CFD industry, which would provide more benefit to making better engines. To the third reviewer, it is not clear how the money was spent and this program seems borderline excessive. Having said that, the reviewer does understand that projects such as this do require a fair amount of technical experts running and working on the code. This reviewer would like a bit more detail on some of the specific advancements in the future.

Chemical Kinetic Research on HCCI & Diesel Fuels: William Pitz (Lawrence Livermore National Laboratory)



Reviewer Sample Size

This project had a total of 13 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

According to the first reviewer, reduced order computational models are critical for reducing the computational time required for fully predictive combustion modeling. The second reviewer commented that chemical kinetics input is key to combustion modeling and can accelerate progress, and the third reviewer remarked this is important work on basic chemical reactions of fuels that is needed to supply models for combustion modeling which is needed for investigation of efficient engine combustion systems. The fourth reviewer said this project indirectly supports DOE goals by providing engine designer with more accurate diesel and gasoline fuel surrogates for modeling ignition and intermediate heat release rate, and an outstanding effort has been seen to date. Another reviewer remarked this project investigates important effects for understanding and predicting the start of combustion in compression ignition engines. The sixth reviewer said having fundamental kinetic mechanisms for combustion is very important for modeling and simulation efforts to improve the fuel efficiency and reduce emissions of vehicles. The focus of this work is on components found in nonpetroleum fuels as well as petroleum based fuels. The final reviewer commented recently, the role of fuels and their reactivities are being appreciated greatly in the pursuit of high efficiency. It is very important that chemical kinetic models for fuels are developed to enable the design of high efficiency clean engines.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

According to the first reviewer, this is a very well focused and directed program, and the second reviewer commented on an outstanding utilization of unique national lab capabilities. The team is focused on pushing the state-of-the-art of fuel models and has established a good bridge between BES and VTP. For the third reviewer, developing reduced order mechanisms with the functional group method is good news. The fourth reviewer said overall, this is a good approach. As usual, it would be nice to see additional validation of the newly developed diesel and gasoline fuel ignition mechanisms at engine relevant boundary conditions. The fifth reviewer saw excellent focus on working on the important components first, and good use of experimental measurements to create surrogate models of the fuels. The team has made good use of experiments with these fuels to create computer models. The sixth reviewer remarked that the approach of first developing fundamental kinetic mechanisms for individual components and then comparing to existing experimental data is excellent. In addition, the approach also includes reducing the size of the mechanisms to significantly reduce computational time.

Another reviewer questions, if more attention should be given to oxygenated reference fuels (E10) as well as future fuels such as E15 or E20. The final reviewer remarked the work looks good, but was mostly beyond the reviewer's area of expertise.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers generally saw good progress, with the first reviewer commenting on good progress year-to-year, and the second reviewer remarking on excellent progress, especially in kinetics modeling, directly leading to improvements in early heat release predictions for HCCI combustion. The third reviewer saw significant accomplishments, including developing mechanisms for 2-Methylalkane isoparaffins that are present in diesel fuel, improving the mechanisms for toluene and benzene resulting in better agreement with experimental data, and development of a diesel PRF model, which demonstrated the big effect that cetane number has on the low temperature portion of reaction. The fourth reviewer thought model comparisons seem to show very good agreement and results look impressive. The fifth reviewer remarked the project pushed the envelope further. The team extended the usefulness by adding more components to the mechanism library: improved toluene and benzene mechanisms, high and low temperature mechanisms for selected higher molecular weight iso-alkanes, high and low temperature mechanism for a high molecular weight alkyl-benzene. The development in reduced mechanisms is encouraging. The sixth reviewer felt there was good progress on reducing the mechanisms to reduce the computational times needed. This makes this work more usable to industry and useful for achieving DOE targets. This reviewer thought the correlation of simulation to experiment is quite impressive. Another reviewer remarked that much progress has been made in the last five years in the area of developing surrogate fuel ignition chemistry for automotive fuels. Nevertheless, we need more validation. The final reviewer commented that the good agreement with Dec's data of cool flame heat release is very encouraging.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer saw a well-respected group with a wide range of collaborators. The second reviewer thought the collaboration was appropriate for a more scientific project, and the third reviewer remarked on good work at using the various labs. The fourth reviewer approved of working with a good cross section of people working in similar areas. The fifth reviewer remarked that the project includes representation from many partners including national labs, U.S. universities, and European universities. There has been much collaboration among these various partners in developing full and reducing mechanisms for various heavy hydrocarbon fuels and surrogates. Another reviewer summarized that main collaboration mentioned was with Sandia, but also some collaboration with industry via participation in AEC/MOU and CRC. The final reviewer remarked this is a difficult area to find competent collaborators. The team has connected with SNL.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

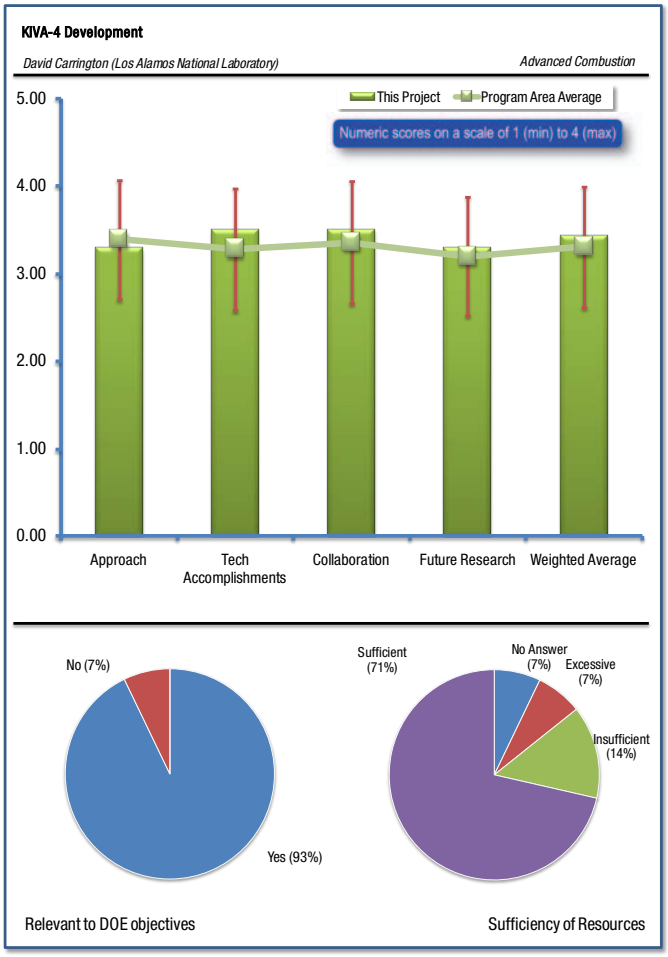
Reviewers generally saw clear plans. According to the first reviewer, future path is fairly clear - increase number of components for an increased number of fuels useful in current and future combustion regimes. The second reviewer commented on plans to continue to fill the gaps that exist by developing mechanisms for other isoalkanes and alkyl aromatics and to develop more accurate surrogates for diesel and gasoline is very worthwhile. The third reviewer remarked there was outstanding work to date, but had no input on how to do it better.

Another reviewer suggested the team consider increasing the effort of development of reduced mechanisms for use in multidimensional engine simulation codes, and consider joint efforts on a “real-life” engine validation effort, maybe with ORNL. The fifth reviewer questions if future work should include a sensitivity study of fuel effects with gasoline containing 10-20% ethanol. Another reviewer commented the proposed modeling advances are great, but more validation is needed. The final reviewer’s only comment is that it would help to better understand how this work gets us better kinetics on the fuels we use in production, but this is probably more a result of the reviewer’s lack of understanding.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer remarked a task that could consume a much larger budget and still be incomplete. According to the second reviewer, this is exactly the kind of basic research the government should do. If more funds would speed it up then spend it here.

KIVA-4 Development: David Carrington (Los Alamos National Laboratory)



Reviewer Sample Size

This project had a total of 14 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Reviewers generally saw the work as highly supportive of DOE objectives. The first reviewer commented KIVA has evolved into a very important engine development tool that is widely used by industry, national labs and universities alike. It is an integral part of the engine and emissions research "palette." The second reviewer remarked KIVA has become a standard tool for engine simulation calculations and used by researchers the world over, in industry, government and academia. Thus, this program supports the development of advanced combustion and high efficiency engines, which can lead to petroleum displacement. To the third reviewer, development of improved modeling and simulation tools such as KIVA-4 is important for improving capability to better model combustion and to develop engine designs for better fuel efficiency and reduced emissions. The fourth reviewer observed continuous improvement of this important combustion analysis tool is key to efficient advancement of combustion technology. The fifth reviewer remarked that this is a pioneering work in simulation that gives a viable tool to design more efficient powerplants. The sixth reviewer commented that even though KIVA is not prominently used by industry, it is definitely needed and required by the labs and universities. They need the open-source tool that KIVA provides, and which is lacking in commercial codes. The seventh reviewer remarked good work on the continuous improvement of KIVA, a tool that is of great significance as we move forward with new combustion system designs.

Another reviewer remarked this project indirectly affects DOE engine efficiency and emissions goals by providing engine designers a higher fidelity combustion system modeling tool that eventually might be used to explore advanced combustion strategies. A reviewer remarked that improving the tool will especially help advance LTC modeling efforts in industry and academia. A reviewer commented that the base of modeling program is key to productivity. Continuous improvement is critical. The reviewer recommended to keep pushing the envelope. The project should be careful not to compete with private sector programs, but to push the level of technology to the benefit of all. A reviewer noted that the project aims to develop more robust and efficient algorithms for understanding and predicting combustion processes and emissions from engines. The KIVA-4 code will also be used as a tool for engine design. The cut cell method of grid generation should reduce the time taken for grid generation to around 30 minutes (currently it is on the order of days).

Another reviewer said good combustion modeling tools are needed for development of high efficient engines, but what this project is providing is being provided by commercial companies. This is just supporting a government code that competes with an established and growing CFD industry. The final reviewer would like to see a concise list of current KIVA users in industry.

QUESTION 2: WHAT IS YOUR ASSESSMENT OF THE APPROACH TO PERFORMING THE WORK? TO WHAT DEGREE ARE TECHNICAL BARRIERS ADDRESSED? IS THE PROJECT WELL-DESIGNED, FEASIBLE, AND INTEGRATED WITH OTHER EFFORTS?

Several reviewers had positive feedback on the approach. According to the first reviewer, this is a core competence that is really unparalleled. The second reviewer remarked the code features being added are well-considered, and significantly enhance the usefulness of the tool. The third reviewer said this was a good cooperative effort with other researchers and industry to identify key issues and target solutions and used an excellent approach to verify outcomes. The fourth reviewer saw a good focus on providing improvements to KIVA that will improve the code. Some of these features are already commercially available in other codes. The fifth reviewer said the well established protocol does not need changing. Emphasis should be on pushing the envelope on modeling and transferring the technology to the private sector.

The sixth reviewer remarked that physical and numerical methods are developed to get high accuracy. The code is designed to be user-friendly so the user can make changes to grid and geometry relatively easily. The seventh reviewer highlighted the work on grid algorithm improvements, adaptive finite element approach (cut cell) and conjugate heat transfer. These all serve to improve capability to model engines and specifically advanced combustion strategies with faster and more accurate calculations.

The eighth reviewer thought the approach is very comprehensive but the emphasis on certain areas (over or to the exclusion of others) is not well motivated. Another reviewer remarked the approach sounds reasonable. This reviewer continues, as mentioned, it is important to understand fundamental processes. The reviewer mentioned importance of getting feedback from users, although it is not clear how that is being done at this point other than collaboration between LANL and the several universities mentioned. Another reviewer remarked that this project is one of those that elicits flexibility in exploring non-standard modeling methods for combustion system modeling in the hope of providing engine designers a better design tool. The only concern is that it is difficult to validate the new submodels and it would be beneficial to explore ways to ensure such new models are truly predictive and trend wise accurate. The final reviewer remarked the improvement work on improving the numerics is certainly impressive and well directed. What this reviewer struggles with is a clear KIVA vision for the user community. This is not the fault of this program, but more a lack of a single (perhaps commercial) body driving the long term direction the code.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Reviewers saw good progress. The first reviewer remarked on the outstanding progress with added features to the model and solver, and especially to the grid flexibility and moving body algorithms, and the second reviewer said real progress was delivered in some key problem areas that are immediately useful to engine developers. The third reviewer thought the team persistently addressed the various building blocks to advance the state-of-the-art of engine combustion simulation, and the fourth reviewer saw impressive improvement in performance. It is nice to see the blend of technical progress and addressing of customer needs. The fifth reviewer saw progress in several areas, including better heat transfer model, modeled the piston crevice which has resulted in better HCCI modeling, and developed 2D and 3D CBS codes. The sixth reviewer thought the project covers both fundamental developments and applications: hp-adaptive CBS FE method; parallel KIVA-4mpi beta version released; cut-cell technique for grid generation is improving and is helpful; and Iowa State work seems helpful too.

The sixth reviewer remarked that code improvements to support LLNL HCCI simulations and enhancements to code include ability to use unstructured meshes via third party software. KIVA 4 beta has been released. Conjugate heat transfer capability is in the code and being tried on test cases. The seventh reviewer remarked there seems to have been good progress made. Unsteady turbulence modeling has progressed. Heat conduction is being modeled. Cut cell strategy work has progressed to create grids quickly. Sprays and spray-wall interaction has progressed. The eighth reviewer remarked clearly a lot of high powered very smart people are working on improving the KIVA code and KIVA-4mpi.

Another reviewer commented that this is very important work, but has been poorly presented and motivated, which is a disservice to the investigators. The tenth reviewer thinks the barriers are missed. The problem with combustion CFD codes is their lack of getting good results–KIVA included. Making them run faster isn't going to help. This reviewer thought there needs to be a concentrated effort on modeling some engine results as exactly as possible, and studying all the reasons why the modeling is wrong and address these

issues. The reviewer thought better progress would be made in this area if there was a collaboration effort in doing this with the CFD code companies. Combined, they have way more resources than this project has. The final reviewer commented the PI and partners have obviously spent much time and effort developing and incorporating new submodels into KIVA-4, which is difficult for a reviewer to quantify from a software modification viewpoint. Nevertheless, this project needs some level of validation which has been weakly addressed at this point...possibly next year or later on?

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration with a variety of stakeholders. The first reviewer remarked KIVA development and usage is widely promoted through user groups and collaborations, and the second reviewer thought the project is working closely with four different university groups on test cases to try out additions to the solver. The third reviewer remarked it is good to see national labs and academic collaboration. It is key to get students and the next generation trained and productive in these tools. The fourth reviewer remarked this project includes an excellent partnership between the PI (LLNL) and three other U.S. universities with expertise in various portions of CFD including software development. The fifth reviewer focused on collaboration with higher education, commenting that very good collaboration exists with Iowa State University, University of Nevada, and Purdue University. The work is being immediately transferred to these universities.

The sixth reviewer remarked KIVA is a fairly unique and successful collaborative group within DOE, but it may help overall progress if some of the code support can be offloaded to others (unless there is value added in customer interaction). According to the seventh reviewer, collaborations are limited to several universities and Los Alamos. No collaboration with industry is indicated–perhaps appropriate at this stage. Another reviewer remarked that this is a difficult area to find competent collaborators. The team is connected with the relevant community: more is not necessarily better. The final reviewer commented there is no tangible link to industry other than the MOU.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer saw a good plan to further verify changes and to look at remaining areas for improvement, and the second reviewer remarked future work is evolutionary by nature, necessity and design. The third reviewer thought it seems like a good emphasis on advancing the technology. The fourth reviewer summarized plans include further validation of recent additions to gridding and solver capabilities. The team is continuing development of new methods, refining the cut cell grid approach and improving the moving body meshing capability.

The fifth reviewer remarked generally the future research is very good; the only concern is lack of validation looking into the future.

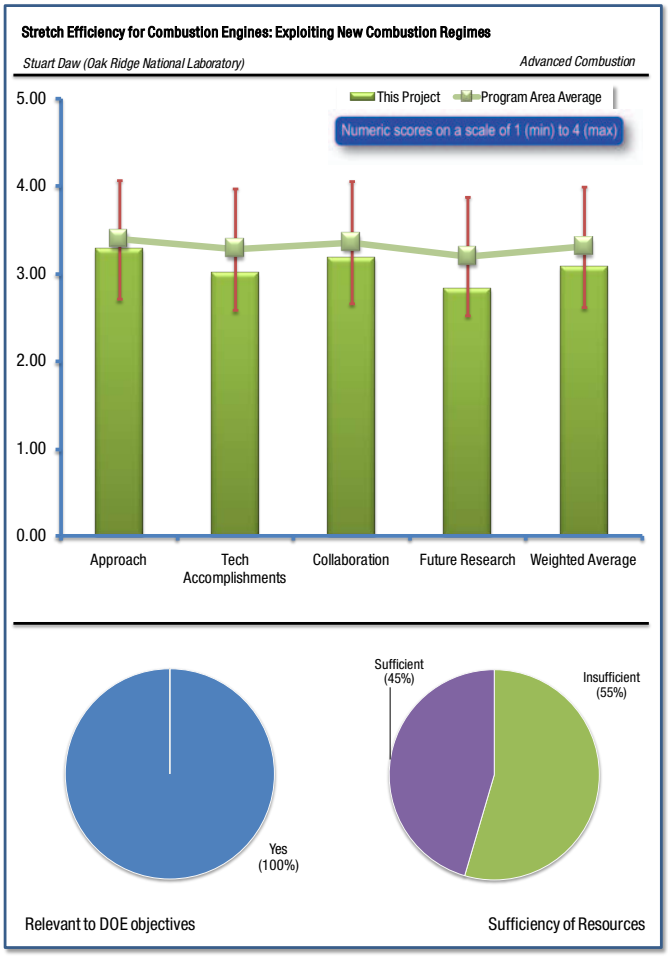
The sixth reviewer suggests it may help to tackle a real-life engine combustion system model and progressively exercise it to demonstrate progress. The seventh reviewer remarked chemical kinetics will be brought into the code. The cut-cell method will be perfected. Also immersed and moving body algorithm. The final reviewer understands the focus on numeric improvements, but KIVA continues to suffer from being very non-user friendly. At some point it needs to be “dumbed down” so a wider range of CFD experts, who are not KIVA experts, could be active users and use this tool for industry combustion system development.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

According to the first reviewer, “increase the funding if LANL can provide a robust increased effort proposal.” The advancement in this area helps DOE's mission. It also has significant positive impact on its industrial benefactors, if they know how to capitalize on it. Consider protecting the investment by avoiding the “knowledge dump” via publications, open forum “exchanges” that exploit the good work reported here, etc. Somehow, IP protection is needed. The second reviewer said the development of fundamental tools could always garner more support but this is probably not feasible in a resource-constrained funding environment. Another reviewer commented the team could do with more funding to increase staffing to get the work done more quickly.

The fourth reviewer remarked that this is a valuable program. Many of the technical issues described by the speaker were well beyond the understanding of this reviewer. It may be valuable in future presentations to provide more introductory discussion of the nature of the improvements to KIVA. The final reviewer commented there is no indication that resources are not appropriate.

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



Reviewer Sample Size

This project had a total of 11 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

According to the first reviewer, fundamental studies (and reassessments) of our most basic thermodynamic and physical assumptions about engine design are to be encouraged. The second reviewer commented breaking ground on these new areas will only help in the development of future programs, and the third reviewer remarked the focus is on identifying ways to reduce fuel consumption (and thus lower petroleum usage). The fourth reviewer said pushing the boundaries of engine efficiency is an important fuel saving opportunity, and the fifth reviewer commented it is very important to fund out-of-the-box exploration of combustion. The sixth reviewer noted the work is looking at long-term, high risk concepts to increase the efficiency of the internal combustion engine. This is the kind of work that a National Lab should be expected to do. It is estimated that brake thermal efficiency can be improved to 50-60%. The seventh reviewer remarked the team is trying to demonstrate how to recovery waste heat in the exhaust. The final reviewer commented on the limited LD vehicle application.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

According to the first reviewer, it is great to see really free thinking, even if it may stretch the state of the art. According to the second reviewer, general approach of engaging experts to generate ideas on improving efficiency, downselecting and then conducting some proof-of-concept experiments is a good one. The third reviewer remarked that the USCAR workshop is impressive. It is a great idea to leverage the expertise of the field and use this to push the limits. Use of reforming is great out-of-the-box thinking based on thermodynamics fundamentals. It also fits nicely with today's engine base and can be phased in very nicely. The fourth reviewer thought that the team is looking at some interesting technologies and likes that this includes a fair amount of experimental testing to validate real potential.

The fifth reviewer pointed out a second law analysis is being pursued, which points to sources of irreversibilities. Combustion irreversibility is reduced when syngas is burned relative to a more a complex HC molecule. The sixth reviewer remarked that the project is modest in scope due to budget constraints, but jumping into hardware-based experiments before all theoretical options have been considered is unnecessarily risky from a project direction point of view. The seventh reviewer understands the basic concept, but has little idea on how it would be put on an engine. Another reviewer remarked that the long-range approach is appropriate for extending beyond near-term efforts. However, the approach must also consider how the vehicle system, especially hybridization, will determine the degree to which these long-range technologies will be effective. The final reviewer commented that the team needs to clearly outline assumptions (barriers) to practical implementation.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Some reviewers saw some excellent progress, with the first reviewer remarking the progress with the design and development of the TCR system is very good, and establishes a good building block for future work in this area. According to the second reviewer, modeling of TCR is intriguing and excellent. The results set the framework for experimental verification. Also, work on 6-cycle engine is exciting and results are forthcoming: ditto on RAPTR. The third reviewer saw great progress considering the small budget.

According to the fourth reviewer, this project's move into hardware-based experimentation seems to be a post hoc justification of what was deemed to be the most important area of potential benefit, namely thermochemical recuperation. But what about other areas of engine design such as split cycles, for example? New (or rediscovered) thermodynamic cycles offer far higher potential efficiency gains. Exhaust energy availability in real world applications is very low on a cycle-integrated basis, due to low exhaust enthalpy with LTC or drive cycle demands. What about the complexity versus WHR as an alternative? Reformate will have to be used immediately with no capacitance or storage capability, unlike WHR.

The fifth reviewer remarked meeting with experts to generate ideas was held. This reviewer was not sure that the idea of thermochemical recuperation including reforming to produce syngas that is being pursued has enough potential to significantly improve efficiency or that it is different or better than what others (including OEM's, national labs, and universities) are working on. According to the sixth reviewer, good ideas were shown but much is to be done to show the real potential on TCR. The colloquium is a good idea and should be repeated perhaps with better guidance. The seventh reviewer remarked it looks like the RAPTR project is needed to provide needed chemical reaction data, but then the team jumps into this 6 stroke engine with hydraulic actuated valves. Is the RAPTR data needed? It appears the team does not think so. The eighth reviewer thought the project is an interesting area to explore, but power density cannot be ignored. The team should keep looking for efficiency gains, but keep in mind that a 100% efficient cycle that produced no power is of no value. The final reviewer said that work has progressed on thermochemical recuperation, particularly on reforming methanol into syngas using exhaust energy. A concern is the nature of the duty cycle for light-duty applications, where the energy in the exhaust is being reduced via increases in engine efficiency due to other concepts.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Reviewers generally saw good collaboration, with the first reviewer remarking the PI has gone to great efforts to get a wide range of inputs and this is an example of outstanding collaboration. The second reviewer remarked on good use of the industry working group, which is to be encouraged, and the third reviewer said collaboration with the combustion “community at large” is a promising start. Sustaining the collaboration with industry as the program develops will be important going forward. The fourth reviewer remarked there was good outreach to a broad spectrum of the engine community. According to the fifth reviewer, partners include GTI and several universities. Industry partners limited to mainly one OEM and catalyst supplier through GTI. The final reviewer remarked that universities are well-represented, but industry is lacking. The PI should bring in engine companies, Sturman, reformer companies, etc.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

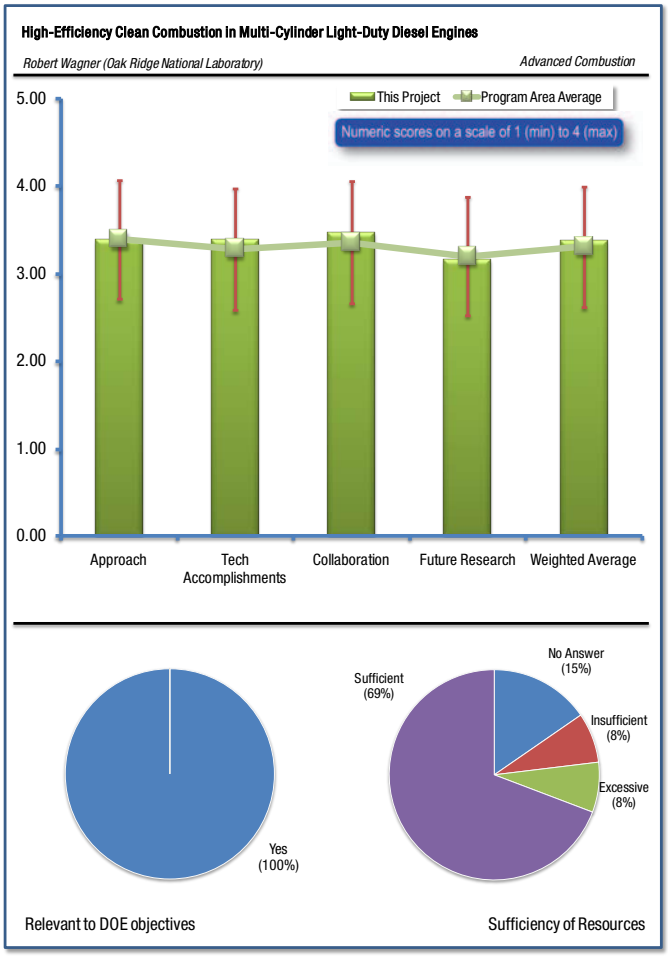
The first reviewer saw a good plan to further evaluate TCR. According to the second reviewer, resources are quite limited, so future work needs to focus on setting the stage to justify further resources. Focus on modeling and analyses to make thoughtful decisions on where to spend the bigger money that should come.

The third reviewer understands how the 6-stroke engine will run, but the reviewer did not know how the team plans to run an engine with a fuel reformer. This reviewer was not much of a fan of the 6-stroke engine: displacement was downsized by 50%. The fourth reviewer remarked future moves into hardware-based experimentation can be seen to be premature–it locks in one particular physical setup rather than retaining flexibility. The final reviewer suggests the focus on TCR catalyst development and demonstration is appropriate, but perhaps greater emphasis on dilute (vs. lean) combustion would be a better long-term strategy.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Several reviewers thought funding was insufficient. According to the first reviewer, funds are probably insufficient now that real-world experiments are being contemplated. The second reviewer remarked funding seems too low for achieving a successful project outcome for the experimental work in timely fashion. The third reviewer commented there is nowhere near enough money to pursue this work, and the fourth reviewer remarked "not enough to do all you want." The fifth reviewer remarked the team is yearning to move into experiments to verify the excellent modeling foundation. There are not enough resources to do hardware. The final reviewer doesn't recommend spending more than $250K on this specific idea, although that funding will quickly be consumed when experiments are started.

High-Efficiency Clean Combustion in Multi-Cylinder Light-Duty Diesel Engines: Robert Wagner (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 13 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

According to the first reviewer, advanced combustion strategies specifically address improving efficiency and lowering emissions. The second reviewer remarked this is of particular relevance to light duty trucks, for future CO_2/fuel economy compliance. The third reviewer commented that the focus is on evaluating advanced combustion concepts to improve efficiency and reduce emissions. The fourth reviewer said light-duty uses the majority of petroleum based fuel and offers the biggest fuel saving opportunity. According to the fifth reviewer, these high-EGR gasoline engines are showing much promise in both HD and LD: efficiency high, CO_2 low. This is a very nice project that is demonstrating real improvements. The sixth reviewer remarked the project demonstrated significant thermal efficiency improvement. The seventh reviewer saw very good use of multi-cylinder hardware to explore advanced combustion schemes including dual fuel to increase the thermal efficiency in advanced engines while meeting emissions targets. The final reviewer commented the engine efficiencies reported from this work has been tracked for several years. Advanced concepts proposed by several workers in the field are demonstrated on a multi cylinder platform.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer remarked on the good mix of analysis and experimentation. There is appropriate use of available hardware. The second reviewer commented on the classic evolution of development. The third reviewer remarked, the approach is multi-faceted–experiments, modeling and control-based. The fourth reviewer thought the approach of combining modeling, experiments, and analysis is appropriate. The fifth reviewer remarked that the combination of modeling, experimentation, and collaboration is excellent. The project addresses current barriers. What new barriers are created? This could be outlined. The sixth reviewer said this project is a great combination of experimental and modeling activities for studying dual fuel combustion approaches or other combustion approaches. Eventually other speed and load points should be explored to give a more modal approach toward assessing the capability of the dual fuel concept for truly meeting EPA emission standards.

The seventh reviewer said, by using a multi cylinder engine, real-world challenges and issues are kept in the forefront. Results are better related to commercial applications. The eighth reviewer commented that the barriers are emissions and combustion control. Approach includes modeling collaboration, multi-cylinder engine work and thermodynamic analysis. This overall dual-fuel approach seems to have serious practical limitations because filling a vehicle with two fuels is not a practical option in the marketplace. Could this be accomplished with reforming the primary (diesel) fuel and putting that reformate into the engine? The final reviewer is concerned that the dual fuel approach may be relatively expensive for much of light duty, except perhaps in Class 2b and 3 trucks, where diesels are widely used. Would more emphasis on larger displacement engines therefore be appropriate for this work? Also, the load/speed points chosen for this work should be revisited in light of future powertrain systems.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

Several reviewers saw excellent progress. According to the first reviewer, excellent progress in evaluating the dual fuel concept on a light duty engine, and the second reviewer also saw very good progress in several areas: testing the University of Wisconsin dual fuel concept on a multi-cylinder engine, and exploration of expanding range of PCCI operations. The third reviewer commented that results are impressive out of the chute: good progress and confirmation/conflicts with modeling. The team should keep plugging away to address discrepancies. The fourth reviewer commented on the very good progress on verifying dual-fuel concept on 1.9-L multi cylinder. Indicated thermal efficiency of about 42% has been obtained, but this gain is not being seen in brake efficiency mainly because of cylinder balancing. By improving cylinder balancing this should be improved in the future. The fifth reviewer remarked that the project is making good progress in a number of areas, and certainly has some interesting test data. It would be good to try and get a better feel toward BSFC. The reviewer understands the need to start with ISFC, but there is certainly a need for the dual fuel approach to get out to a BSFC number just to make sure there are no unexpected big hitters on efficiency.

Another reviewer remarked the initial experimental results are very important for assessing differences between predicted fuel consumption gains with the dual fuel approach versus real world multi-cylinder actual fuel consumption impacts. Nevertheless, the future work is necessary to fully explore the capability of the dual fuel approach to improve thermal efficiency. The sixth reviewer remarked on quantifying the efficiency/emissions potential of a dual-fuel advanced combustion approach, and characterizing transient/practical issues of using such a mode in a practical engine. There is a sophisticated engine test stand with a heavily instrumented engine to support thermodynamic analysis. Results are informative of the potential of dual fueling with a liquid gasoline or equivalent fuel. The work shows that the practical benefits are more strongly related to emissions, rather than efficiency. The seventh reviewer thought it was nice to see real engine results, but efficiency is not that encouraging.

The eighth reviewer questions if this project is designed only to check and confirm UW's recent modeling and dual fuel experimental results. This is a limited and derivative scope of work. The final reviewer questions how well would the diesel engine have done if timing had been optimized for efficiency? A NOx vs BSFC plot of the diesel compared to a NOx vs BSFC for this dual fuel engine would be helpful. Also, the diesel can be equipped with more EGR, remapped turbos, higher pressure injection, etc and achieve some pretty good fuel efficiency. This is out of your scope, but this could be modeled and compared to test results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

Most reviewers saw good collaboration, with the first reviewer noting good use of collaborations, especially with University of Wisconsin, and the second reviewer observing direct and active collaboration with University of Wisconsin, Delphi and others. The third reviewer remarked on the good cooperation with industry and universities. The fourth reviewer saw a well-rounded team with much involvement: top caliber. The fifth reviewer commented this effort historically and also within the last year has included clear collaboration with universities and various industry partners. According to the sixth reviewer, the main collaboration seems to be with Wisconsin (at least for dual fuel concept). There is some collaboration with Delphi that appears to be related to supply of injectors. Other industry collaboration was vaguely referred to as “industry tech teams” and “one-on one” interactions. The final reviewer suggests the project should be more engaged with Class 2b and 3 OEMs, who might be first adopters of this technology in light duty.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

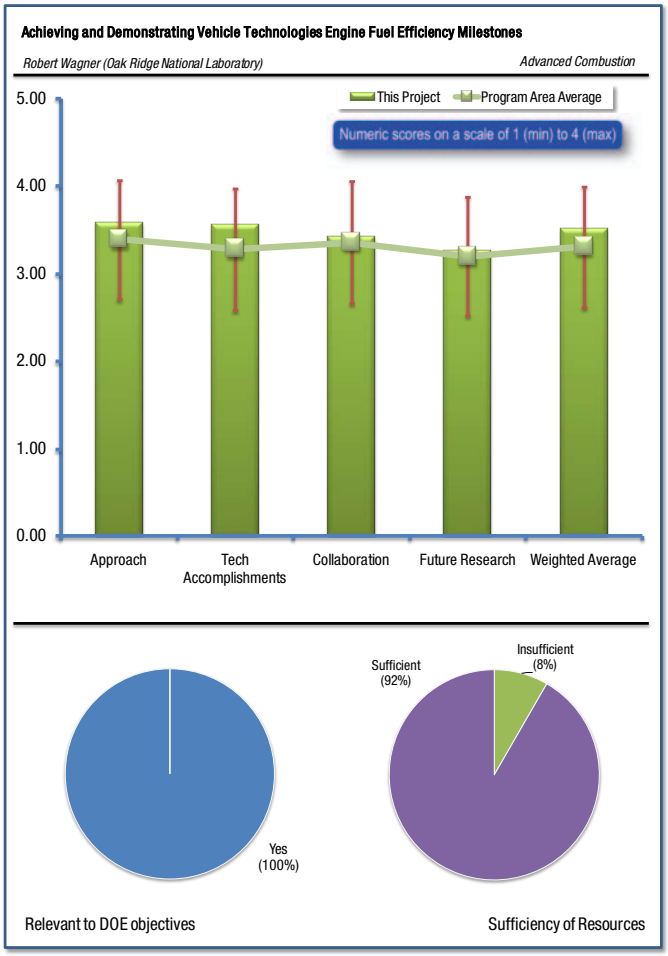
The first reviewer generally saw a good approach. This reviewer added that there are so many areas to explore in the future but exploring pushing up thermal efficiency while relaxing NOx levels would be beneficial and also exploring other engine speed/load operating points would be very helpful to the community. According to the second reviewer, plan is in place for necessary further evaluation. The team needs to see how to get real benefit relative to diesel to make this engine system competitive. The third reviewer commented the presentation proposed continued effort to explore other advanced combustion concepts such as partially premixed combustion and Dec's HCCI concept.

The fourth reviewer suggests to keep moving on refining and improving performance and see where we can go. Focus on BTE with no emissions constraints for now. The team needs to move from indicated to brake measurements to really account for losses. They might overwhelm everything and makes this look non-competitive. The team needs to move into testing and use modeling only to supplement direction. The fifth reviewer thought it looks as though future work will be responding to advances of others, or is there some other plan? The sixth reviewer remarked on expanding the range of conditions considered, and integration of oxidation catalysts. The work would benefit from including different fuel types or formulations. The seventh reviewer questions if the emissions goals should be stretched to something more aggressive, like Tier2/Bin2, for this work.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Responding reviewers commented that resources may be insufficient. The first reviewer remarked funding seems to be ok, but may be insufficient as development progresses. The second reviewer commented as more experimentation is used, more resources might be needed. The sense is that this is well within UW budget. The third reviewer remarked it takes money to test and the team does not seem to have a lot. Also, with more resources the team could look at the re-optimized diesel.

Achieving and Demonstrating Vehicle Technologies Engine Fuel Efficiency Milestones: Robert Wagner (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Many reviewers saw the work as supporting DOE objectives. According to the first reviewer, increasing the efficiency of engine-based vehicles is a critical need for fuel consumption reduction and petroleum displacement. The second reviewer remarked the project is seeking to improve thermal efficiency through turbocompounding and bottom cycling and is directly responsive to displacing/reducing petroleum use. The third reviewer remarked the project supports DOE goals of shorter-term efficiency improvement goals (45% BTE). The fourth reviewer commented this part of the ACE program is possibly the area of greatest direct relevance to the goal of reducing petroleum use, and the fifth reviewer commented that exhaust energy recovery is important to boost engine efficiency. The sixth reviewer thought bottoming cycles will be a key new technology in 2016+. It is very critical to set the stage and find obstacles. The work is cutting edge. The seventh reviewer thought the project does a good job of showing the tremendous effort and cost of a bottoming cycle on a diesel engine. The eighth reviewer remarked this is the only project which directly addresses a 45% BTE demonstration. The ninth reviewer remarked the exhaust heat recovery aspects of this work are very interesting and highly relevant to work being performed in many places. The final reviewer commented that this is the main project in the DOE portfolio that directly addresses and is devoted to meeting the Vehicle Technologies goal of reducing petroleum usage by increasing engine efficiency. The engine efficiencies reported from this work have been tracked for several years. Advanced concepts proposed by several workers in the field are demonstrated on a multi cylinder platform in order to meet the goals.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer commented seems to be very focused in 2010 on assessing whether the organic Rankine cycle can achieve 45% BTE. The second reviewer saw a good mix of analysis and experiment, but would like to see more focus on vehicle integration and duty cycle. The third reviewer commented that the approach is outstanding. It is a comprehensive approach that includes simulation, experimentation, thermodynamic analyses, and collaboration with other researchers in universities, national labs and industry. The key is the willingness to incorporate concepts and progress made by many collaborators on one test site. This gives this project great value. The fourth reviewer commented it is very good to look at modeling and thermodynamics to look at opportunities and then turn it into hardware. It is nice to see the tight collaboration and development of analyses on the engine, incorporating cutting-edge thermal management. The fifth reviewer commented about incorporating turbocompounding and bottoming cycle in a multicylinder engine, including experimental and modeling studies. The team has clearly identified that typical road load operating conditions are low efficiency and need to recover thermal energy or reduce exergy loss.

The sixth reviewer remarked that the focus on WHR, and specifically ORC, limits the potential application and scope of this project. The seventh reviewer thought the approach was outstanding, but would like to see consideration and prioritization of these advanced technologies relative to the anticipated improvements in conventional and hybrid vehicle technologies over the next decade or so. Another reviewer remarked that implementing an ORC on a LD vehicle is problematic, but it is OK for proof of principle. The final reviewer wanted to know what the team would recommend to help with the road load efficiency.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

The first reviewer saw outstanding peak performance. 45% BTE is the highest the reviewer has seen: the reviewer suggested to keep pushing. The second reviewer commented that against a goal of 45%, a peak brake thermal efficiency of 44.3% has been demonstrated. This was achieved with experimental results from the organic Rankine cycle that was designed, constructed and tested during this period that moved the overall brake thermal efficiency from 41.8% to 44.3%. Modeling of the organic cycle for transient application has also been completed. This effort is setting expectations for application of the organic Rankine cycle to road load conditions.

The third reviewer remarked the use of WHR adds an enormous increase in complexity for a small potential increase in efficiency (from say 42% to 44%). What about looking for other cycle-based improvements from a holistic point of view? The fourth reviewer commented the progress with bottoming cycles is very good, but how might this technology benefit from vehicle hybridization, especially with PHEVs? The fifth reviewer summarized that the project is studying organic Rankine cycle system and demonstrating increasing BTE on a multicylinder engine. The team has identified where in a typical range of operating conditions there is availability in the exhaust and EGR gases. The team has completed benchmarking of the organic Rankine cycle system (>11%) and identified difficulties in operating the device and key components to optimize (evaporator).

The sixth reviewer thought the concept was demonstrating some potential in the lab, but it is disappointing to see such low potential at road load. The final reviewer was concerned that the ORC offers no benefit at light load. Is this the best path forward for light duty?

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

Generally, reviewers saw excellent collaboration. The first reviewer remarked on good, widespread collaborations with industry and universities. The second reviewer commented that interactions are focused with organizations that could provide ORC hardware and software. The third reviewer remarked on the good cross section of people involved and liked the team's willingness to share GT Suite models relative to bottoming cycle. This would be very helpful and is an example of excellent collaboration. The fourth reviewer remarked, as mentioned already, collaboration with other researchers, OEMs and suppliers for hardware is excellent. The fifth reviewer believes that system modeling is key / good to see. Also the interaction with Gamma is good. It is a way for the knowledge from this work to be available / useful to industry.

The sixth reviewer saw close collaboration with component suppliers, but saw no identified university involvement, even though this project and the supporting analyses would be ideal educational opportunities. The seventh reviewer saw good use of industry inputs and collaboration with industry, and suggests that the project could broaden collaboration with more industry effort now focused on Rankine WHR. The final reviewer saw good collaboration with state-of-the-art components, and suggests that moving forward, the team will need OEM involvement for technology transfer and for addressing practical issues.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

The first reviewer commented future work is on track towards the 45% peak thermal efficiency goal. Simulation tools will be used to assess the potential of thermal storage for better utilization of thermal heat recovery. The second reviewer remarked that the goal of continuing to assess various technologies to improve efficiency is appropriate, although no specific plans were discussed. The third reviewer remarked keep working on the modeling and experimental interaction. Key will be to answer the question: Where should the aftertreatment go, pre-turbo or pre-ORC? Can the engine be run for high-exhaust manifold temperature to deliver aftertreatment needs,

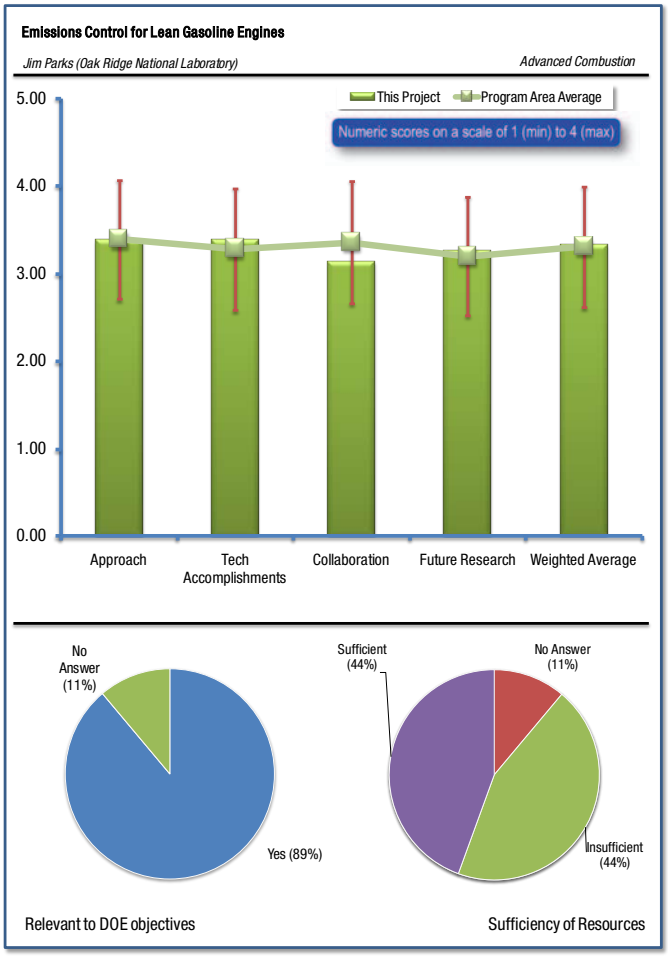
but counting on the turbo and/or ORC to minimize losses? The fourth reviewer summarized that the project is pushing to 45% BTE in the engine stand, understanding matching of the organic Rankine cycle to match the available energy. The team is expanding consideration of energy storage and recovery to enable full effectiveness during transient operation.

The fifth reviewer suggests that WHR is better suited to heavy duty applications. Hybridization, downsizing and engine cycle modifications would be a better potential fit for light duty. The sixth reviewer thought more emphasis on vehicle-level modeling with these technologies may be warranted, using representative 2020+ baselines (conventional and hybrid). The seventh reviewer commented that there are still many barriers to make this a productive approach to real vehicles. It might be worth a colloquium on key issues to address. The eighth reviewer would be "visiting the super turbo guy and finding out if they actually have made one that really worked." The final reviewer remarked that project appears to be drawing to a close.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Reviewers had no comments on resources.

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



Reviewer Sample Size

This project had a total of 9 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Several reviewers saw lean-burn gasoline as relevant. The first reviewer remarked that lean burn engines may be a critical part of future light-duty engines. The second reviewer commented lean gasoline is an attractive and viable approach to meeting future CO_2 requirements. Lean NOx is problematic and significantly limiting. The third reviewer remarked that lean gasoline is an interesting item to study and the results do have relevance to fuel consumption goals. For the fourth reviewer, cost is the primary barrier, so this reviewer is pleased to see it expressly stated. The fifth reviewer agreed that lean burn gasoline engines provide fuel economy benefits and thereby can lead to petroleum displacement, but their emissions control presents challenges that must be overcome in a cost effective manner. The sixth reviewer remarked this is work to enable lean burn operation in a gasoline car to meet Tier 2 Bin5. This is a more efficient operating mode.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer commented that the vehicle benchmark testing is thorough, and a useful reference for future comparisons. The second reviewer remarked the approach does focus on some of the fundamental questions, and this is a good thing as there are a lot of unknowns here. The third reviewer summarized the PI is studying exhaust from an LNT equipped lean burn gasoline vehicle initially. They are looking at a combination of technologies (LNT, SCR, TWC and combinations LNT+SCR). Complementary bench flow reactor studies and integrated results with CLEERS were performed.

The fourth reviewer would have liked to see what speeds and loads the engine sees when running these cycles. The 3500 rpm data is very interesting and shows the challenges faced, but this is faster than the reviewer runs a personal car engine (which is a 2.0L 4 cylinder.) The fifth reviewer observed that the team has the car, the analytical equipment, and access to devices. The reviewer presumed the project will have calibration control. Everything seems set for a survey-type study aimed at approaches to meeting very tight (Bin 2) emissions levels. The final reviewer commented not being a turbo is fine.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

The first reviewer saw outstanding progress in characterizing the performance of lean burn vs. stoichiometric operation. The second reviewer felt the results are very interesting and provide a nice base of understanding how the current system works, with limitations and gaps to meeting Tier 2 Bin 2. The reviewer is anxiously waiting for more results to yield even more understanding of the system characteristics. The third reviewer remarked on the good job of collecting useful engine data for the project, but asked if BMW would have given this data if they were asked. That would have "sure saved time." The fourth reviewer observed that benchmarking

information is being generated by chassis dyno tests of the BMW vehicle with LNT. Some important dynamic and regeneration behavior was observed, although shouldn't much of this information have been available from BMW since they engineered the vehicle? The team is performing LNT flow reactor studies and has installed an advanced lean burn engine for further studies.

According to the final reviewer, the fuel economy improvements shown are impressive, but it would help to have some comparison to diesel. The reviewer's basic question is this: is the desire to improve efficiency of gasoline engines, or try and get better than diesels as the benchmark? In any case, this is good technical work with very interesting results.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

The first reviewer remarked that sharing data with CLEERS is a great thing and the reviewer appreciated this contribution to basic understanding of the aftertreatment device. The second reviewer saw little inputs coming from outside ORNL. The team may wish to pull in a catalyzer for LNT understanding so to avoid re-inventing anything. Also, vehicle calibration work from OEMs might help: this can come later. The final reviewer saw interaction with GM and CLEERS.

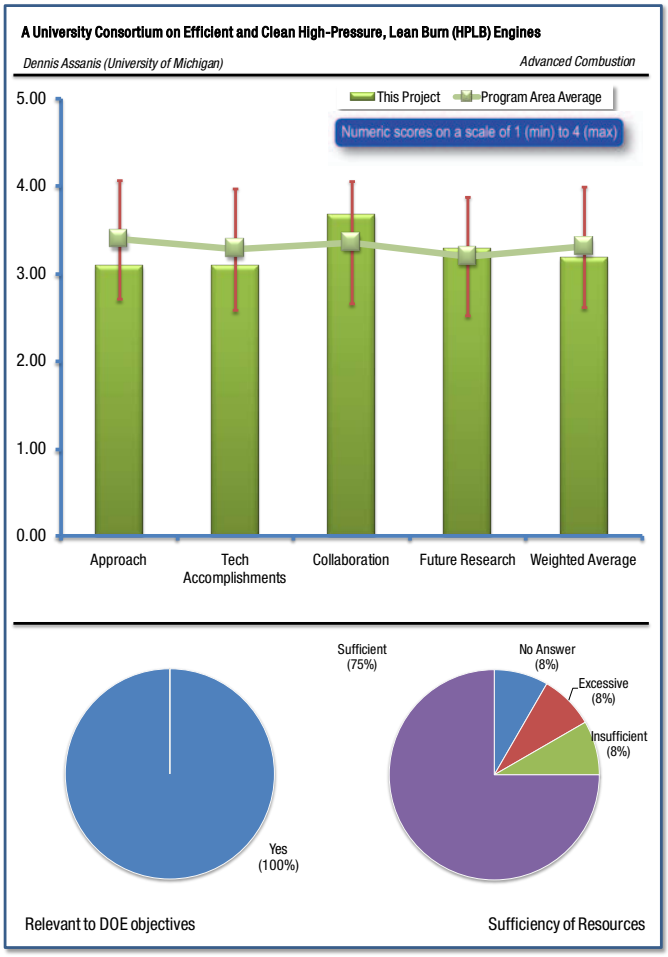
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

The first reviewer believes it would be interesting to compare the benefits of lean vs. dilute (EGR) in future work. The second reviewer remarked the general direction is certainly valid and leaves room for flexibility. The final reviewer commented the PI will continue vehicle studies, flow reactor studies and development of advanced lean burn gasoline engine test stand with capability to study various lean NOx strategies.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

Responding reviewers thought the budget is too low. The first reviewer remarked that the budget seems low for such a commercially relevant program that could have near term benefits in the marketplace. The second reviewer said if this is to extend much beyond benchmarking work, and the reviewer thinks it should, more resources will be required. The third reviewer commented this was not much of a budget for doing test work.

A University Consortium on Efficient and Clean High-Pressure, Lean Burn (HPLB) Engines: Dennis Assanis (University of Michigan)



Reviewer Sample Size

This project had a total of 12 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

Reviewers generally saw the project as supporting DOE objectives. The first reviewer remarked about the focus on high-efficiency new combustion approaches with multiple parties and the consortia split of efforts, judged to be excellent. The work has the objective of maximum efficiency without emissions constraints. The second reviewer commented it is useful to explore long-range potential for advanced multi-mode combustion. The third reviewer commented there are a lot of good items being worked in this program. The fourth reviewer remarked this coalition of universities provides a combination of advanced combustion strategy exploration and engine duty/vehicle level fuel economy assessment; the emissions modeling portion of this effort will be challenging, but at a minimum, this project can provide DOE with feedback on vehicle level impacts of the various combustion strategies. Another reviewer stated that the work is trying to push HCCI operation (which is efficient) into higher power operating conditions. Work is being done on the transition from SI to HCCI (using SACI).

The sixth reviewer noted the goal of the program is to demonstrate the pathway to achieving a 25-40% improvement in light-duty vehicle efficiency in order to reduce petroleum use, and the final reviewer remarked that the project focuses on pushing the boundaries of engine efficiency and emissions reduction to reduce petroleum consumption.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

The first reviewer saw a good focus on simulation that is appropriate to early evaluation of technology. The team made good use of available engine test equipment. The second reviewer saw very good progress, and excellent coordination; covering many bases. The third reviewer remarked the overall approach is a good basic and applied research effort that covers fundamental combustion studies of gasoline/ethanol SACI and HCCI, includes metal engine experiments, optical device experiments, and engine system/vehicle simulation to assess potential fuel economy gains. It wasn't clear how wide an actual engine operating range was going to be addressed in this project–it would be valuable to cover a very broad region of an actual engine operating map.

The fourth reviewer suggested pursuing high pressure lean (dilute) burn, building from past HCCI consortium and final in-vehicle fuel economy gains. Combustion is a spark assisted compression ignition process, using charge/fuel stratification and using fuel tailoring to improve efficiency. Multiple modeling tools are being employed to support the experimental efforts. The fifth reviewer summarized that the PI split tasks among competency centers and highlighted interaction pathways. The work covers the keys: dilution, stratification, fuels, multi-mode, and spark.

Other reviewers commented on the project's complexity. The sixth reviewer remarked it was a very complex project. It is difficult to understand all aspects from a 20 minute presentation. It is nice to see the vehicle integration as part of attribute demonstration. The

seventh reviewer remarked that maybe it was the presentation, but the reviewer could not discern the real focus on this program; there were 6-8 different areas being discussed and the reviewer was unclear as to what was the real focus. The eighth reviewer said the work was a broad-fronted scattershot approach to engine efficiency improvements and novel combustion regime investigation. For the ninth reviewer, the approach is a bit concerning. There is a long list of things to investigate, but no clear integration of the tasks. Emissions are the challenge, more so than any incremental thermal efficiency gains. There were no specific emissions tasks listed.

The final reviewer remarked that the demonstration of a path to 20-40% will be on a FFVA single cylinder engine and via the use of models based on concepts and data. Also, work will possibly be done on a multi cylinder project jointly with Bosch. The pathway to be explored contains several elements. These include assessing the potential of novel engine cycles, stratification strategies, multiple ignition, and fuel chemistry opportunities.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

The reviewers noted that the project is in its early phases. The first reviewer said results reflect the excellent managerial skills of the PI and the solid core competency of the collaborators. The second reviewer noted it is early in the project, but the previous consortium demonstrates a winning track record. There is a high probability of achieving 45% BTE using practical approaches. The third reviewer said it is early days in the life of this project. It has a wide range of programs, and it is not clear what the focus is. It seems to be a catchall – methods, tools and procedures. What does 'demonstrate' mean in the context of this project: on an experimental platform, on an engine, or in a vehicle? The fourth reviewer summarized that the work done over the past years under the previous consortium has been extended by developing a vehicle fuel economy assessment tool, improving the CFD models, and identifying and demonstrating the SI, SACI, and HCCI combustion regimes on the FFVA single cylinder engine. The sixth reviewer observed that the team developed a framework for assessing vehicle efficiency improvements with advanced combustion. They have developed and applied a new wall function heat transfer model to improve heat loss calculations. They have demonstrated distinct combustion mode operation in an engine platform, permitting shifting between modes for optimal combustion and efficiency. Another reviewer remarked that the project is pulling together work in multiple combustion regimes. It is always hard to see how all these elements will come together. The eighth reviewer commented this follow-on effort to past HCCI has contributed to the understanding of load limits for HCCI and now is pushing in a direction to address multi-mode combustion in “gasoline” SI type engines. The work is in its early stages, but it would be nice to see some type of projected vehicle analysis fuel economy improvement analysis based on this early SACI and HCCI work. The final reviewer remarked that it was hard to tell what the progress was. There seemed to be a lot of topics touched upon for two minutes without a real explanation of technical progress.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

Reviewers generally saw good collaboration. The first reviewer characterized the good, wide collaboration, and the second reviewer remarked that strong cooperation is fundamental to the project plan. The third reviewer observed a strong multi-university effort, with national labs and numerous industrial partners (component suppliers and OEMs). The fourth reviewer remarked it doesn't seem to get better than this. Top-notch academic centers are included, and incorporating UW, MIT, and UCB will help develop these centers for training scientists and engineers, and yet bring high-probability results. There is a nice mix of industrial partnerships. The fifth reviewer remarked the PI is dealing with a good cross section of individuals. The sixth reviewer also commented that good collaboration with a number of industry, national lab and university organizations exists. The final reviewer questioned, “are there too many chefs and cooks in the kitchen?”

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

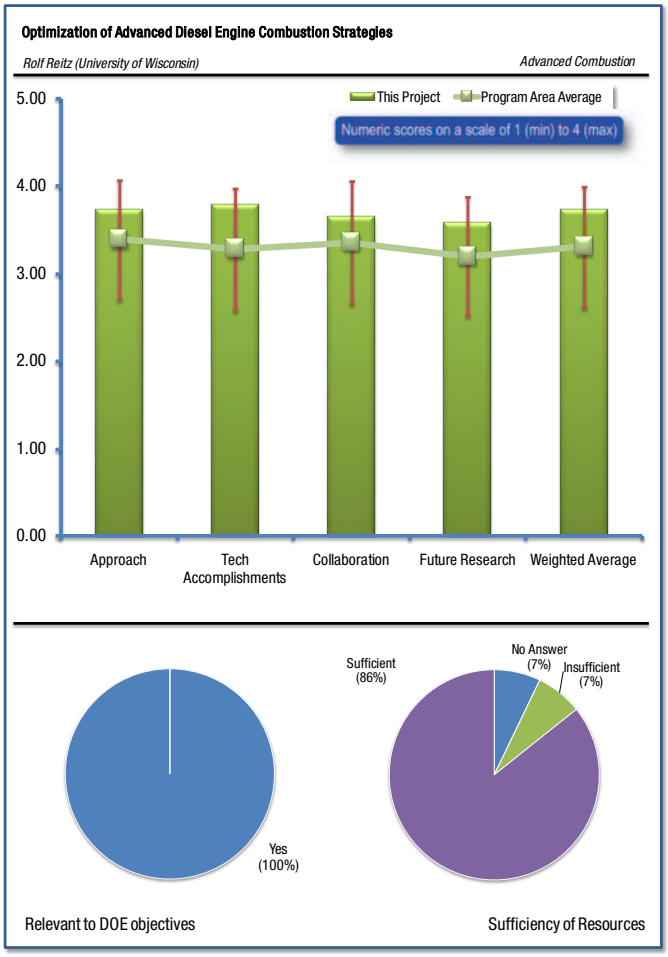
The first reviewer commented that plans look appropriate to moving forward. Focus on control strategies should be included. The second reviewer remarked on the good plan with much involvement. It is nice to focus on efficiency, with some biofuels work. Turning concepts into hardware will be key to get at issues. The third reviewer commented the team will do further development of experimental capabilities in engine and RCM facilities to consider fuel and charge stratification.

The fourth reviewer suggests that future research areas need to be refined or focused down to a select few areas, or else this project comes across as merely a means to fund the University of Michigan to do the sorts of projects that it already finds the funding to do. The fifth reviewer asked if the plans need narrower but deeper coverage of the topics, or are the team members satisfied with the depth of coverage within the broad areas being addressed. The sixth reviewer's only suggestion is to consider setting up a vehicle level simulation such that any generated engine results could be readily integrating a duty cycle simulation that could quickly assess any potential fuel economy gains. The final reviewer remarked the project needs to have more clear focus on specific topics.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

The first reviewer saw a nice blend of fundamental and applied experiments, yielding new knowledge and engineering outcomes. The second reviewer was not clear that the money will be well-spent and what the actual deliverables will be. The final reviewer does not recall that it was stated what the resources were. It is therefore hard to make a call on if the resources are sufficient or not.

Optimization of Advanced Diesel Engine Combustion Strategies: Rolf Reitz (University of Wisconsin)



Reviewer Sample Size

This project had a total of 14 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A researcher said that the project has the potential to show significant fuel efficiency improvements in engines and that this is an example of how fundamental engine research should be conducted at universities. A separate reviewer said that the work at UW is important fundamental combustion work, leading to advancements in LTC. A different reviewer said that there was good potential for increased engine efficiency. One reviewer said that this project focused on improving engine efficiency by focusing on the combustion process directly.

A reviewer said that improving fuel economy will be enabled by developing improved advanced combustion modes will displace petroleum. One reviewer said that the focus is on development of high efficiency ICE's with 20-40% improvement in fuel economy for light duty vehicles and achievement of 55% brake thermal efficiency in heavy-duty vehicles. The reviewer added that if successful, these achievements would decrease the consumption of petroleum.

A reviewer said that this was a large comprehensive project aimed at maximizing efficiency using practical methods and that there was excellent transfer of technology with broad collaboration. The reviewer added that this is one of the better DOE projects that will deliver fruitful results. A reviewer said that the project supports modeling of efficient combustion systems and is investigating more efficient combustion systems.

One reviewer said that this project does support DOE fuel efficiency and emissions goals by detailed combustion research on dual mode approaches combined with engine system simulation. The reviewer added that portions of this project are pushing the limits of understanding in dual fuel combustion approaches. A separate reviewer said that the work is being done in a number of areas with good direct relevance to improving engine operating efficiency.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that this work was a comprehensive yet well-thought out approach to engine research. A separate reviewer said that the approach is well-integrated with efforts of DOE and industry, and is significantly contributing to tangible advancements in LTC. A different reviewer noted that the project is focused on key barriers to implementation, not just a narrow area, and there was good use of analysis tools and experiments. A reviewer said they were great projects.

A reviewer noted that the approach of combining experimental work with modeling/simulation was excellent. The reviewer added that the project was also exploring alternate concepts such as dual fuel.

One reviewer said that the team was applying high fidelity engine simulation and high-resolution engine experiments to create and employ advanced tools for development of high efficiency low emissions engines. The reviewer continued that the barriers identified are combustion phasing and heat losses.

A separate reviewer commented that the project took a sound and thorough approach capitalizing on best-in-class scholars and engine research experts. The reviewer continued, commenting that the team is using high fidelity computing and high-resolution engine experiments synergistically to create and apply advanced tools needed for high-efficiency, low-emissions engine combustion design–cannot do better than that.

One reviewer commented on the project's broad approach with much complexity. In general, the reviewer felt, it was very balanced between combustion, efficiency, fuels, aftertreatment, metal engines, modeling, and optical. The same reviewer felt that the results were very impressive. The reviewer did feel that SCR injection and optimization were a "fish out of water" here. The reviewer added they still felt the work was complimentary, but that this consortium might be better spent on combustion. The reviewer added that the project is very worthy, but unless there are unique challenges presented here, this one might be moved.

One reviewer felt there was "too much stuff." The reviewer added that the technical approach is OK, but they were not sure the baseline performance is well established.

A reviewer said the work is being focused on areas of direct interest to industry and getting higher efficiency out of IC engines. The reviewer suggested that at some point soon, there needs to be more focus on BSFC of the dual fuel engine, just to understand if there are any unexpected losses on a full engine.

A reviewer commented that a comprehensive approach has been taken as outlined in Tasks A, B, C and D. The reviewer added that combustion strategies to improve thermal efficiency are undertaken with experimental as well as CFD tools. The reviewer continued that fuels are recognized as being a key enabler for combustion strategies and reducing emissions are recognized as being an integral part of any high efficiency design. The reviewer also noted that system-level optimization and demonstration is also undertaken to address real-world challenges.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said there was outstanding progress in all areas. A separate reviewer commented that the efficiency improvements shown through dual fuel injection processes were very exciting. Another reviewer said that there were outstanding results, especially in tasks A3, dual fuel engine: 55% efficiency. One reviewer said that there were a very good number of accomplishments in several areas and that the project had demonstrated that 55+% brake thermal efficiency could be achieved while meeting U.S. EPA heavy-duty emissions standards without using an aftertreatment device. A reviewer said that the ISFC numbers being shown are very impressive, but the project needs to show more on stability and transient operation, adding that the progress to date on this program is just outstanding.

A reviewer said that the project had uncovered new frontiers / grounds in optimization and control of diesel combustion for maximum fuel efficiency with minimum penalty to meet emissions mandates. The reviewer added that the state-of-the-art of diesel combustion and efficiency had been advanced.

A reviewer commented that an outstanding accomplishment of the project has been the demonstration of a dual-fuel concept that has achieved 55-60% indicated thermal efficiency in a heavy-duty engine. The reviewer added what is particularly impressive is that EPA 2010 emissions regulation have been met simultaneously. The reviewer continued that the key is to introduce reactivity gradients with the use of dual fuel and multiple injections. The gradient in fuel reactivity broadens the heat release, which generally is expected to decrease efficiency. The same reviewer noted that this is thought to be more than offset with the efficiency that comes from the low temperature combustion, on the order of 1600-1700^{o}C. The reviewer also commented that low temperature combustion reduces heat loss and results in a net large increase in efficiency.

A reviewer noted that it was a new project but milestones included the development of 55% BTE engine operating conditions using simulation through combustion chamber and spray optimization. The reviewer also said that the project had found that fuel type is less important at high load than at low load, while optimizing injection strategy. In addition the reviewer said the project was upgrading the LES model for simulation of multi-mode combustion. The reviewer noted that the team had performed a dual fuel strategy study

and met US 2010 emissions while achieving 53-59% thermal efficiency at a 10 bar operating condition. The reviewer noted they had looked at fuel effects in light duty engine and ran fuels similar to the FACE fuels. The reviewer continued, saying the project had compared optical and metal engine behavior in 1.9L engine platform and developed reduced mechanisms for model fuel mixtures including ethanol. The reviewer commented that modeling behavior within exhaust aftertreatment systems including urea sprays. The reviewer also commented that the project team had made length scale measurements within an engine to study mixing control.

A different reviewer said that the work on comparing gasoline and ethanol as the second fuel in a dual fuel approach is outstanding and that much insight is being generated from this work. The reviewer also said that as such, approaches show ISFC levels near 60%. An assessment needs to be made of what type of BSFC can be anticipated once this combustion approach is actually implemented on multi-cylinder engines; it would be beneficial to address this looming issue. In addition, the reviewer said, it is not clear how the turbulence scale engine experiments will tangibly contribute to this overall effort.

One reviewer said it is tough to evaluate so much work in a short presentation, adding that accomplishments seem impressive with good promise.

One reviewer was not sure about some of the performance numbers quoted. The reviewer added that this gets back to establishing a baseline. The reviewer believes the baseline operating conditions need to be established somewhat. The reviewer gave that example that the project had shown some cases of 40-50% EGR, yet run a very low intake manifold temperature. The reviewer wondered if this is realistic and how the project was handling all the condensation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was good cooperative work with industry and others. A different reviewer described a strong cooperative effort with collaborators within industry and academia. One reviewer said that this was the right combination of collaborators and partners. A separate reviewer commented that this multi-disciplinary approach appears well coordinated between various UW-ERC members and GM when appropriate.

One reviewer said that this work is being widely shared and a lot of participants are aware of this work, showing excellent collaboration. A separate reviewer said that collaborations exist with a host of industry and national lab partners. A different reviewer commented that the membership was the right size. A separate reviewer commented that the work was being performed under the existing consortium which has many members.

One reviewer noted this was an industry collaboration mainly with GM and Woodward and also through members of their DERC consortia. The reviewer added that input and collaboration through the latter may primarily be limited to annual meetings.

A reviewer noted that this is a huge program with many collaborators. The reviewer suggested that, although the project is fresh and refunded, please consider longer term how to shift resources from “mature” projects to more optimistic ones.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said the plan is complete and thorough. A separate reviewer said there were good plans for continuing to build on the results that they have already obtained. One reviewer said that it was good to see a systems approach to evaluating emissions with LTC (including transient behavior). A reviewer said that the future work planned is right on and is focused very well.

One reviewer commented that the future research plans are ambitious, suggesting they might need to be focused down somewhat in the future to ensure success on a wide range of fronts.

A reviewer said that there were excellent accomplishments and plans are to extend and continue this ongoing work. The reviewer also suggested that the project needs to address the practicality of dual fueling strategies with gasoline and E85 as a supplementary fuel.

One reviewer said the project planned a broad look at many aspects, adding that it is difficult to judge how well focused the objectives are. A separate reviewer suggested that Task A1 be moved to LTC only if efficiency gains are objective and Task A3 should have the emissions limitation removed and the project focused to really push efficiency. The reviewer suggested a decision can be made later on aftertreatment fuel penalties and optimization. The reviewer believed the team needs to know efficiency limits.

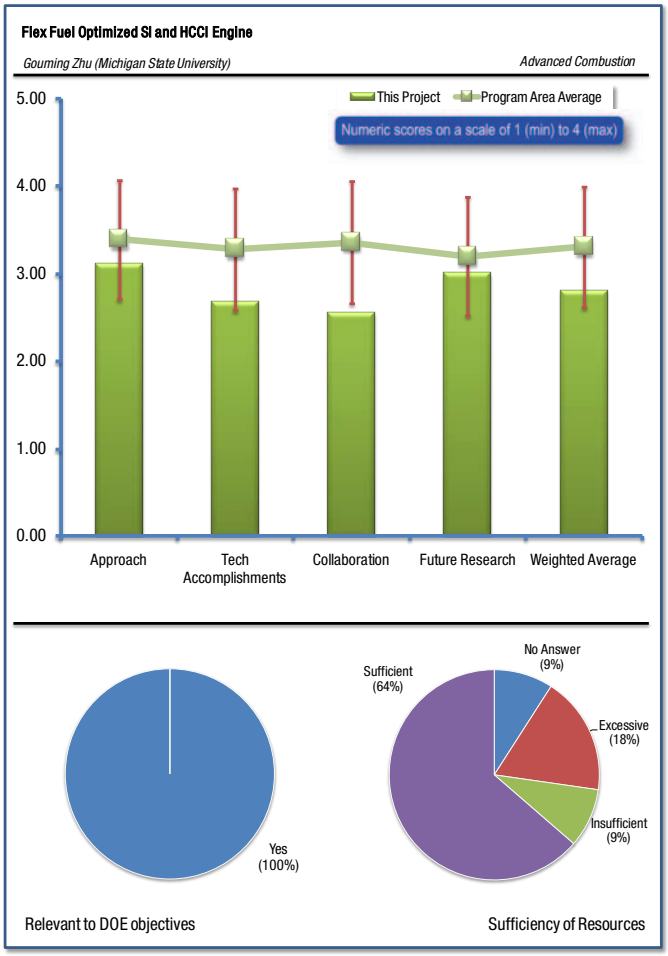
A reviewer felt that the presentation did not include a detailed future plans effort, though it did include a general plan, adding it would be nice to see more detail.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that progress has shown a good return on investment so far. A separate reviewer noted their belief that last year's budget was low: there was a good increase this year, and we should see substantially more advancement at the next AMR. One reviewer said that it looks okay but difficult. One reviewer said that progress seems good and there was no indication that resources are not sufficient. Another reviewer said that it looks okay, but there it is difficult to assess as there is so much on the plate.

A separate reviewer suggested that there was a need to address the practicality of dual fueling strategies with gasoline and E85 as a supplementary fuel. Another reviewer said that the dual fuel work is somewhat a duplication of the work on ACE16.

Flex Fuel Optimized SI and HCCI Engine: Gouming Zhu (Michigan State University)



Reviewer Sample Size

This project had a total of 11 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer stated that a dual combustion mode engine that is optimized for flex fuel has the opportunity to be more efficient and allow use of alternative fuel, providing multiple ways to displace petroleum. One reviewer added that flex fuel efficiency can both displace petroleum with ethanol and reduce total energy consumption. The value of ethanol can be increased if it is used in dual mode to improve gasoline efficiency. One person commented that the project's efficiency objectives are consistent, adding that it was nice to get funding into MSU with the need to develop an engineering base outside of the larger centers. MSU has advantages of location and access to OEMs.

A reviewer commented that this project supports DOE thermal efficiency goals by exploring gasoline-type HCCI in metal and optical engines toward pushing up thermal efficiency.

One reviewer simply stated that the project was learning how to run an engine in a more efficient mode (HCCI) and was using ethanol. Another reviewer believed that this project aims to further develop the HCCI concept by demonstrating a dual combustion engine that operates in both an SI and HCCI mode. In the process, real world issues with regards to controlling this complex mixed-mode combustion process will be surfaced and addressed. The reviewer added that the only downside of this project is that some of this work is duplication of work already done at Oak Ridge National Lab. The new feature of this project would perhaps be the inclusion of E85 and addressing of a flex fuel engine. The researchers involved should use the work already done at ORNL as a starting point to avoid duplication.

One reviewer concluded that the project only had tenuous relevance and that this project looks a lot like others that are better thought out, planned and executed.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer was of the belief that the barriers are robustness and cost effectiveness of a dual combustion mode engine, developing a control-oriented combustion model that can be included in active engine control, depending on fuel composition and operating conditions, using GT-Power simulation to develop tools that can be used in engine control while developing a combustion model, developing design of single cylinder optical engine, and the combination of metal and optical engine studies with an emphasis on monitoring spray behavior as fuel composition changes.

A separate reviewer felt there was a good use of modeling to guide the work and liked the cycle simulation work being done to get early guidance. The reviewer added that the modeling of transitions between SI and HCCI is good work and that it will be interesting if the results agree with the models.

One reviewer noted a multifaceted approach of modeling, metal, optical, control. The reviewer believed there was good feedback and on-the-fly optimization using multiple methods and that it was nice to see milestones and go no-go decision points.

A separate reviewer was of the opinion that the means for a practical approach to transitioning between LTC and SI combustion is good. Another reviewer stated that working on a dual fuel engine seems like a good approach and a good item to investigate. The reviewer continued that the overall approach d seemed relaxed and appears to have room to have major milestones moved forward. One reviewer was of the belief that model-based controls and hardware-in-the-loop control strategies will be employed by the project. Also, the reviewer added, an optical engine will be included to investigate in-cylinder flow, mixing and combustion. The same reviewer went on to state that it seems like the design of the HCCI combustion system is going to start from scratch and that it seems like the project is not just going to focus on controls. The reviewer expressed that it could be that the scope of the project is more than what one single project can handle.

A reviewer opined that the approach is ambitious but naïve, and that the investigator is not very well informed about the current state of the art or of the potential pitfalls (of attempting to predict the transition between conventional SI-initiated combustion and HCCI, for example). A separate reviewer concluded that the project held nothing new and had no innovation. That reviewer continued that this "project" barely qualifies for a master degree student's work at any other university and that most, if not all, of the subscribed work has been already done by academia, auto companies, and leading first tier suppliers like Bosch, Delphi, Continental, Denso, Matlab, dSpace and others.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer stated that modeling of SI and HCCI combustion using GT-Power has progressed to a good extent. The hybrid mode of combustion, where an engine cycle starts out in the SI mode and ends in the HCCI mode has been accomplished. This control feature will allow smooth transition between SI and HCCI modes of combustion. The reviewer also stated that the design of the optical engine is complete.

A separate reviewer commented that there was progress toward engine simulation, control based model development and single cylinder engine design and fabrication. Another commenter described the modeling results as providing good direction to the hardware part of the project. The same reviewer also saw interesting limits and opportunities for SI-HCCI.

A reviewer commented that if the modeling of the transient mode switching turns out to be accurate, this project will have achieved quite an accomplishment.

One reviewer stated that the simulation shows good potential, but added that it was still too early to assess how well the system will work in actual engine. The reviewer continued that caution is in order as modeling SI-HCCI transition is not proven. Two reviewers were of a similar mindset: one stated that the project was at very early days, while another said the project has only started so progress is thus minimal.

One reviewer stated that while the exercises presented were nice, the project activities and results have been completed a few years ago by various entities. A separate reviewer said that for what appears to be a multi-year project with a couple/few years of history, the amount of progress seems slow. The reviewer commented on a basic design being laid out, the control system being roughed out, and some modeling done, but felt that there should have been more progress. The same reviewer added that they were especially concerned about the real life transition between SI and HCCI and that does not seem to yet be considered.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer remarked that because of collaboration with an industrial partner (Chrysler), technology transfer should occur rapidly. A separate reviewer stated that the parent company in Torino, Italy has the results of the project objectives, at least in the advanced research organization "Centro Ricerche Fiat." A different reviewer commented that Chrysler seems interested. One reviewer commented that there had been efforts to collaborate with Chrysler, but it appears that an agreement is not in place as yet. The reviewer went on to state that they have received engine hardware and some technical support and have gotten some support from GT-

Power. Another reviewer noted that the collaboration was only with Chrysler and that this has apparently not been finalized yet. One reviewer said this is an isolated project focused on MSU and that even Chrysler is an unknown at this stage. The reviewer added that the project is important and should strive for more collaboration in the future.

A different reviewer opined that some of the work looks like duplication of the University the Michigan combustion R&D and wondered if the PI has coordinated with UM to ensure complimentary versus duplication of work. The reviewer went on to say that LLNL and UM have done a lot of work on simplified modeling of premixed combustion including HCCI and SA HCCI/PCCI and asked if the PI has coordinated with these researchers to ensure their GT Power combustion model is giving reasonable results. The reviewer concluded that the project has pending support from the Chrysler group, but otherwise seems to be operating in a vacuum.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

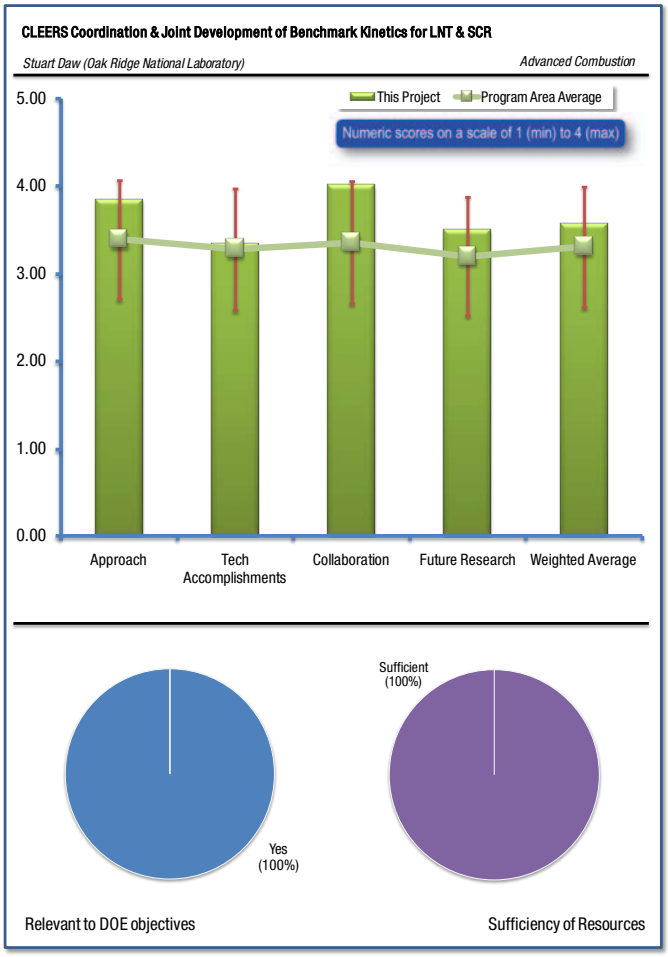
A commenter stated that the program seems to be on time and that Phase II of the program will involve optical engine tests to visualize combustion and modification of the cylinder head for VVT actuation. The reviewer added that other subsystems include ignition feedback and the HIL simulator development with the inclusion of a real-time engine model. A separate reviewer suggested that the project continue work on engine, modeling, sensing and control developments. One reviewer felt that the plan was impressive and now needs execution. The reviewer added that transients and mode-shifting will be very interesting.

Another reviewer commented that a better acknowledgement of the barriers would instill more confidence in this project and that there needs to be a more frank assessment of the tremendous hurdles to be overcome in building HCCI control expertise. An additional reviewer concluded that this project covers old bases.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer stated that they were not sure the team can get this all done and that doing a new optical engine sure seems like a large investment in itself. A separate reviewer wondered why DOE is funding another school to build an optical engine and a green field ICE lab. The same reviewer also asked if this is an objective of the EERE VTP.

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



Reviewer Sample Size

This project had a total of 6 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer stated that this was a key group to stimulate cooperative catalyst modeling development. Another reviewer added that this project supports DOE objectives strongly by bringing together the people who work on efficient emissions control with a wide range of fuels and technologies. Another reviewer noted that this work enables the implementation of lean burn engine capability and that it seems clear that the future requirement of higher fuel economy will require lean burn engines. The reviewer added that the implementation of lean gasoline technologies is especially relevant. The same reviewer continued that gasoline engines account for approximately 95% of all the light duty vehicles and consequently are providing the emission technologies that all the implementation of lean gasoline engines goes a long ways towards reducing the overall vehicle petroleum consumption.

One reviewer said that moving forward deNOx means high efficiency for diesel engines. CLEERS provides a solid baseline for pushing the envelope. A separate reviewer maintained that in terms of petroleum displacement, diesel and lean gasoline are the key powerplants, here but more work could be done to push it further with advanced fuels such as biodiesel and ethanol, as examples.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that this was an amazing success in bring many researchers together in common efforts. Another reviewer noted that the implementation of a global LNT mechanism will help with the implementation of this work. Another reviewer commented that the approach of developing models for "generic" catalysts is very instructive for most of the issues in developing these models. The reviewer added that the CLEERS conferences and webinars are excellent. A separate reviewer opined that good fundamental items are being researched and that they are a huge fan of the workshops and working groups. A different reviewer said that they have no new comments for improvements and the project should just keep doing what it is doing. A different reviewer commented that the project had a comprehensive approach with an advisory committee, modeling, correlations with experiments and communications/workshops. That reviewer added that this was a model program.

One reviewer concluded that the development of the understanding of the spatiotemporal chemistry of the LNT is very important in assisting in the development of engine control strategies that reflect the actual condition of the LNT catalyst. It is interesting to understand the toluene poisoning of the SCR catalyst. The reviewer believes the difficulty is providing a range of hydrocarbon materials that can have an effect on the SCR catalyst. The reviewer added that there was also more emphasis on hydrocarbon species emitted from lean gasoline systems.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that developing the relationship between the oxygen storage and the NOx storage on the LNT is a major accomplishment and will have a significant impact on the efficiency of the device. The reviewer continued that since there is a significant growth in the coupled device technologies such as LNT-SCR, the understanding of the conditions in which a LNT produces ammonia is clearly on track with the needs of industry. One reviewer commented that the ability to build communication between active players in the field is excellent and that this will lead to the development of protocols for testing at different laboratories and the evaluation of the effect of the various approaches on fuel economy is evaluated. The reviewer continued that LNT work has been a staple of the activity in the past, but now SCR is being much more fully explored. The same reviewer added that HC poisoning of urea-SCR is an example of an area of research that has received attention. That reviewer ended that the effect of sulfur has been studied along with the explanation of why more ammonia is made after S deposition in LNT and that ammonia production under rich regime has been studied and the formation of N_2O from it has been examined. One reviewer commented that there had been good results already and more on the way. A separate reviewer found the Fe-zeolite reaction paths quite interesting and that it sets the stage for optimization by industry. LNT modeling and NH_3 is delivering new understanding that will move field forward.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer was of the belief that this project involves more collaborative work between industry, national labs, and universities than almost any other project. Another reviewer commented that the effort is by nature collaborative and the leaders are very good in fostering the team effort. A third reviewer commented that all key sectors represented and that tech transfer and advisory committees were excellent. Another commented that this was just an outstanding job in getting a broad-range collaboration.

A separate reviewer said that the sharing of results with industry through CLEERS is a very good method to get this information into the industrial sector. The reviewer continued that it is also clear that the interaction with the work going on at PNNL and SNL is solid and that it does not appear that “fiefdom issues” are occurring, which is very good. A different reviewer commented that coordination with the industry is very important and that they see that some projects may be studying out-dated catalysts. The same reviewer suggested that more catalyst information from catalyst suppliers and auto companies would be helpful.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

One reviewer urged the project to keep up the good work. Another reviewer commented that a focus on the unburned fractions of gasoline as possible poisoning agents for SCR would be helpful and that continuing the work on SCR protocols and comparing the results from other laboratories is very beneficial. A separate reviewer believes that there was a strong focus on LNT and SCR, but it would be good to include HC-SCR in the overall modeling approach, especially in the determination of effects on fuel economy between the technologies. The same reviewer added that there has been an increase in interest in new developments with Ag HC-SCR by some in the catalyst industry, which is not covered in this program. The reviewer felt that this could offer an interesting new direction, since there may be mechanistic similarities to what happens in LNTs, especially surrounding NH_3 formation.

Another reviewer said that they think it is time to move away from the current Umicore benchmark LNT catalyst. The reviewer would like to see a laboratory comparison/benchmark of commercially available LNT and SCR catalysts under the CLEERS protocol. This would help determine what issues have been solved. For example, HC poisoning is likely to less of a problem on the newer CuSCR catalysts. A separate reviewer commented that key gaps include a major trend towards integrated components. LNT+DOC; SCR+DPF; which are leading concepts. The reviewer saw that models form a basis of understanding, but there is no evidence here of tying all this together (the POx material being added to LNT for NH_3 and desulfation). The reviewer concluded that there seems to be a gap here and highlighted PM oxidation by SCR catalysts. Base metal catalysts show dual functionality and this might be worth modeling and exploring.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said more funding certainly could be helpful; however, this laboratory has been very effective in the utilization of their resources in addressing these problems. Another reviewer commented that they do not recall any requests for further resources to evaluate, but could be supportive for them depending on what they were. A separate reviewer commented that there was appropriate funding and staffing.

CLEERS: Aftertreatment Modeling and Analysis: Darrell Herling (Pacific Northwest National Laboratory)

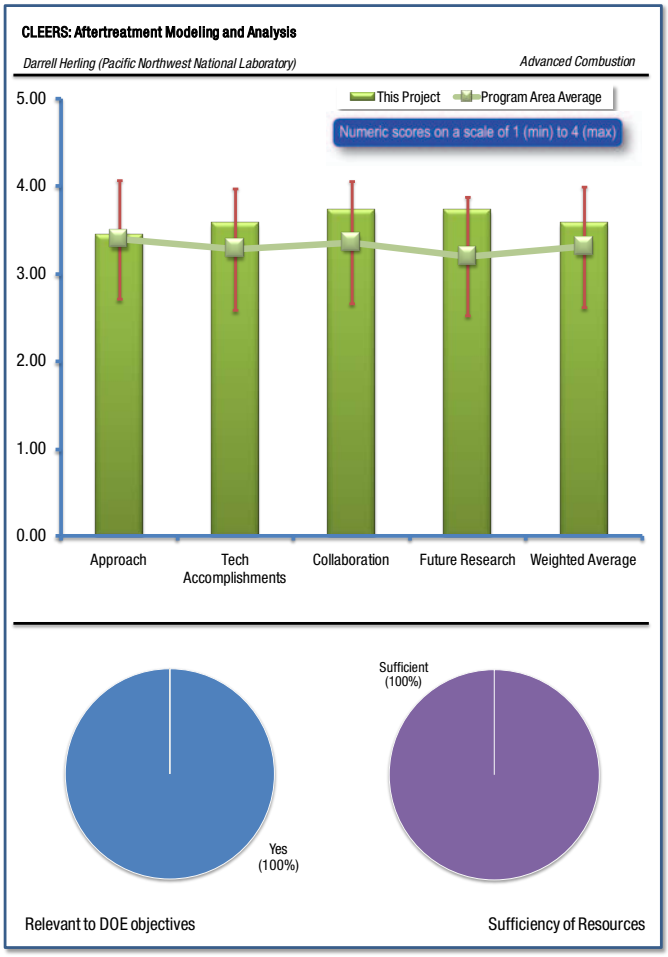
Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that the development of the fundamental science to enable high efficiency emissions control for high efficiency engines will further the DOE objective of displacing petroleum, since high efficiency vehicles must meet stringent emissions standards. Another commenter said that both SCR and LNT catalysis is very relevant to the implementation of lean engine technologies. The reviewer continued that the focus on the factors that limit the implementation of these emission technologies assists in the implementation of these technologies. What is especially interesting are the effects of hydrocarbons on the SCR performance. Another reviewer said that the relevance of the CLEERS-related program appears high, as it supports the goal of identifying efficient after treatment systems to support efficient engine systems. Yet another reviewer said that the project displayed useful leadership of team work on catalyst modeling.

One reviewer said that technology transfer is important, and that industry inputs are being taken into account. The same reviewer added that the work on ASCR and LNTs is fundamental to several high-efficiency engine types.



Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that some good fundamental studies are being performed. Another stated that the mix of modeling and experiment is especially strong, especially with the range of specialized experimental tools at PNNL. A reviewer stated that the "science to solutions" framework for achieving advanced cost effective emissions controls is a sound approach that is much more likely to yield successful product development in the end. The reviewer continued that this project builds from elementary measurements, e.g., morphology changes as reactants adsorb on the barium- alumina support interface, to yield guidance for enhanced material design.

A reviewer said that the project was showing reception to shifting work to areas of interest. Modeling foundations seem responsive to needs. Another reviewer commented that the kinetic analysis of the SCR catalyst is very appropriate. The same reviewer continued that most of the modeling work on these catalysts in industry is via global models and there was little discussion of discussion of the forms of the global reactions that will be needed to describe these kinetic effects.

One reviewer commented that it seems the H_2O impact on the SCR catalyst is not very important: the reviewer recommended to stop chasing after this one. Another reviewer noted that they were not interested in modeling FeSCR catalysts. Please quickly move on to available CuSCR catalysts. These are the ones industry cared enough to put in production.

Another reviewer said that there seems to be some fuzziness about the plans and efforts: is this an effort to support modeling, or work to learn about catalysts surfaces and reactions? Both are useful, but CLEERS is nominally about modeling and not surface science. Of course, the surface science is very interesting and worthwhile on its own.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer said that evaluating the possible poisoning effect of hydrocarbons on the SCR catalysts is important, since hydrocarbon poisoning will most likely occur when there is hydrocarbon slip from upstream devices. Another reviewer commented that the structural analysis of gamma alumina is very interesting and provides a good basis for future understanding of the LNT kinetic behavior. A separate reviewer commented that there were very interesting results on alumina surfaces etc.

A different reviewer was not convinced that the H_2O inhibition studies were necessary. The SCR mechanism shown in the presentation is a global mechanism. Consequently the water inhibition effect will most likely roll into the global ammonia kinetics.

Another reviewer commented that this was very interesting work on a range of HCs and showing the effects are different for NO-SCR vs. NO_2 SCR. It provided valuable insights into SCR and HC adsorption effects. The same reviewer said that the critical issue going forward is that 95%+ efficiency SCR systems are in demand, and a key foundation moving forward was adsorption. Learnings are interesting, but perhaps lack practical clarity. The reviewer added that research feeds the knowledge base and adds to the portfolio interesting "what-if" scenarios.

A separate reviewer said that the determination of the surface structure of gamma alumina is very useful to build models, adding there are five-fold species at surface and that there is a 1:1 match between Ba and 5-fold sites, about 16% of surface, more like 100 gamma alumina. (Isolated Ba atoms are seen). The reviewer also stated that they could see isolated Pt also.

A reviewer said that the project identified inhibitory interactions between species, identified detailed interactions between barium and alumina support, and identified dispersed individual Pt atoms on alumina (results in Science article).

One reviewer commented that a successfully LNT must be durable. The reviewer questioned whether a link could be drawn between the penta-coordinate alumina ion to activity/storage? The reviewer also wondered what happens to the penta-coordinate alumina ion and the catalytic phase with aging and sulfur poisoning.

A separate reviewer noted that there has been a shift to working on urea-SCR, and that there is a DPF, SCR, and LNT subgroup work, but focus has been on SCR and LNT this past year.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer commented that there was extensive collaboration with component suppliers and OEMs. Another reviewer commented that the collaborative aspects of the CLEERS-related programs are excellent between industry, national labs, and some universities, particularly for programs at ORNL and PNNL and one program at SNL-Livermore. The same reviewer wondered if there might also be groups in Illinois or New Mexico that may have skills that would support these programs as well.

A separate reviewer commented that there was excellent collaboration with industry, academia, and other labs. One reviewer noted an excellent flow of information and that there were inputs to direct work and workshops and website to transfer knowledge.

One reviewer said that it would be good if there was a more direct collaboration with an OEM. A separate reviewer said it was not clear if there is an OEM partner on these work.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer stated that future programs look excellent, adding that continuation of the studies of urea and its surrogates and their ability to form ammonia should be a priority. The reviewer continued that there has been an increase in interest in new developments with Ag HC-SCR by some in the catalyst industry which is not covered in this program. The reviewer suggested that this could offer an interesting new direction, since there may be mechanistic similarities to what happens in LNTs, especially surrounding NH_3 formation.

A reviewer was in favor of continuing work on surface interactions, aging, kinetic modeling and fundamental materials studies. A separate reviewer stated that this was an important to move into Cu-zeolites and that competitive adsorption of NO_2 and NH_3 (Yezerets 2010 SAE paper comparing Fe- and Cu-zeolites) is very interesting with significant practical application. The reviewer believed that this is in need of fundamental understanding. The team needs to supplement with Fe-zeolite comparisons. A reviewer said that the work continues to be good. The reviewer would like to see more detail about the SCR kinetic mechanism and especially would like to see inhibition terms for hydrocarbons. The reviewer added that they would also like to see the ammonia storage handled by an isotherm. Both of those advances would be very good for the modeling community.

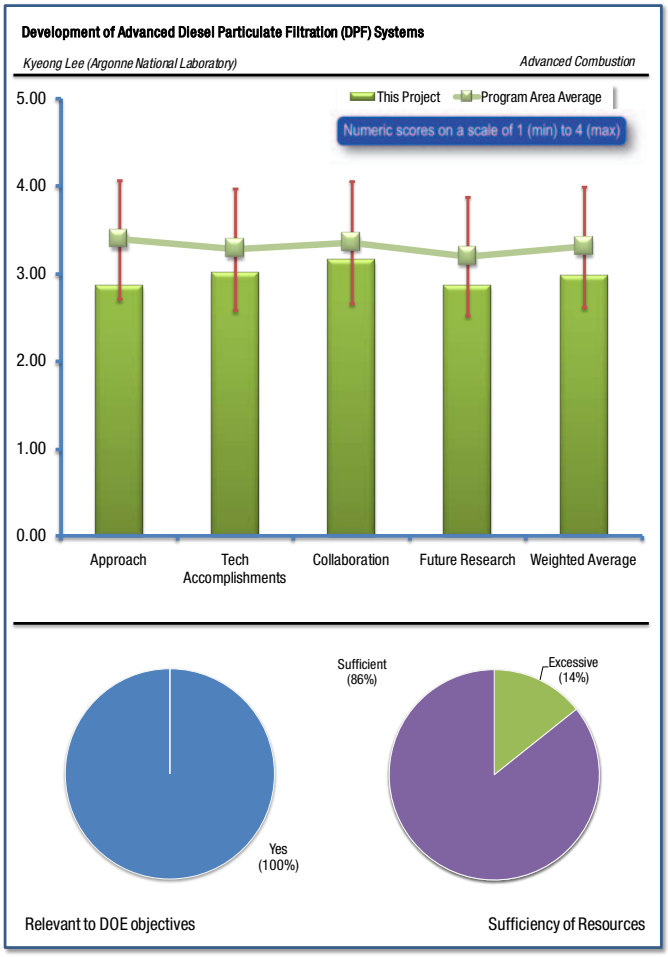
A reviewer commented that the future work points are very good except the one on further modeling on the Fe/zeolite catalyst. The reviewer recommends very quickly finishing this work and moving on to the commercially available CuSCR catalysts as a higher priority. Another reviewer stated that each of the proposed efforts sounded interesting, but felt some don't seem to fit the CLEERS modeling charter.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer stated that many of these results grow on previous accomplishments, so consequently as long as the rate of accomplishment continues then the funding is sufficient. The reviewer continues that it is not clear to them that there are many problems that are not being addressed due to lack of funding.

Another reviewer noted that the funding was appropriate to the work being done. The reviewer continued saying perhaps CLEERS funding could be trimmed and some of the funding shifted to another program to cover the non-modeling part of the work. The reviewer would not like to see that work cut since it is also very interesting.

Development of Advanced Diesel Particulate Filtration (DPF) Systems: Kyeong Lee (Argonne National Laboratory)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer commented that diesel particulate filters do support the effort to implement clean diesel engines. With the higher fuel economy, diesel engines do support the overall object of petroleum displacement. Similar comments came from a separate reviewer who said diesel particulate filtration and trap regeneration are essential to advanced technology high efficiency diesel and DI gasoline vehicles, which by providing higher fuel economy will displace petroleum. Another reviewer added that efficient use of DPFs will improve efficiency of diesel and lean gas emission control systems. One reviewer said that there is a continuing need for improved DPFs.

One reviewer stated that the project's relevance was marginal. The reviewer continued that DPF is fundamental to diesel engines and is migrating to gasoline adding that the shift is more towards passive operation with high NOx/C exhaust from efficient engine operating points and that PM soot membrane is becoming obsolete in favor of ash/catalyst/soot/gas interactions. The reviewer feels there has been a shift to instantaneous PM oxidation and dynamics. The reviewer continues that the results are still significant to LDD and optimization of them over next five years and that very few HD applications (Navistar is the only one) build soot membranes anymore.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that the development of fundamental understanding with base experiments and model fit was within the realm of DOE/NL work. The reviewer continued that the work on plug changes is creative, but is more applied research and seems out of scope with fundamental understanding and more in line with product development. The reviewer continued that base understanding now lays a foundation and may be important for improving initial filtration.

A reviewer thought the approach to addressing rate constant determination is outstanding, and the reviewer thinks the future work looks exciting. However, the same reviewer did not fully understand the approach to the modified DPF changes and how that testing would help the understanding of what is going on that leads to improvements at least at low loading times.

One reviewer commented that they fully support development of an improved fundamental understanding of the DPF performance, especially during oxidation of the trapped soot. The reviewer remained unclear about using graphite vs. diesel soot. The reviewer added that that they assume this is acceptable, but would prefer using actual diesel soot. The reviewer also noted that it was not clear if the reaction rates were done on a filter or just on the soot itself in a free state.

One reviewer commented that the project was performing TGA and DSC analyses on carbon and soot sample and determining reaction kinetics for soot oxidation and relative contributions to DPF back pressure from different fluid flow phenomena.

Another reviewer said that it was a nice procedure, but they did not see any information on generation of CO vs. CO_2. The reviewer added that they were unclear how this is handled since some potential heat from CO is not accounted for in the TGA measurements and wondered if the project planned to test with NO_2 as well.

Another reviewer commented that it sounds as though some parts of the program are successful but not available for review, continuing that based on what was shown, much of the work duplicates work others have previously published.

One reviewer said that this project has shown some relevant data on the oxidation kinetics for soot, but the reviewer felt that the unusual proposed DPF structure appears to have very little possibility of producing an improved DPF activity.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that the project contained impressive fundamental work on reaction dynamics and activation behavior, but needed to delineate fresh soot properties, as this will be the future soot in passive DPFs. A separate reviewer said that the project measured the transient heat release from diesel soot oxidation using DSC. The team is determining permeability behavior of DPF materials and modified DPF material configurations. The reviewer continued that the invention disclosure submitted for defining pressure drop and soot mass relationship in the DPF.

One reviewer said that it was very good to get activation energies for graphite and soot with preexponentials, and noted the presentation showed that most of the pressure drop is from flow through wall in wall-flow monoliths. The reviewer added, that even after our discussion, the reviewer still not sure they understood the assumptions in the Modified DPF model (unless there is a block at the front of the lower channel in the Modified DPF). The reviewer added that of course then, the flow would go through two walls, so the basis of the benefit was unclear.

A separate reviewer commented that the project has demonstrated an oxidation rate for soot that reproduces previous work from Cummins, however, the reviewer added that he author did not even comment on that comparison.

One reviewer said that a question was raised on oxidation rate constants staying the same or having two zones.

A reviewer said that activation energy needs to be compared to published literature and wondered what the H/C ratio was for the soot used, what the conditions of the collected soot were, was biodiesel used anywhere, and how much sulfur was in the fuel. The same reviewer said that 1/2 PP DPF has higher back pressure than conventional DPF up to about 4 hours. The reviewer continued that 60 miles per hour for 4 hours is about 240 miles and that this corresponds to most of the soot loading, especially for applications where there is high passive regeneration. The reviewer stated that 1/2 pp system would always have higher back pressure compared to the conv. DPF.

A reviewer said it was hard to judge since the team states there is a control algorithm but it can't be described. The reviewer added that what was described seemed to repeat previously published work. The same reviewer said that it would rate higher if the control system is really successful. The reviewer was not clear on the concept behind the central-plug filter and why it would behave as it does; this may be a limitation of the short time for presentations. The reviewer finished by commenting that the different DPF structure seems to have very little physical reason to be more effective and that this seems like a waste of time.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer noted that there were collaborations with component suppliers, materials developers and OEMs and academia. Another reviewer said that it is good there is an OEM and a substrate supplier involved while a third commented that there was good industry NL interaction and feedback.

A separate reviewer stated that the partners seemed very appropriate adding that it would be good to be clear about the involvement of Corning and Caterpillar in the project and the issues that they found to be most important.

One reviewer said that a number of collaborators were reported; however, there was no evidence in the presentation that the partners were active.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer stated that continuing the soot oxidation work appears to be worthwhile: however, it would be appreciated to discuss it with the CLEERS industrial community and make sure that the work is complementary and not simply repeats of work already in the literature.

Another reviewer said that it seemed there was a need to improve the rate constant determinations for soot oxidation, although the approach seems appropriate. The reviewer continued that it would seem best to use more fresh soot as an element in the testing, especially as the contract is ending in 2011. The reviewer added that this should be available off engines at Argonne. The reviewer also said that active regens are very unlikely as we go forward in time, as OEMs are running more in the high NOx, low PM regimes. The reviewer suggested that partially blocked DPF results need clarification. It would be good to include measurements and evaluations of alternative approaches relative to particle number improvements. The reviewer would look forward to the optical studies of oxidation and location of heat release.

A reviewer suggested the project continue soot oxidation studies with more practical exhaust gases, continue DPF membrane studies and analyze soot structure and morphology at various stages of oxidation. The reviewer continued that the soot study should include the engine operating condition as an experimental variable, since soot nanostructure and particle morphology should be influenced by load, EGR level and fuel type.

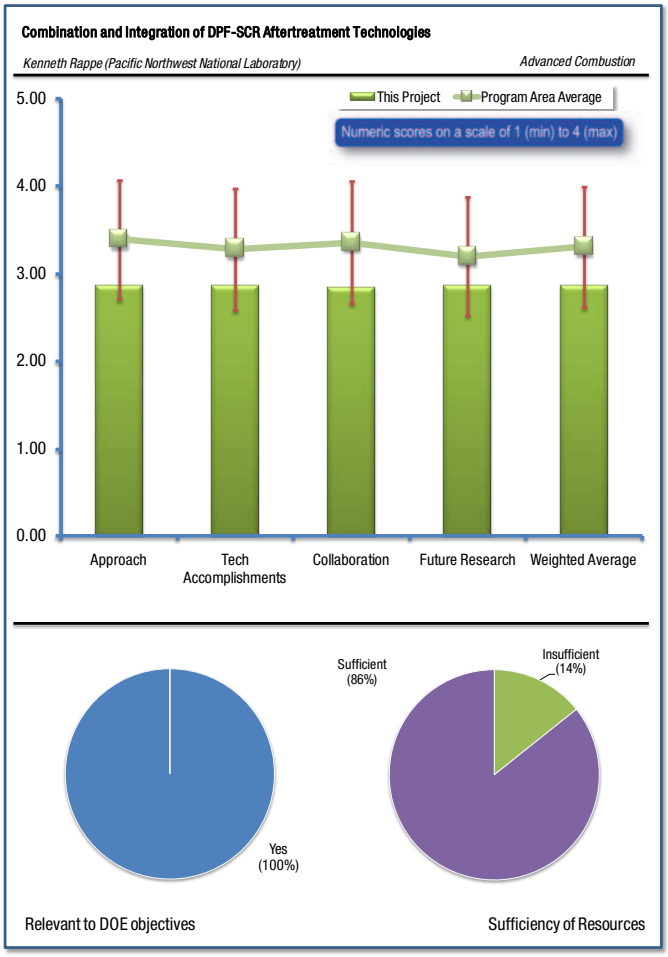
One reviewer saw a need to shift to passive DPF operation, noting that reaction kinetics with various gases is important, especially under "marginally passive" operation wherein NO_2+C reactions are limited. The reviewer asked if there is enough NO_2 and kinetics to burn the small amounts of soot under low load operation. The reviewer also suggested shifting away from active regeneration quantification because this has been studied significantly. The same reviewer state that much work is needed on the "new DPF" which hold individual soot particles for a short period of time and soot-catalyst-ash interactions become key.

A reviewer stated that it was somewhat hard to judge without understanding more about proposed modified membranes etc.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that resources were appropriate assuming there really were successful control results. Another reviewer felt that this seems like an enormous amount of money for the limited results at this point. One reviewer noted that optical studies of heat release were mentioned, and assumes the equipment is available. The reviewer also assumed that particle number studies can also be addressed.

Combination and Integration of DPF-SCR Aftertreatment Technologies: Kenneth Rappe (Pacific Northwest National Laboratory)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer stated that this work is directed toward enhanced packaging effectiveness for the after treatment devices. The reviewer added that the value of this is that high catalyst volumes can be employed, which improves the ability of heavy- duty trucks to more effectively meet stringent emission standards. A separate reviewer saw potential for significant cost and size reduction of a key emission component.

A reviewer said that the project advances more efficient aftertreatment systems that enable high efficiency engines and thereby displace petroleum use. A different reviewer said that using a more compact system, like SCR-DPF, to accomplish NOx and particulate removal is clearly a more efficient way to do emissions control.

Another reviewer said that high efficiency deNOx is the future and getting extra deNOx off a DPF is an important step. Also, LDD and non-road have space constrictions, so combo systems help. A separate reviewer said that the coating of an SCR on a DPF structure is certainly of interest, and directly relevant to potential needs moving forward.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that this was a good approach and study of the DPF+SCR integrated system. The reviewer added that certainly there is strong interest in the impact on passive regeneration of soot on the DPF, with the assumption that active regeneration might well be required to make the system sustainable.

Another reviewer said that the project was studying the interaction effects between DPF and SCR combined operation, such as effects of active site blockage, thermal nonuniformity and other issues; integrating SCR active materials into DPF wall flow support and addressing NOx conversion with accumulated soot.

One reviewer said that the tools available appear to be quite effective, although things are very basic so far using Jetta soot and smoke number analysis for soot exposures. The reviewer added that they hope more quantitative measures of the loading of soot mass and number will be used. The same reviewer noted that PACCAR has brought the University of Utrecht into the project, but it was not clear what they were evaluating from the one slide of capabilities.

A separate reviewer said that the approach would have been rated outstanding, but since the team planned to do the coating themselves the reviewer must rate it as fair. The reviewer continued that they have to absolutely involve a catalyst washcoat supplier in the project. The reviewer added that the project team has been optimizing their latest SCR technologies for each of the DPF substrate

types for years, and they know how to apply the SCR within the DPF wall and avoid the overlayer that is responsible for high back pressure. The reviewer believes that this work is out of the team's scope. The reviewer added that a catalyst supplier can then provide commercially interesting SCR formulations.

Separate reviewer stated that apparently the CRADA partner PACCAR does not want to include an experienced catalyst coater into the CRADA. The reviewer continued that this leaves PNNL in the position of having to learn how to coat various types of flow-through catalysts: this is not an effective use of National Laboratory expertise and resources. The same reviewer also asked if a smoke meter is an effective method of loading these samples. This is especially of concern since the back pressure of these monolithic cores is dependent on the coating density and the porosity of the monolith.

One reviewer expressed similar concerns, stating that there were key issues of substrate strength versus washcoat loading versus pressure drop are hard to evaluate in a realistic way without a real washcoater involved. The reviewer continued that the approach taken seems to be to make pieces; this may be best left to washcoaters and substrate suppliers. The reviewer added that few plans seem to be in place for theoretical understanding of pressure drop fundamentals; that is the sort of area where labs can make real contributions.

A separate reviewer said the approach seems reasonable. The reviewer continued that emphasis needs to be on increasing loading while reducing back pressure. The reviewer continued that this is being addressed, but what is missing is a quantification of washcoat loading in pores (x% goes into Y-size pores). The reviewer continued that once established, this can be used to evaluate materials, processes, performance, etc.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was a good preliminary foundation, included single sided, double sided, etc. Another reviewer said that the project had completed detailed substrate evaluations, was defining attributes for integrated system and defined cordierite as the primary substrate candidate and SiC as a secondary option.

A reviewer said that they would certainly like to see data on SCR conversion efficiency as well as soot loading rates compared to current production type DPFs. A separate reviewer said that the objectives for the project are well laid out and next year should show the fruit of many of the efforts on the best location for the NOx catalyst washcoat, e.g., if having it on more than the exit channels is effective or even helps in soot lightoff.

One reviewer said that it is disturbing that one of the accomplishments is to develop coating technology which is done routinely at various suppliers. The reviewer added that given the partnership constraint, they believe that this work was well done.

One reviewer said that the laboratory cores do not have a skin and that this will be very difficult to accurately determine back pressure due to possible leaks. The same reviewer questioned how the team knows that the SCR formulation is durable enough. The reviewer suggested the project team determine the hydrothermal stability of all SCR candidates ahead of time before picking one for coating and drop Fe/zeolite SCR formulations.

A reviewer said that the lack of suitable catalyst materials is a major problem, and that washcoating required significant art that may be lacking here. Another reviewer added that the collaboration with a coater would seem very important.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that working with the University of Utrecht should be very effective. The same reviewer expressed concern that the lack of a quality coater in the CRADA is a major disadvantage and that it was not at all clear what direct interaction was going on with PACCAR. Another reviewer said that there was direct collaboration with PACCAR as a potential user and technology transfer path, in combination with DAF and University of Utrecht.

One reviewer saw a direct need to develop a partnership with a coating company to perhaps tailor the washcoat of the NOx side of the wall flow surface with the most appropriate structure for current SCR catalysts to function. A separate reviewer said that the team needs a catalyst source, and that involvement of OEMs is valuable but perhaps of limited direct utility.

A separate reviewer said that expanding the collaboration to a coater of SCR catalysts and catalyzed DPFs or obtaining vendor-supplied samples will enhance the timeline and credibility of this important project. One reviewer believed that there was a need to bring in a substrate supplier and coater and that they will know what's known and where the gaps are. The reviewer added that the team can also get the latest materials designed for these applications.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that the proposed future research looks excellent. The reviewer added that hopefully the impact of beneficial or negative impact of a NOx catalyst in the inlet channel, walls, and exit channel could be explored.

A separate reviewer stated that it is clear that the PI would prefer to use the coatings from a supplier. It would be helpful to know what is preventing this from occurring. Another reviewer said that the project will configure combined function samples, age and examine performance with an internal formulation developed by PNNL.

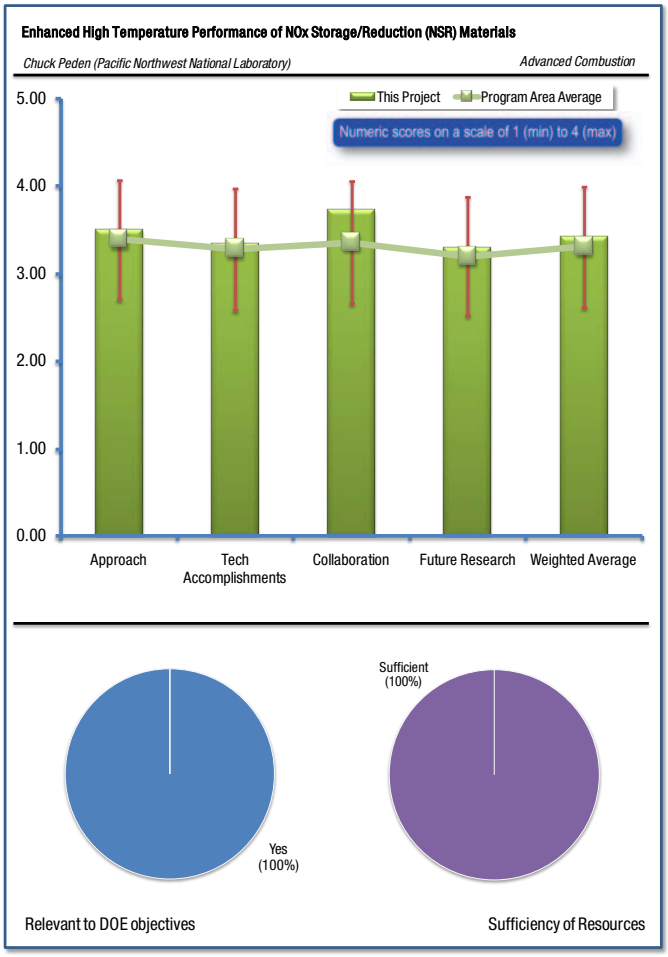
A reviewer suggested that the team include other interesting information such as the changes in mechanical strength and the pore size distribution changes of the filter wall. A separate reviewer suggested the team will want higher porosity substrates, and then mechanical strength becomes an issue. The reviewer also stated that the team will need representative catalyst sources and fears that without a catalyst source and substrate source they may have limited success.

One reviewer suggested the team drop active regeneration quantification and efforts, and move towards fundamental characterization of the coating and back pressure contributions. The review also said there were limited resources, so focus on critical understandings.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that most of the tools for a good study are there, but there is a need for more impact-based particulate measures for mass determination and other methods for number determination, if the project can move that far. A separate reviewer said that resources are far short if you have to make your own substrates and catalysts, and perhaps excessive if the team does not have sources for those items. One reviewer said that it would be very helpful to see the extent of the contribution that has been supplied by PACCAR. Another reviewer said that the team needed a major washcoater involved in project.

Enhanced High Temperature Performance of NOx Storage/Reduction (NSR) Materials: Chuck Peden (Pacific Northwest National Laboratory)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this was a very significant program to develop catalyst technology. A separate reviewer commented that extending the range of NSR catalysts can allow the highly lean engine technologies reach application and reduce fuel consumption. One reviewer said that LNT catalysts with good performance at high temperatures are important for emissions control in newer diesel and lean gas systems that may be closer to the engine.

One reviewer commented that NOx control may be one of the most critical functions to enable 55% BTE engines for high efficiency vehicles, so this work can be highly relevant to petroleum displacement. A separate reviewer said that HT means HL, which means high NOx flux and as such HT LNTs are important.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said it is helpful that this work has debunked a wide range of NSR materials that have been floating around in the literature. The reviewer continued that potassium has been known as the high temperature storage material for quite a number of years and expanding the study of it to other support materials is the logical way to circumvent some of the deficiencies of the alumina based potassium oxides. The reviewer continued that having a supplier-produced high temperature NSR provides a very good benchmark for the work. A reviewer said that a team of lab, industry, and supplier with a history of good research has laid out a program and is very likely to make excellent progress.

One reviewer saw the project as looking at cutting edge industrial materials for benchmarking in developing "model" materials from PNNL and looking at gaps in commercial material and use information to develop a model is a strong approach. The reviewer added that the use of advanced analytical tools is important and needed to offer new insights.

A reviewer said that the characterization tools are more than appropriate. Another commented that the barrier to improved NOx storage capability for LNTs might require better support or storage materials, SOx stability/instability or develop a whole new concept. The reviewer added that working to develop a fundamental understanding for NOx storage materials for high temperatures for lean burn engines, by examining roles of precious metals, storage mechanisms, regeneration mechanisms and other topics and that this is done by studying commercial model materials using PNNL's catalyst characterization facilities.

A reviewer warned to try not to focus too much on fresh catalysts, and that there is a real need to understand the deactivation of aged catalysts but, most importantly, improve the thermal durability, SOx suppression, and DeSOx efficiency.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer commented that this program is just starting but there has been good progress so far. Another reviewer said that the project was starting to get some good results, and is looking at some areas of interest. The reviewer continued that it is very good to see results already for a project this is still relatively new; well done.

Another reviewer said that there was a good base of understanding on current formulation. The reviewer continued that this was very interesting progress on changing support material and added that this was an excellent direction.

A reviewer said that the novel area was looked at first, asking if NOx decomposition occurs at higher temperatures with new materials. The reviewer continued that the project has shown that this is not the way to go: even for BaO/MgO cat, there is less than 2% conversion at reasonable conditions. The same reviewer added that the high temperature JM material shifts peak conversion without S to 400 to 450^{o}C vs. 100^{o}C lower in previous material. The reviewer also said that this was a very interesting result to understand. The reviewer also wondered what the lower temperature desulfation at 500^{o}C means. The reviewer noted that here the NOx adsorbed peaked for desulfation at 600^{o}C and then fell with temperature. The reviewer felt that it would be good to see the amount of sulfur still on the catalyst in these studies along with precious metal and Ba particle sizes.

A reviewer stated that the technical accomplishments seem to just reinforce what we already know in the literature. The reviewer added that K is known to improve high temperature storage but the key open issues have been stabilization and deSOxing at lower temperatures. The reviewer said that the interaction and characterization of K on the various supports is interesting and hopefully that will provide insight on how to stabilize it.

A separate reviewer commented that most of this work has been background work so far. Mostly the work is duplicating and validating what is already in the literature. A reviewer said that the project has surveyed recent reports of recent materials developments, but that these materials have too little activity. The reviewer continued that new materials are needed. The same reviewer also said that the project studied commercial catalysts for high temperature NSR and found some J-M work well in 400-450^{o}C, but sulfur exposure and desulfation at elevated temperature degrades the material dramatically, and improved performance is seen for model Pt-BaO on $MgAl_2O_4$.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the collaborations with Cummins, JM and BNL are well designed and should give this project the best possibility of success. A separate reviewer stated this collaboration with Cummins appears to be very strong, while a third commented that there is obviously a close and valuable working relation between the lab and industrial people and that the trust indicated by availability of state of the art commercial catalysts is a sign of the close collaboration and earned trust.

One reviewer said that having Cummins and JMI as partners will really enforce what is really important for high temperature NSR applications and determining realistic formulations that can be manufactured. Another said this was a perfect collaboration with OEM and catalyzer. The reviewer continued that this looks like a close collaboration with catalyzer. They know much.

A separate reviewer noted the project has had regular contact with Cummins, Johnson-Matthey and Brookhaven Nat Lab through a CRADA arrangement. The reviewer continued that there was no involvement of universities, which is a weakness of the project since this involves in part such fundamental, precommercial concept development.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer stated that working with both new materials and the best materials from a supplier plus the high powered instrumentation at the national labs is the best approach for this project. Another reviewer said that the plans are excellent and they have already commented on how nice it would be to have more details from the desulfation studies. The reviewer continued that looking at role of

K & Mg-aluminate in HT performance are important issues. The same reviewer continued that this is an opportunity also to see if there are ways to understand what the materials PNNL is making have to offer.

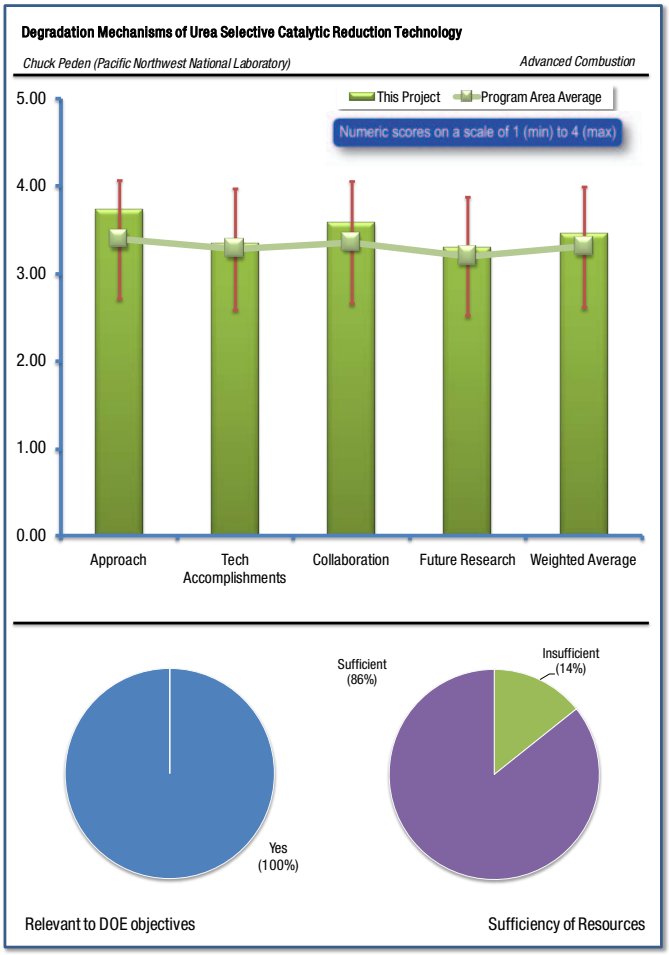
One reviewer said that the program direction seems solid and the program seems to be heading in a direction that should provide further interesting data moving forward. Another reviewer said that continuing studies of new NSR materials and characterization of NSR materials from J-M. A reviewer said that K migration must be solved for this type of NSR to work and suggested a focus on thermal stability and that the project should consider using Oxygen Storage Components in the formulation development and that they hoped the formulation information can be made available. Another reviewer added that there were excellent plans.

Another reviewer noted that a continuation of baseline understanding is proposed here. The reviewer felt that this was more of the same, and that while this might be called for, fundamentals on support/adsorbant seems warranted as well to set future direction. The same reviewer added that POx material to generate hydrogen will separate HT NOx capacity and HT sulfur adsorption.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer saw no evidence that this project has no studies that are not being done because of a lack of funds. A separate reviewer noted an appropriate level of effort for this valuable effort.

Degradation Mechanisms of Urea Selective Catalytic Reduction Technology: Chuck Peden (Pacific Northwest National Laboratory)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that understanding of the degradation of DOCs and SCR catalysts is important for efficient diesel emissions control. A separate reviewer said that this was useful support for emission system development. Another reviewer said that examining the ageing of an SCR catalyst is of direct relevance and could have significant impact on the current state of the art in SCR design and development.

One reviewer commented that it seems that urea SCR will be a major part of future emission control systems and that understanding the degradation mechanisms is important to satisfying the long term durability requirements of the aftertreatment system.

A reviewer said that high-efficiency deNOx is the future: the reviewer continued that aging dynamics and test protocols are critical to this. The reviewer concluded that the project is right-on target to high efficient diesel engines.

Another reviewer said that SCR NOx control is an essential component of 2010 emissions compliant diesel vehicles and is potentially a critical component of 55% BTE engine systems. So, mitigating aging of the SCR catalyst supports deployment of high BTE vehicles which will displace petroleum.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that in their view this is exactly the correct use of National Laboratory facilities where the unique instrumental techniques of the laboratory are used to investigate production-like materials. The reviewer added that in this case, GM acquires and ages the catalyst samples in the manner that they evaluate all their samples and PNNL uses instrumental techniques to determine the degradation mechanisms.

A reviewer said that the approach to work seems appropriate. Another reviewer saw this as a useful application of PNNL's analytical capabilities to up to date commercial catalyst with product relevance. One reviewer commented on the simple logical approach taken, noting the procedure of “age, test and analyze.” The reviewer concluded that there were mutual benefits of OEM collaboration with NL analysis and that good teamwork is critical here.

A reviewer noted that the project was using model and commercial, fresh and aged SCR samples for analysis using PNNL's characterization tools to define the deactivation mechanisms, and to relate the performance to specific physicochemical changes in the materials.

A separate reviewer commented that on the DOC aging, stating that PGM sintering is interesting, but not really helpful. The reviewer continued that examining the SCR aging for root cause is also interesting, but it would really help if there was a component about

what can be done about this. The reviewer ended that without quantifying how to improve the catalyst, this is just a materials project to show what changed; not why or what can be done about it.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said that this work seems to be well on its way to showing a direct relationship between PGM crystallite size and aging conditions. The reviewer added that this has long been predicted anecdotally, but this may put a clear functionality to it. The same reviewer continued that for the SCR aging there is evidence of a loss of zeolite cage structure with aging and that again, this has been long postulated and inferred from other work. Hopefully, this will give a direct functional relationship for this aging behavior.

One reviewer commented that considering the size of the project, a considerable number of results have been found, adding for DOCs, PNNL finds that the performance degrades because of sintering of DOC particles and their alloy formation. The same reviewer also stated that for SCR the work looks interesting with non-linear performance drop off in slide 13 and linear change in zeolite structure parameter in slide 14. The reviewer continued that the aging conditions are spelled out, so it is impossible to correlate the results. The reviewer does not believe this was asked during the presentation.

A reviewer noted that for DOC's, severe sintering of PGM is seen up to 100 nm crystallites, with a rapid size increase followed by a more gradual but continual increase and Pt-Pd alloying. The reviewer continued that for SCR catalysts, dramatic loss of function was shown over 40 hours of operation under aging tests. The reviewer continued that XRD shows some structural changes in the zeolite and there is sintering of the active phase particles.

One reviewer said that is seems very interesting; although with enough being confidential, it is hard to judge fully. Another reviewer said that DOC aging is quantified nicely. The same reviewer continued that NO_2 formation is tied to HC light-off quite strongly (need to eliminate CO/HC before NO_2 can form). The reviewer added that quantification should be done together with NO/HC/CO gas mixtures. The reviewer was not sure Pt/Pd alloying is causing the aging. Some formulations are alloyed purposefully. The reviewer concludes that grain growth is the culprit and needs to be quantified.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

One reviewer commented that there was an active collaboration with GM with regard to materials preparation, characterization and performance analysis. A reviewer said that it is clear that GM is a direct and active participant and produces the optimal samples for investigation. The reviewer added that it would be helpful if this work were regularly reported on the CLEERS conference calls. Another reviewer said that this is a close collaboration with key companies, and that the willingness of industry to supply current state of the art catalysts reflects a high level of trust in the lab personnel. A reviewer said that they will assume the collaboration with GM is excellent, because of the quality of the people, although there is little evidence at this point of work done with GM.

Two reviewers were of a similar mind, one stating that it would help to have a catalyst company tied into this. However, the collaboration is good to see and synergistic. A separate reviewer suggested that the team needs to get the catalyst supplier involved so you can start to look at why the ageing occurred and what can be done about it.

One reviewer said that correlation of laboratory vs. vehicle aged catalysts is very important and that they believe the right approach is being taken.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

One reviewer said that the team appears to be headed in a direction to develop those much needed aging relationships for each device. Another reviewer commented upon the complete characterization of lab aged samples, the opportunity to potentially modify aging protocol and define best tools for characterization.

A reviewer noted that the conclusion of Pt/Pd alloying appears to indicate sintering of the two metals. The reviewer wondered if in the fresh DOC, the Pt and Pd were completely independent of each other or were they already alloyed but very dispersed. The reviewer continued that the low temperature SCR deactivation involved the destruction of the zeolite and wondered if the acidity or NH_3 storage capacity could be checked. Was there a linear decrease? In addition, the high temperature deactiviation was non-linear. A good understanding of the active component would be very interesting.

One reviewer said that there was a good plan in place, suggesting that an emphasis needs to be on characterizing and confirming aging mechanisms because this will set future direction on improvements. The reviewer urged the team to make sure they have this confirmation. (Is it really Pt/Pd alloying that is causing the problem?)

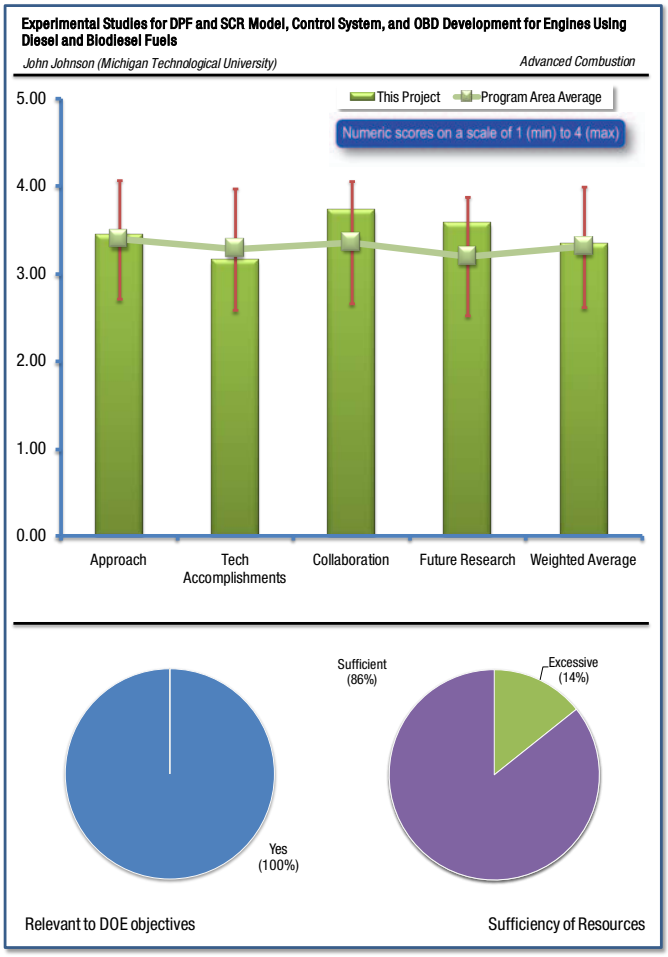
A reviewer suggested that for DOCs, it would be good to evaluate the ability of DOC to supply heat as well as NO_2 to the SCR and that it would also be good to independently, to the extent possible, vary the agglomeration of particles and their alloying. The reviewer asked if there is an explanation for why an alloyed particle is less effective. The reviewer assumed the aging conditions in the SCR will be done at temperatures and humidities that will bring out those effects explicitly.

One reviewer said to keep up the good work. A reviewer said that it would help to have the proposed work examine why the changes that were seen in the catalyst occurred and what can be done to make it more robust. Expand the scope and funding if need be.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the funding limits this to a small effort; it might be useful to expand the effort. A separate reviewer recommended an increased scope of work to include what can be done to make catalysts more robust, and this change is scope would certainly require increased funding. A separate reviewer saw no evidence that any part of this study is not being accomplished with this level of funding.

Experimental Studies for DPF and SCR Model, Control System, and OBD Development for Engines Using Diesel and Biodiesel Fuels: John Johnson (Michigan Technological University)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this is an effort to develop a system integration approach which uses experimental information and system state software. The reviewer added that ultimately this type of approach will be used for control strategy development for these complex aftertreatment systems. Another reviewer said that the project addresses a significant gap in technology – OBD, adding that these are expensive and can take away from efficiency. The reviewer noted that better models and fundamental understanding is critical.

A reviewer said that improving exhaust system controls and OBD for biofuels will enable higher efficiency diesel vehicles that meet emissions standards and tolerate biofuels, all of which will displace petroleum. A separate reviewer commented that this project covers a range of topics that are relevant to efficient emissions control. OBD is an important topic that impacts on DOE objectives in terms of meeting them over the life of the vehicle. One reviewer said the project supports emission system needs. A reviewer said that it is also important to support this lab to maintain a core competency of the industry–modeling of cutting edge DPF and emissions systems.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that developing an integrated software approach to predicting the state of the aftertreatment devices is absolutely crucial to full system modeling of these aftertreatment systems. Another reviewer said that this seems to be the start of a very good project.

A separate reviewer stated that it was a large collaboration and that key issues are being addressed. The reviewer continued that there was a good advisory committee and resultant approach. The reviewer also said that the approach of fundamental spatial measurements feeding into models was a good approach.

A reviewer said that the hypothesis is that if OEMs can access information on the "state" of aftertreatment devices (e.g., species storage), then system performance can be improved and understood to enable more frequent passive regeneration events which will save fuel.

A reviewer said that the focus is on DPF and SCR, but with the system view the DOC is very important to work on as much. Another reviewer commented that the ammonia will be measured in collaboration with Oak Ridge, but how is not clarified. The reviewer wonder if that will be done at Michigan Tech and would Watlow also be capturing temperature and species.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that it was a good start, but still early in the program. Another reviewer said that data is just coming in making it too early to comment. The reviewer added that the set-up seems ready for productivity. A reviewer commented that the preparation work seems to be completed, but there are no major accomplishments at this point.

One reviewer said that there are enhanced existing test cell facilities, and that protocols have been developed. The reviewer added that they have started engine testing for baselining of system performance.

One reviewer said that it is very early in this project and it has many ambitious deliverables and that several of the needed tools have been set up, but that it is too early to really evaluate the accomplishments.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer says that a good team has been brought together for a successful project. Another reviewer said that the interaction with ORNL is especially needed to make this project successful and that PNNL is very experienced in DPF loading and evaluation. The reviewer concluded that this is a highly integrated program and hopefully will be effectively coordinated.

A reviewer commented that there was a large team of collaborators with extensive experience and they were using a data inventory system to enable collaboration. One reviewer said that there was exceptional communication in place and the right players on board–multiple OEMs and approaches.

One reviewer said that this project has many important collaborators and that it will be important for them all to participate fully. Another said that it seems this project has many very important collaborators. It seems like a good team of industry, academia, labs, but the actual level of collaboration remains to be demonstrated

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

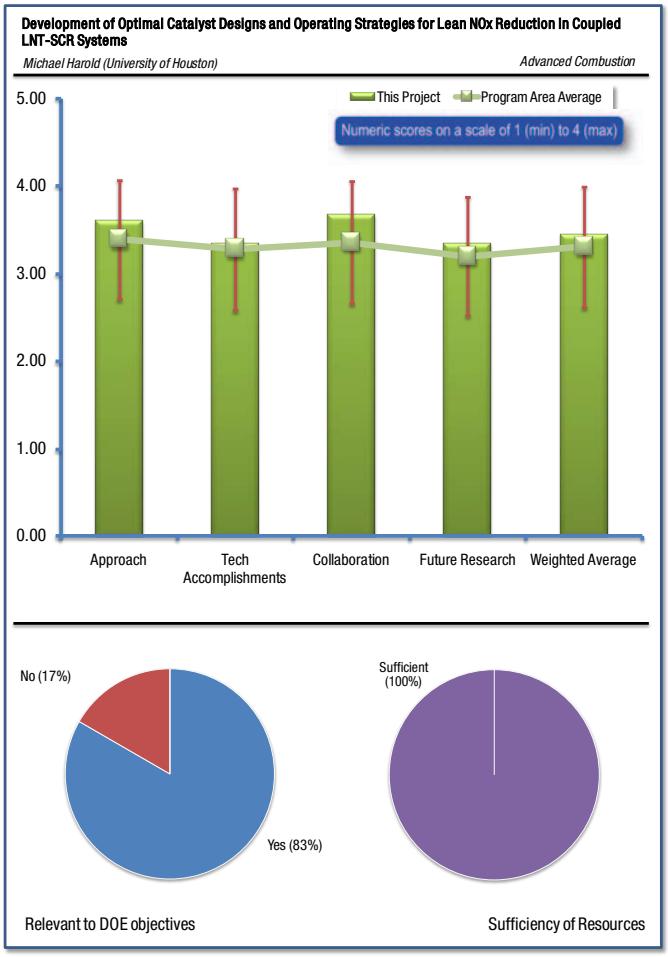
One reviewer said that it looks like a very good plan. One reviewer said that this seems to be a well focused future plan and they hope that delivery follows the plan. Another said that there was a good plan in place and that it was moving in a very impressive direction. The reviewer added that the work emphasizes passive DPF and characterization. The reviewer asked if soot will burn fast enough at low temperature and if there are mal-distribution issues.

Another reviewer said that the plans for research are very good, adding that it might be good to reconsider the importance of active regeneration of DPFs as a major topic, since more OEMs are using passive regeneration. A separate reviewer said that the team should complete model development, deploy soot morphology determination instrument, and complete ammonia storage study.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said there was an appropriate level of funding. A separate reviewer said that the budget seems very large for the potential benefits that are likely from this program.

Development of Optimal Catalyst Designs and Operating Strategies for Lean NOx Reduction in Coupled LNT-SCR Systems: Michael Harold (University of Houston)



Reviewer Sample Size

This project had a total of 6 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that development of advanced lean NOx control is enabling of high efficiency vehicle systems and thereby can directly lead to petroleum displacement. A separate reviewer commented that this is designed to enable the implementation of non-urea SCR for either gasoline or diesel engines and that both of these engines are lean with higher fuel economy and consequently assist in the objective of petroleum displacement.

A reviewer said that LNT-SCR systems are ones we need to understand as non-urea systems that can still show excellent emissions control. A separate reviewer commented that LNT+SCR systems are a very interesting and promising approach to high-efficiency deNOx low cost systems for smaller HD and LD applications. Another reviewer said that SCR/LNT systems are clearly relevant as we move forward with diesel catalysts and there are certainly a lot of open questions on this subject.

One reviewer said that this project does not support petroleum displacement and that it is aligned with the ACE 2009 goals posted on the DOE website. The reviewer concluded that at best, there is only a very remote connection between the output of this effort and petroleum displacement.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the tools being brought are excellent and the involvement between the partners appears to be well thought out. One reviewer stated that this project has gained access to a very new supplier technology and that the connection to Ford who is planning to implement an LNT/SCR lean gasoline technology is the best way to transfer the technology.

Another reviewer saw this as a fundamental/academic study of chemistry of LNT-SCR. The reviewer added that toward this purpose, some progress has been made but it is hard to assess the impact of the program or recent results as no strategy or risk mitigation plan was presented. Is the goal of this work just observations and hypotheses to drive suggestions for catalyst design? The reviewer continued that the approach stated (use noble metals in the SCR instead of LNT and generate NH_3 in LNT) is good, the presentation does not focus on this...program and presentation needs focus toward goals that are measurable and time driven.

One reviewer said that the team is examining LNT/SCR reactor and catalyst coupling, looking to learn what specific species are emitted by the LNT that assist the SCR to function and that the objective is to reduce or eliminate the need for urea.

A reviewer said that the project was heavy on fundamental kinetic measurements and modeling, with some vehicle testing. The reviewer also said to work closely with CLEERS to avoid duplication of work already done and that it is important to focus on fundamental chemistries, as this will drive innovation in the private sector.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that for a project that does not start until this October and is already 10% complete, this project is doing very well. The reviewer continued that the project is ambitious, but all of the pieces have the potential to get excellent results. The reviewer also said that the LNT-SCR system shows considerable promise and is important to understand. The reviewer also commented that the Ford results suggesting organo-nitrates are formed along with ammonia are very interesting and that ethylene ammine may exist at mass 42 in this work. The reviewer ended by saying that the data and understanding will come from ORNL and UK. The modeling at UH will provide much of the ultimate benefit.

A separate reviewer commented that was a very impressive array of data and implications on directions. The reviewer was really looking forward to more data coming in and also said that this is quite a complex system and the team has the tools and demonstrated analytical capability.

One reviewer said that project was producing kinetics of ammonia based SCR and storage and regeneration of LNT and produced and surveying evidence of ammonia release from the LNT that reacts in the SCR to reduce NOx. The reviewer suggested that to verify the HCNO formation mechanism, the team should consider using an isotopically labeled HC reductant.

Another reviewer suggested that there are a large number of observations that are very provocative. The same reviewer expressed concerns that there does not seem to be closure on a number of the observations. The reviewer gave the example of the propylene NOx reduction observation being quite interesting; however, there was no closure on this observation. The reviewer suggested that perhaps there would be more clear accomplishments if there were more focus to the work.

One reviewer said that it seems that even after a year of work, this is still at an observation stage, adding there was some speculation, some early pathway proposed, but it seems like it could behind schedule. The reviewers aid that it was hard to tell without visible time driven goals in the presentation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this incorporates an OEM, catalyst supplier, national laboratories and academic institutions and that this work has been reported at the CLEERS workshop and the conference calls. The reviewer concluded that clearly this work is regularly held up to scrutiny by a number of high expertise parties.

One reviewer said that there was an excellent choice of collaborators, making a very strong project. A separate reviewer commented that all key players are in place with good communications and project planning. The reviewer added that technology transfer is in place as well as checks and balances.

A separate reviewer said that there was a good cross section of participants which seems to cover all the main technical areas in question here and that thought was clearly given to get participants with varying areas of expertise.

A reviewer said that the project had multi-university, national lab, supplier and OEM involvement and that there was an exchange of materials, sharing of testing expertise and capabilities, and exchange of information to support modeling efforts. One reviewer stated that from the results presented, the synergistic impact of the collaboration is not obvious–appears partners are acting a bit independent.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that the plans are well thought out and continue in the direction laid out already. Another reviewer said that the plan is right on target for accomplishing meaningful results. The reviewer suggested that the team should be careful on spending too much time on interesting but low impact kinetic studies, for example on the complexities of the non-NH_3 route unless warranted.

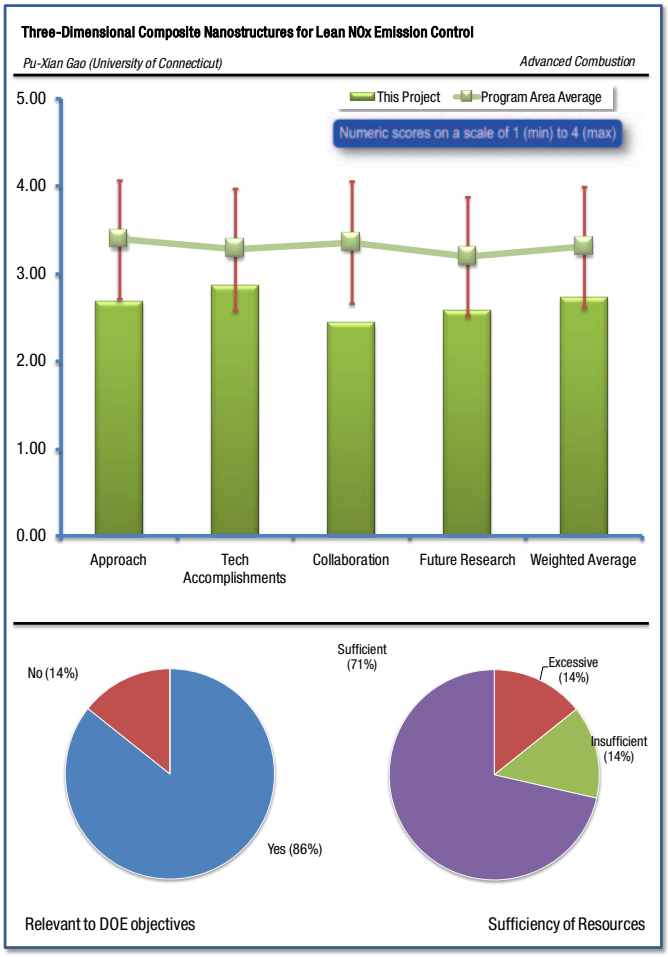
Another reviewer commented that there were continuing spatiotemporal studies of species to support model development, and suggested in-situ DRIFTS studies to better understand mechanisms.

A reviewer was concerned that the project has gotten too unfocused due to the large number of collaborators and felt that the presentation did give the feeling of a number of experiments that were not tightly coordinated. A separate reviewer commented that there were lots of parallel paths–too broad and fundamental in scope. The reviewer added that future research does not show a path of down selection which drives the effort to a goal or deliverable.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer commented that there were lots of resources and wondered if they are creating synergies. Another reviewer said that there are quite a number of partners in this project and that funding of this level is necessary to accomplish the goals. The reviewer added that they did not see evidence that this project is not accomplishing its goals.

Three-Dimensional Composite Nanostructures for Lean NOx Emission Control: Pu-Xian Gao (University of Connecticut)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that new materials for lean NOx control could make NOx control easier and more cost effective for high efficiency lean burn engines. Another reviewer commented that exploration of novel catalyst materials is important to make sure we have the best nanostructured catalysts.

One reviewer said that there was a very appropriate expenditure of some funds on new classes of catalysts for deNOx and that this is an interesting approach for a class of materials that have interesting deNOx potential. A separate reviewer said that a goal of reducing the precious metals in the emission control systems assists the DOE objective of petroleum displacement by reducing the costs of the emission control systems.

One reviewer stated that this project is very removed from having direct impact on petroleum displacement and that this is a fundamental research program on catalysts and emission reductions. A separate reviewer stated that the relevance of this seems strange, especially since there is not a substrate or catalyst supplier involved. The reviewer understands the importance of this type of work and will call it relevant, but without engine catalyst/substrate supplier involvement, this really is “borderline.” The reviewer also said they supported the development of new materials, as there are certainly deficiencies with today's systems.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the approach described in the presentation is ambitious, but chooses correct things to study. The reviewer added that for this new project, if they can be achieved, it will be very successful. The reviewer continued that one major goal is ultrahigh surface area for the catalyst and that it was not clear what method(s) would be used to show that. The reviewer continued that the 3D structures shown are like overlapping dendritic arrays, which still have large open spaces relative to the surface area available.

One reviewer said that this was an interesting plan and that they support the development of new materials and uncovering what could be a potentially new direction for catalysts.

A reviewer said that the project was looking for non-precious metal emission control catalysts and synthesis of nanostructured metal oxide arrays. The reviewer added that there was characterization and performance analysis as well as atomistic simulation of catalytic reactions.

One reviewer said that the approach is all about synthesis, but gave very little information about how it would affect engine emission reduction. The reviewer continued that the project has spent a lot of time in developing and characterizing the various material

compositions. The reviewer was hoping for some performance data by now and didn't see any evidence the team will meet the overall objective of lower or no PGM usage and an enhancement in the activity and durability of lean NOx catalysts.

Another reviewer said the approach dives right into synthesis without a pre-screening step on determining what to make. deNOx functionality seems to be missing or coming in a later stage.

A reviewer said that the concepts for catalyst design do not evidence a path to displace use of noble metals or a mechanism as to why the design was considered and that there were too many materials growth approaches. The reviewer added that it seems like the background research was weak and that the work would benefit from experimental design approach.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was very impressive synthesis range and ability and that one can see how these structures might have strong catalytic activity. The reviewer suggested that perhaps a surface area measurement is needed, as this is what drives catalyst activity, particularly at low temperatures.

One reviewer said that they had begun the synthesis activities. The reviewer added that the team had made 3D nanostructures of various oxide materials, such as shell layers and nanowire arrays, and coated these nanostructures with surface layers of LSMO. The reviewer added that some catalyst surface modeling had been completed.

A reviewer noted good progress on creation of structures, but that the project does lack some direction of what they are going to do with this and which catalyst is truly required and how it would fully interact with these structures. The reviewer added that the substrate and the catalyst need to be very well integrated to operate at high efficiency and this requires program direction.

A reviewer said that there was a fantastic job of characterizing the materials but no catalyst performance accomplishments are shown yet.

One reviewer said that it is very early in the life of this project and they have shown several materials that may be interesting and there also is modeling on some of those surfaces. The reviewer suggested the project needs to focus on demonstration of all the criteria listed on slide 5 - Approach. It was also said that it was not clear how enhanced surface areas would be demonstrated.

A reviewer stated that this group is very good at design and synthesis of perovskites, but there is no indication of engine exhaust emission reduction.

One reviewer said that no cause-effect learning reported, no alignment to a materials specification or properties goal that would give desired catalytic performance, and there were many random, unrelated results reported, not obvious to catalysis. The reviewer felt that the project organization is poor and that the vision is not supported.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this is an interesting fundamental synthesis study but practical direction will be critical to get good return on investment. The reviewer added that UT provides practical synthesis and Honda on practical application, noting that the UConn lab has very interesting analytical and modeling capability but may be lacking in application to catalytic application to automotive. The reviewer suggested the team leverage Honda strongly on making sure the right experiments are performed to link back to the application.

A separate reviewer stated that there was collaboration with Honda Research Institute (catalyst testing) and United Technologies (materials characterization).One reviewer stated that Materials Development was inspired by Honda support with further support from UTI, but the actual capabilities of partners to fit with responsibilities are not spelled out in detail.

Another reviewer said that obviously Honda has shown interest in this project, but they have not shown any obvious interaction on this project. The reviewer added that it almost feels as if this is a fishing expedition and indicated they would like to see more indication

that Honda is directly involved in showing why this is a good set of materials to investigate. One reviewer was not clear on what Honda has contributed yet and a separate reviewer saw no evidence that Honda or United Technologies is doing anything and where their activities kick in. The reviewer added that this program would benefit from a group experienced in materials characterization for catalysts.

A reviewer commented that there was no involvement of major catalyst suppliers. Another reviewer said that the major partner is Honda, and wondered why DOE is funding a project where there is only a 20% cost share with a Japanese supplier. The reviewer felt that this project collaboration absolutely needs to be broadened to include U.S. based companies, and this absolutely should include a catalyst and substrate supplier. The reviewer added that this poor collaboration is a gray cloud over what could be a very interesting project.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that they like the modeling aspect of the project. The reviewer felt that an answer, by the team, to one of his questions was clearly "hand waving." The reviewer would like to see more application input for this project.

One reviewer commented that the plan is good and very necessary right away, adding there was a need to know how the material behaves as a catalyst, what the durability is, and what the cost looks like. The reviewer asked if there any benchmarks that could be used to compare the activity and durability of the material and show how it is better.

A separate reviewer commented that it is key to get performance results ASAP to help guide synthesis and material choices. The reviewer continued that NOx testing on planar surfaces would be a good start and needs to be implemented for feedback, asking if this process can yield improvements over current materials. The reviewer concluded that this is key and direct feedback from performance is critical.

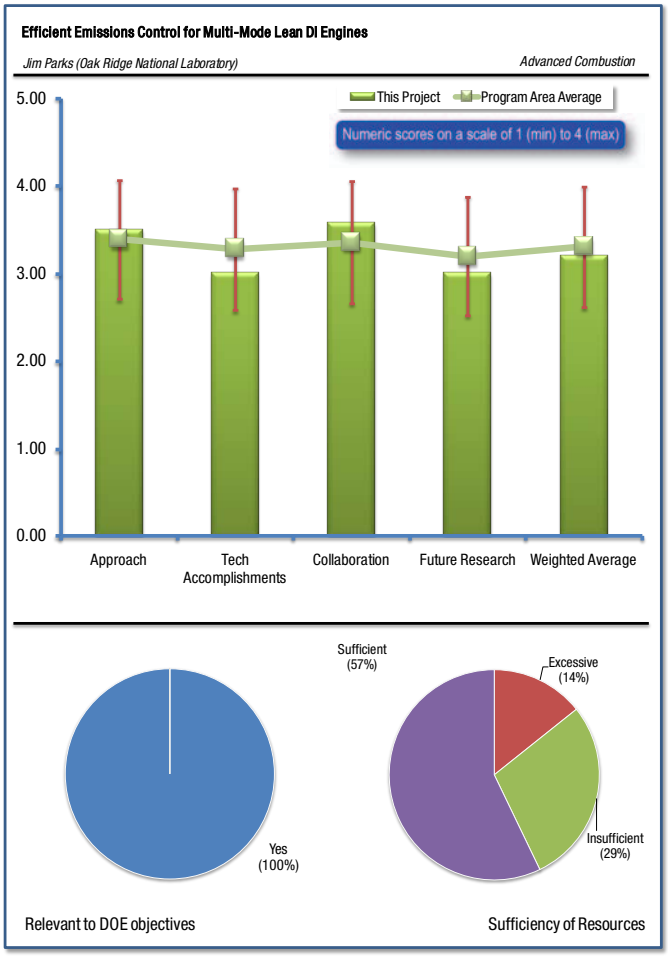
One reviewer noted testing of catalyst performance and behavior, continuing simulation efforts. The reviewer saw no mention of poisoning resistance studies of these candidate materials.

A reviewer felt there was too much effort on materials growth, materials testing–no timeline or criteria for downselection shown.

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

A reviewer said that so far the team is not getting much at all for exhaust emission reduction.

Efficient Emissions Control for Multi-Mode Lean DI Engines: Jim Parks (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that lean burning engines provide efficiency improvements over stoichiometric engines that comprise the majority of the passenger vehicle fleet, so development of efficient emissions control strategies for lean burning engines will help to displace petroleum. Another reviewer said that lean-burn technologies have practical limitations in the U.S. that are being addressed here.

Another reviewer said the soot sensor and the dual fuel engine are both projects with high relevance to our plans moving forward. One reviewer commented that developing a good DPF loading sensor and the relation to low temperature combustion enables the low temperature combustion technology, which is designed to reduce over diesel emissions.

One reviewer said that the range of deliverables is all related to more efficient engine operation or more efficient emission control. A reviewer said that it is closer to the goal than other projects, highlighting tradeoffs of emissions and efficiency in DI engines.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that examination of multi mode engine operation to achieve low engine-out emissions and coupling (or lack of it) to aftertreatment systems is a very important system view in the project. Another commented that this approach is well focused on determining and regenerating loaded DPFs from HECC combustion systems.

One reviewer commented that characterizing emissions from advanced combustion operation and looking for synergies with aftertreatment strategies. The reviewer added that the approach leverages the skills and experience at ORNL.

One reviewer said that the exploration of dual fuel systems is an extension of the above work to verify the work at the University of Wisconsin and that RF sensing of particulate matter is a separate and interesting project. A reviewer said that it appears to focus on survey of methods and performance. The team needs to show a path to convert learning to improve engine performance.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer said that developing and implementing the RF soot loading sensor technology is a solid accomplishment. A reviewer noted that the results for all to the aspects of the project were very satisfactory, but that the prospects for commercialization of RF particulate sensor were not discussed.

A reviewer commented that the program had been moved to a new 1.9L GM engine and the team began studying emissions control in concert with the dual fuel strategy of the University of Wisconsin. The reviewer noted that the project was also characterizing urea-SCR for HECC operation and had completed characterization of RF-based DPF diagnostic strategy.

A reviewer said that the RF sensor shows very interesting results, but needs to see long term impacts as ash and residual soot from partial regens build. A separate reviewer commented that there were some interesting observations. There reviewer continued that the project was missing linkage or plan on how observations will drive improvements in engine performance, but no short or long term targets communicated.

One reviewer stated that the work on the soot sensor was interesting, although a very clean answer relative to its accuracy in soot load measured (RF) vs. soot load weighed would have helped. The reviewer said that this would give a direct answer to the merit of this technology, especially if the "state of the soot" has an impact, as we all know that soot can certainly vary in its structure (solubles, particle size, agglomerate size, etc.)

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said the University of Wisconsin collaboration and the MECA collaboration satisfy both the technical needs and there was a good relationship with industry. A separate reviewer commented that the collaborators are well suited to project along with the skill sets at ORNL.

One reviewer commented on the excellent broad range of participants, technology transfer, direction, and communications. Another noted that the team was working with MECA and suppliers, with a link to CLEERS and other ORNL programs.

One reviewer said that the activity of partners and impact on reaching a defined goal not detailed in presentation.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that these are logical progressions from the work already accomplished. Another said that the project would continue dual fuel emissions and emissions control studies and HECC mode SCR NOx measurements.

A reviewer suggested that it would be good to have a means of connecting the various aspects of the project into a system for different operating conditions.

It will be important to distinguish the testing of urea-SCR catalyst usage for HECC from that of other studies of aging of urea-SCR catalysts. Another reviewer said that the engine needs to focus on delivering high efficiency. The reviewer recommended the team use EGR in the dual fueled engine to gain efficiencies and then look at emission control needs, focusing on most difficult and highest emission impact load point.

One reviewer said that the presentation was focused on observations and test development and asked how this will be leveraged for improved engine performance.

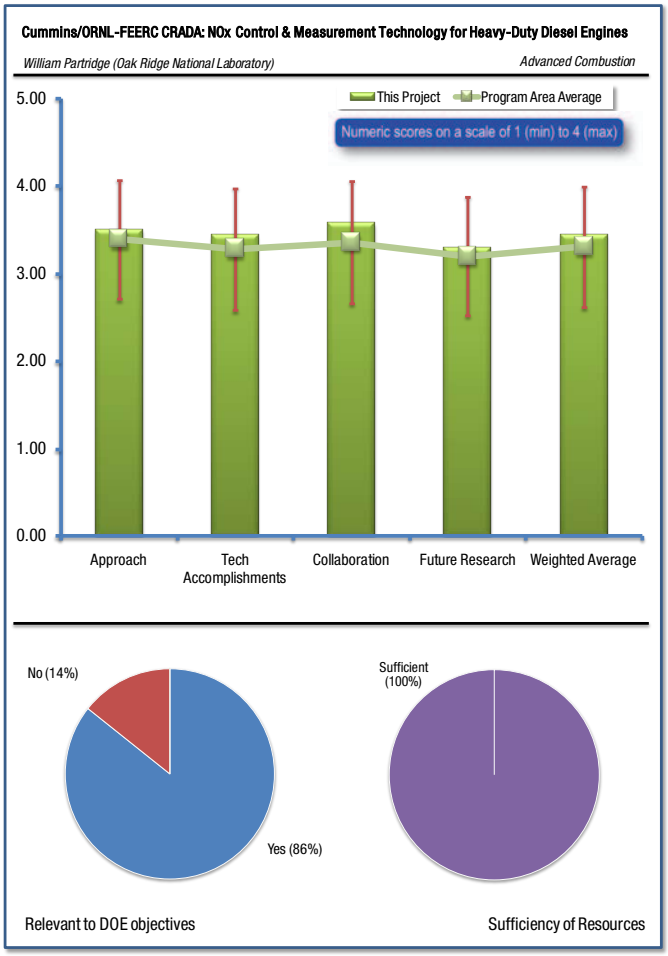
Question 6: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

A reviewer said that this is very interesting work, linking aftertreatment and advanced combustion, adding that more resources should be moved into this program.

Another reviewer said that this is quite a valuable approach and in need of more resources or continuance. The reviewer continued that running at high efficiency delivers new challenges on emission control and the program needs to focus on critical aspects with the current limited funding, and that one approach is to deliver high-value results to justify further investment.

A reviewer said there were too many parallel efforts with no visible alignment to a goal related to engine performance, adding that it would be helpful to see the PI's vision and deliverables.

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



Reviewer Sample Size

This project had a total of 7 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that reducing the burden of NOx control for lean burning heavy-duty diesel engines will lead directly to fuel savings and thereby to petroleum displacement. Another reviewer said that analyses in this project have made advances to meet DOE objectives for many years in an excellent collaborative effort.

Another reviewer said that it was a novel project incorporating new objectives (cylinder to cylinder variability, smart catalysts, new measurements like fuel in oil and H_2O) and that close collaboration with industry is important. One reviewer said that this work is an example of utilizing the unique instrumental capability of the national labs to develop instrumentation that advances engine and aftertreatment technology. By advancing engine and aftertreatment instrumentation this work enables more sophisticated and fuel efficient transportation technologies.

A reviewer felt that the project was very remote from DOE objectives. This is a test and measurement program. It is not obvious from the presentation how this work will improve engine (maybe this is proprietary to Cummins) but something that should be clearly communicated.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that this work is effectively a set of smaller problems that can be solved with improved instrumentation and that each of the solutions presented here is a unique approach to the solution of that problem. The reviewer added that there is not actually a major global goal. A separate reviewer said that this was a winning approach and is a model for others and that the team should keep it up.

One reviewer stated that this was a long-term program seeking to overcome combustion, emissions, controls and durability challenges associated with developing cleaner and more efficient heavy-duty vehicles. The reviewer added that specific areas of study are combustion uniformity (spatially within cylinder, cylinder-to-cylinder) and controls/sensing to improve uniformity.

A reviewer said that the project had reported a good selection of tests in development that can help understand things that impact engine performance and are of interest to the audience. One reviewer said that the Cummins CRADA started in 1998 and continues with modifications and that it uses a wide range of methods along with specific ones that ORNL has developed.

One reviewer commented that the work has been performed in a few areas of direct interest and the results overall have been good. The reviewer added that the overall approach seems to be a bit scattered rather than having one clear cohesive objective, but that this seems okay in this instance.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer noted that on combustion uniformity, a fuel-in-oil diagnostic has been demonstrated and is now being implemented by Cummins. The reviewer noted that the device has been commercialized. The reviewer added that a fast exhaust measurement technique for H_2O was demonstrated and that the project was working toward "smart catalysts" using SpaciMS to understanding how catalysts can form beneficial intermediates. The reviewer saw these as significant practical outcomes.

Fuel in oil was described as a major accomplishment. The reviewer added that the fast exhaust water measurement is an interesting way to measure cycle to cycle variability, but they were not convinced it is an optimum solution. The reviewer added that time will tell if it shows long-term application. The reviewer added that the ammonia measurements are very interesting since this technology seems to be headed toward production application.

A reviewer said that the project met targets for combustion uniformity with water measurement and that the fuel-in-oil (FiO) diagnostic in ten minutes vs. days is a big improvement.

A reviewer said the project took a new approach to cylinder variability yielding new insights such as water and soot. The reviewer described the work as very good. The reviewer added that the intra-SCR distributed NH_3 storage project is also yielding new results that will be very important for ultra-high efficiency SCR deNOx. The reviewer described these as very critical and useful results.

A reviewer saw good progress on short term test development goals, but added that the team did not report having seen impacts on engine improvement.

A reviewer said that although the H_2O measurement technique has been developed, the implementation on the engine combustion seems weak so far.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this group has been very effective in getting their instrumental solutions into the marketplace and this past year has been very successful for them. One reviewer commented that this was a very broad collaboration and in such collaborations communications and coordination become critical, with flexibility to adjust as new results come in. The reviewer added that this collaboration seems well functioning.

One reviewer said that this was largely an ORNL and Cummins team, but that is acceptable in this case. The reviewer understand that there were a lot more people mentioned relative to collaboration, but it seems the main program direction is set between only the two main partners. The reviewer continued that this is not necessarily a bad thing. The reviewer awarded the project bonus points for letting DaVinci commercialize some of the output from this project.

A reviewer saw a direct collaboration between Cummins and ORNL, with support from other industry partners and universities. Another reviewer noted that collaborative partner, Cummins, has a broad view of emissions control.

One reviewer said that it was not so obvious from the presentation how the synergies are coming from collaboration and impact on the engine improvement–too many parallel paths.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that proposed future work is good and the ammonia mapping is especially crucial. The reviewer was not fully convinced that the water measurements would be strongly utilized in the industry. These are new approaches to solving next-generation problems.

One reviewer said that ammonia SCR project is very critical. Industry will need 95+% SCR and this detailed understanding is needed. The reviewer suggested the project move forward with this in mind, focusing on how the results will improve performance. The reviewer suggested the academic groups might focus on fundamentals and interesting findings with the industry groups focusing on implementation.

A reviewer said that diagnostic tests were interesting and wondered which one will impact engine development and improvement sooner vs. later or at all, noting that this was not discussed.

A reviewer said the project was continuing many parallel efforts on in-situ intermediates measurements, fiber-based sensors, simulation and applying the diagnostic sensors.

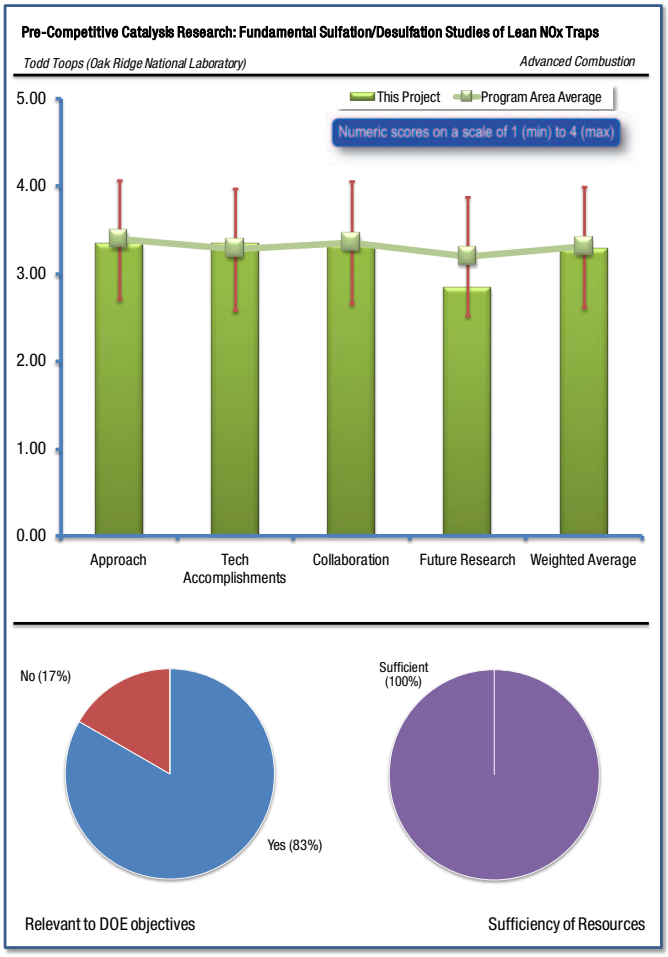
One reviewer felt it was not clear on the type of LNT and SCR catalysts planned for testing. The reviewer encouraged the project to include both Fe/SCR and Cu/SCR catalysts. In addition, the reviewer wondered, is it possible to work on Spaci sampling of the SCR catalyst on the engine with urea injection?

A reviewer said it would be good to study a Cu catalyst that does not have the ammonia coverage dependence that Fe and vanadia catalysts have. The reviewer wondered if temperature sensing is included in project with Spaci-MS.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the group has been very effective in utilizing their in-house resources along with their various industrial partners. One reviewer said that the program would benefit with a goal toward measurable improvement of engine performance factors via the testing methods developed. A reviewer commented that long term support for this CRADA has enabled many successes and an ability to dig deeply into problems and develop effective solutions. The reviewer also said that this is encouraging given how frequently the VTP is asked to shift directions in response to changes in public and government interests.

Pre-Competitive Catalysis Research: Fundamental Sulfation/Desulfation Studies of Lean NOx Traps: Todd Toops (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 6 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that LNT improvements will assist with DOE objectives. Another reviewer said that technologies that improve aftertreatment for lean systems enhance the implementation of lean engine technologies, adding that lean engine technologies will reduce our dependence on petroleum.

One reviewer said that LNT is a core technology for deNOx and high-efficiency lean burn engines and taking new incremental approaches can result in fast adaptation and improvements. One reviewer noted that as far as studies on LNT, particularly catalysts that while there is a known connection to efficiency improvements, not much discussed on how the deliverables of this work will be realized and the projected downstream impact.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer said that the general approach to try new materials experimentally and with modeling is an excellent way to proceed. Another reviewer said that the items being examining with respect to LNTs and methods to further improve and understand them is of great interest and the plan is set to looking into areas of definite interest.

The reviewer saw a two-tiered approach of evaluating current catalysts and functionality of individual components, and exploring synthesized new materials. The reviewer said that the cross fertilization of these approaches is interesting.

A reviewer said that evaluation of dopants and supports is a logical way to approach the problem. The reviewer added that the negative is that the selection of dopants and different supports seems to be anecdotal. The reviewer suggested this study might benefit from a combinatorial approach since most of these materials have already been considered in the past.

One reviewer felt it was not clear on how SO_2 was measured during DeSOx tests. The reviewer asked how the deSOx was performed in Addison and what the gas conditions were during the DeSOx tests. The reviewer noted that depending on the deSOx conditions, a significant amount of H_2S is generated.

One reviewer said that this was a well-organized presentation, but absent of time-driven, measurable goals how is success defined here?

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that Ca-substituted LNT is yielding interesting findings on sulfate stability and NOx interactions. The reviewer stated that the results are impressive and yielding promise. The reviewer added that the impact of high sulfur capacity and stability on NOx functionality is correct bottom line analysis. The reviewer said that there were fascinating results on commercial catalysts and surprising and significant findings on Mg-Al_2O_3 impacts.

One reviewer said that very interesting results were obtained that lead to improved and lower temperature desulfation of LNTs. The reviewer added that using new catalyst materials that allow lower temperature desulfation with 5% Ca is an example.

A separate reviewer said that calcium dopant study is helpful and interesting and it seems as if the $MgAl_2O_3$ has been significantly evaluated by the suppliers. The reviewer added that the addition of Ceria-Zirconia is almost a given since most of the LNT systems rely on an oxygen storage material to enhance the NOx reduction activity.

One reviewer said the impact of work on Ca role is presented well, but the team needs to tie this to a deliverable and a bigger picture.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

One reviewer said that this project has a strong group of collaborators. Another said that there is good opportunity for collaboration on this and it seems this information is being shared across a number of interactive groups, which is an excellent way to get the results out there. A reviewer noted good collaboration with Umicore and other centers at ORNL and CLEERS.

One reviewer said that the collaboration with Umicore is good but expressed concerns that there does not seem to be an OEM in the collaborative activity. The reviewer suggests that this study is perhaps best suited to a lean gasoline application and having an OEM as part of the work would be a significant benefit.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that lowering the deSOx temperature under realistic deSOx conditions is the most important metric. The reviewer asked if the project team can please describe this area in more detail next time. In addition, the reviewer requested the team please report all sulfur compounds during deSOx (SO_2, H_2S, and COS).

One reviewer said that the plans are excellent, suggesting that it would be good to add microscopy to examine the materials with higher Ca content. The reviewer also said that in appropriate places, it would be good to add HC as a reductant to compare with H_2 in desulfation studies to be closer to a more realistic reductant.

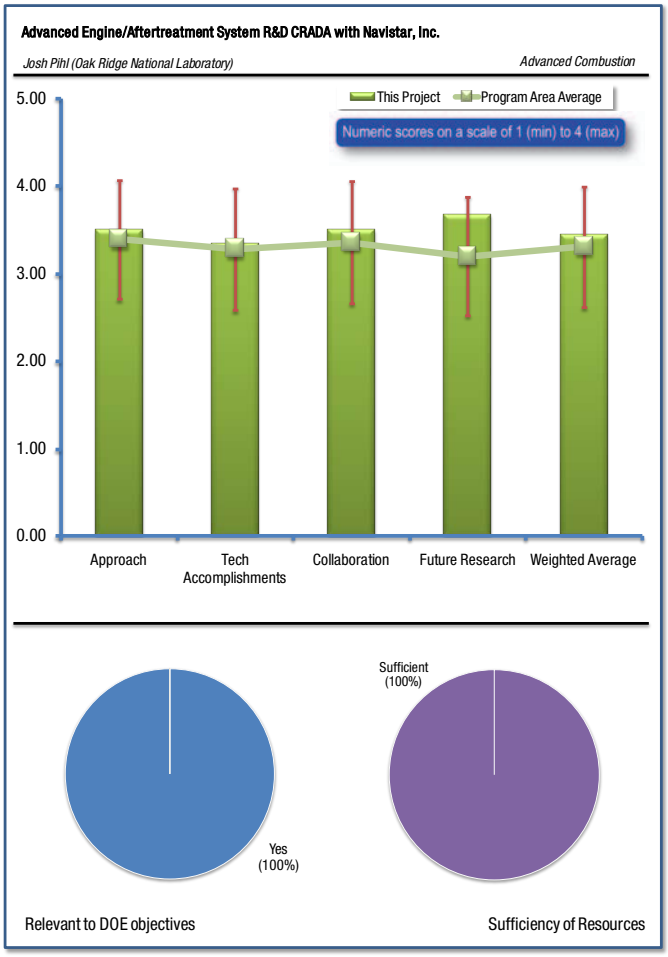
A reviewer suggests that the project may wish to incorporate at least one additional level of PGM in the early screening studies on synthetic mixtures. The reviewer stated that PGM can significantly impact sulfation and NOx functionality. The reviewer said there was a need for close collaboration with Umicore on logic of component additions and expected results.

One reviewer suggested that the project would benefit from discussion on the state of progress with respect to a deliverable or measureable impact on engine performance. A separate reviewer said that the future work is bits and pieces and does not bring any of the present studies into a focus.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer says that this seems like one of the better collaborations reviewed today.

Advanced Engine/Aftertreatment System R&D CRADA with Navistar, Inc.: Josh Pihl (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer says that the pursuit of improvements in NOx remediation and particulate removal is important and has been pursued well in this project. A separate reviewer commented that looking at the performance of SCR and DPFs is very relevant and of direct interest to a good many in industry.

One reviewer said that kinetic development for both DPF's and urea SCR systems is needed to be able to model the optimum configuration of the devices and this work provides information on those kinetics.

One reviewer noted that although long-term approach is towards high NOx, low PM operation for maximum engine efficiency, Navistar sees significant market segments that are resistant to this approach using SCR. The reviewer says that for these segments, DPF FC can become critical. Expenditure is modest and probably worth proceeding despite bucking of the long-term trend.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer stated that the approach of quantifying high level reactions on real life substrates for DPF and SCR is high value work on components of direct interest. The reviewer continued that folding these results into modeling is an excellent approach and should be pushed even harder, as modeling is the best method to exploit this knowledge.

A reviewer said that the range of tools was very appropriate for questions being pursued. Another reviewer said that there was a successful approach and results on SCR and that this was nice.

One reviewer said that this is two separate, relatively disjointed kinetics studies and that both kinetic studies are very worthwhile. The reviewer did add that the project does seem to lack a tight focus. The DPF OEM recommendation on materials, fundamental evaluation by ORNL, OBD and model incorporation with MTU were all aspects observed by the reviewer and stated to be very good.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

The experimental evaluation of the kinetic response of the SCR catalyst is quite good. It remains to be seen if the CLEERS SCR protocol will provide sufficient information to develop accurate global kinetics.

One reviewer said there were many interesting results. The reviewer gave the example of how at low temperature, the system needs more like 1.2 NH_3/NOx ratio to get good performance and the plot of activity vs. NH_3 adsorbed shows where the system should operate. The reviewer also said that for aging, the Pt deposition factor was interesting to prove in sectioned SCR catalysts. The

reviewer continued that for DPF work this year, aluminate, SiC and titanate all look similar in regen, but in back pressure variation is different, SiC falls more slowly.

Another reviewer made similar comments, noting that there were very interesting results on SCR. The reviewer said that this is critical to industry-wide approaches and the future need for 95+% deNOx systems. The reviewer also said that NH_3 adsorption and NO/NO_2 reduction characteristics might be explained by site of NH_3 adsorption vs. site for NOx reduction and NO oxidation (Yezerets, SAE 2010). The reviewer also said there were very interesting results on Pt migration and SCR aging and that preliminary DPF results show interesting trends on substrate impacts on regen and back pressure.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the integration of the supplier, OEM, and an academic institution is very good and provides a wide range of background under which to develop and apply the kinetics. Another reviewer said that the collaborations with Navistar and Michigan Tech appear very strong. One reviewer said that you will need strong collaboration with Navistar on the DPF, as their situation is unique.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

One reviewer said that this long-term project has obtained many excellent results. The reviewer added that the effect of NH_3 coverage on SCR performance should also be done on a Cu catalyst for comparison with Fe. It supposedly has no large coverage dependence and that in an aging study it is also good to check the performance of front of second catalyst to see how it compares with back of first catalyst. There can be more aging at front of second catalyst.

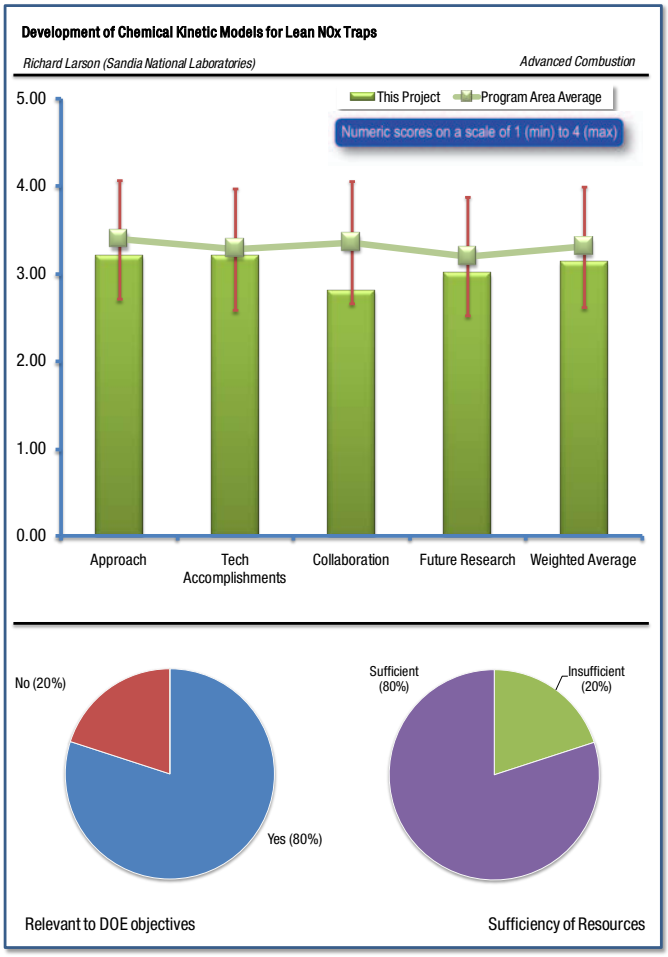
A reviewer said that the focus for the future has ORNL focusing primarily on the soot oxidation kinetics and MTU developing the SCR kinetics. The reviewer suggests that it would have been better if MTU had been developing kinetics while the SCR experiments were ongoing in order to optimize the experimental-kinetic development interaction.

A reviewer suggested the project look at the Cummins SCR SAE 2010 paper on Fe- and Cu-zeolites and NH_3 adsorption vs. NOx reduction and that this might help explain the results better. The reviewer added that DPF direction is valid and will yield interesting findings.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

No comments were made.

Development of Chemical Kinetic Models for Lean NOx Traps: Richard Larson (Sandia National Laboratories)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that model development is a critical part of making use of the data that is obtained on these emission control systems. A separate reviewer said that good kinetics and modeling are needed to advance field and that this is a key cornerstone.

One reviewer said that modeling of aftertreatment devices provides two benefits: one is to provide a global mechanism which can be used to simulate full aftertreatment architectures, and the second is to provide kinetic insight into the microkinetic behavior of the catalyst. The reviewer adds that this work provides microkinetic understanding of the LNT kinetics.

One reviewer said that this is a fundamental study and its impact is very remote to DOE goals.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the modeling approach is very effective. Another reviewer described classic, well-proven approaches to building base as being taken by the project. A reviewer said that the development on kinetic models and comparison and refinement against experimental data is clearly the proper approach in this program and looking at LNT performance is critical work as we move forward.

Another reviewer said that this project uses the well-developed chemical kinetic program package to study the kinetics of the LNT, noting that there are few attempts to do this at present. The reviewer adds that the major weakness in this approach is that the kinetic reactions are included and studied somewhat empirically and there is not an obvious, systematic approach to add or eliminate reactions needed for this mechanism.

One reviewer says that the project does not show how the fundamental learning obtained from the work will be specifically leveraged in engines and that it is hard to tell what is unique in this approach.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer says that in their view the major accomplishment is the development of a mechanism that appears to be effective, and that doing this is quite difficult. The reviewer adds that this mechanism includes NOx storage and release, oxygen storage and release and sulfur storage and release. The reviewer also says that as a micro-kinetic mechanism development, this is quite an accomplishment.

One reviewer said that excellent results have been obtained over the past several years. Recent work is on sulfur impact on NOx performance. The reviewer also noted that more short sulfations will be needed to get a good match for slide 7, which is a new result.

A reviewer said that there were outstanding modeling results on LNT NOx speciation. The reviewer suggested that results showing sulfur adsorption on Pt during rich might explain NOx spike on regen, and asked if the same thing is true on Rh. The same reviewer said that the desulfation simulation was also impressive. The reviewer suggested that the gap in sulfur aging needs to be explored and validated, and continued that they were interested in the desulfation results on Ce and Ba, and adsorption on Pt. The team should look at pulsing desulphation which is used to minimize H_2S.

A reviewer said that it is hard to tell if there is a lot of progress as it is not definitive on hard accomplishments or leveraging recent results for future tasks.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said there was excellent collaboration with ORNL researchers. Another reviewer said that there was collaboration with the right groups, and suggested the group make sure directions are adapted based on CLEERS and ORNL inputs. A reviewer observed the team is collaborating with Loboda. One reviewer said that the primary collaboration is with ORNL and it would enhance this project if an industrial partner was included in the work.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

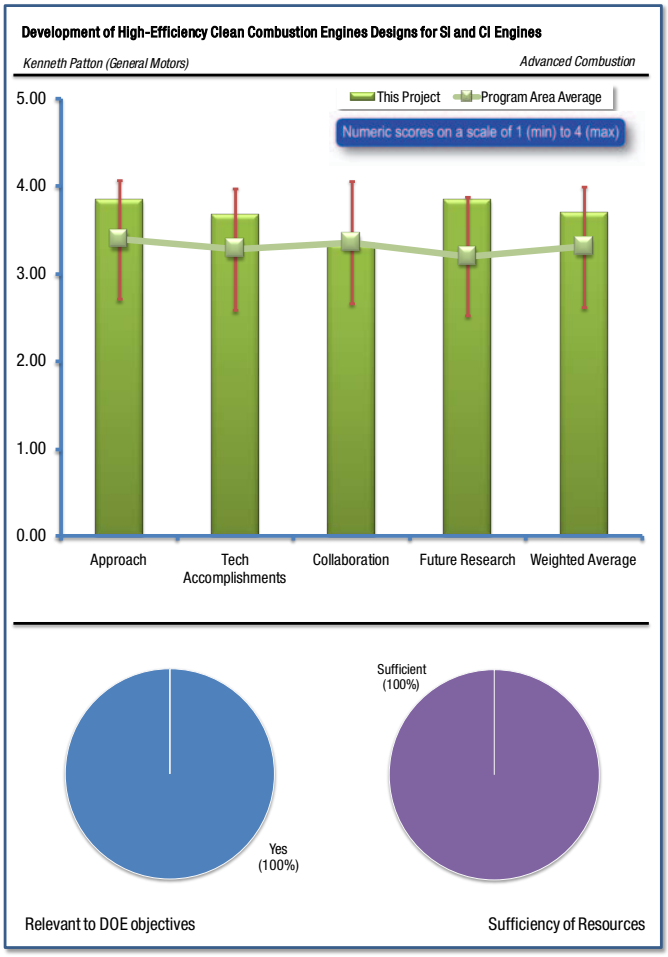
A reviewer said that it was excellent to be looking at reductants other than H_2 and CO in the reactions of interest to include more realistic feedstreams. Expanding the mechanism to include a hydrocarbon reductant needs to be considered. This reviewer believes that the CO and H_2 reductants will affect the oxygen storage components of the catalyst and those effects should be considered. Also the effect of NO as oxidant for the oxygen storage should be considered. Another reviewer said that this was a valid approach to fill gaps, and that migration into new reductants is key. The reviewer recommended developing base kinetics and modeling of sulfur adsorption on PGM during rich regeneration. The reviewer says that this is high potential and needs to be explored and that modeling is the beginning.

A reviewer did not see the path to impact. A separate reviewer stressed that they have a personal bias against LNTs: while they have some interesting characteristics and combining them with SCRs is very interesting approach, the real issue remains sulfur (think performance degradation vs. time). It just seems to the reviewer that sulfur is not a completely reversible poison, especially over thousands of hours. The reviewer knows this might well be outside the time scale of this work, but until someone steps up to long term sulfur effects on LNTs, they will remain SCR's “little brother.” The reviewer added that EPA requires the useful life of emissions devices to be 435,000 miles and at 40-50 mph, the issue is LNTs do not work and that in real life the system must live much longer than 435k miles.

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

A reviewer said that it was hard to tell if there is a critical interaction for synergy or not and that the collaboration slide looked more mandatory than informative.

Development of High-Efficiency Clean Combustion Engines Designs for SI and CI Engines: Kenneth Patton (General Motors)



Reviewer Sample Size

This project had a total of 6 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that for gasoline, diesel, and other advanced combustion approaches, improved valve actuation control is crucial to enabling these concepts and expanding more efficiency, clean operation. A separate reviewer said that advanced gasoline HCCI and diesel PCCI engines will provide significant fuel savings and thereby displace petroleum. A third reviewer stated that GM's involvement is critical to commercialization of LTC technology in LDV's. One reviewer mentioned FE enabling technologies.

A reviewer said that GM is developing relevant technology to improve gasoline and diesel engine fuel consumption and that a bold, high-risk objective of mass-producing camless engines is an appropriate use of DOE funds for this technology. The use of camless for diesel R&D is a good tool for evaluating more conventional VVA hardware and strategies.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the focus on hardware development is appropriate at this stage, so that the barriers for commercialization can be addressed at this stage in the technology development. Another reviewer noted that there was sufficient effort invested to take significant new technologies from idea to hardware stage and demonstrate utility.

A reviewer said that combining analysis, production level practices and use/generation of hardware to produce production feasible system to achieve HCCI and that it was combining spin rig testing to evaluate valve motion control to prevent valve-piston interference. Also, the reviewer commented, the work was using a multicylinder engine with variable valve timing. The reviewer continued that for diesel, it was using VVA for PCCI to reduce/meet emissions and improve efficiency to develop a simpler VVA strategy. One reviewer said that the project is completed.

A reviewer said the project was well focused but was not sure why different VVA systems were chosen for different engines. The reviewer assumed there is a good reason which they had missed or misunderstood during presentation. The reviewer continued that long term, it seems a fully flexible Sturman-type approach would be cost prohibitive on a production engine.

A reviewer said that since the presenter did not provide supplemental reviewer slides, it was difficult to determine what, if any, program changes have been made based on previous reviews.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that it was nicely done with useful technical learning. Another reviewer noted that there was good progress toward overcoming barriers, but enough in the presentation to understand whether this will result in overcoming barriers. The reviewer added that it was good to see technologies out of this program will make it to production, but it was not clear which technologies did. The reviewer knows this is hard to do in limited slides.

A reviewer said the project had eliminated opportunity for valve-piston interference and was finding cycle-to-cycle variations that need further work to understand and suppress. The reviewer continued stating that there was improved thermal efficiency but noise levels were exceeded. The same reviewer stated that the project had completed engine modification for the project and an exhaust rebreathing strategy study, and explored late intake valve closing using a cam phasing approach. The reviewer noted that a patent application on diesel valve actuation to achieve internal EGR had been submitted.

A reviewer said there were VVLT system improvements on spin rig, which is an important step for eliminating confounding effects on results. The reviewer added that the development of the hardware and sensors needed for control of HCCI combustion in production engines is an important step in finally moving HCCI from lab to commercialization.

One reviewer noted that the project is done and it had enhanced internal GM experimental and analytical capabilities and enabled experimentation with "sandbox" VVA and other toys. The reviewer added that, hopefully, the project had increased the competency of the researchers and engineers who worked on the project.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was close collaboration with Sturman Industries on a production-feasible variable valve actuation technology for gasoline HCCI and a large team effort for diesel PCCI activity. A separate reviewer would like to see close collaboration continue toward commercialization, despite the end of the funding period. A reviewer said there was good collaboration with others and that Sturman is expert in the field and the most appropriate choice for collaborator. Another reviewer said that it seems to be good collaboration within the team with the rest of us are on the outside, but that is presumably unavoidable since people will not do such work fully in the public domain. One reviewer commented that it was internal to GM only, with suppliers as beneficiaries.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

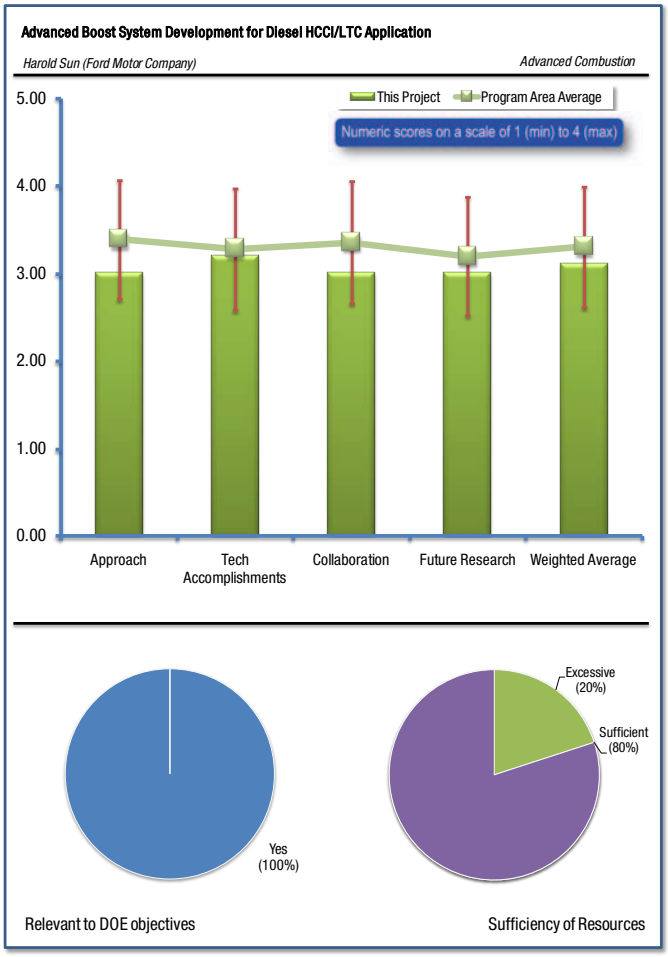
A reviewer said they will take knowledge from this project and move closer to production level hardware, but more work is needed on cylinder pressure sensing and transient operation of VVA system. The reviewer added that the plans for future research are not clearly identified and wondered what will be done in the coming year to address shortcomings of this work.

A reviewer said that the project complete and that GM plans to use technology developed in this DOE program in future products. One reviewer said that the project is done and shouldn't be scored, another said that scoring was not applicable as the program is ending and the technology was likely to be included in future programs. One reviewer was unsure how to score since the project had ended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the project had achieved the objectives for the gasoline HCCI and made progress toward completion of diesel PCCI objectives. Another reviewer said the funding had been appropriate. One reviewer said the budget was higher than many other projects, but that the results seem commensurate with funding. One reviewer said this question was not applicable, another noted the project is done.

Advanced Boost System Development for Diesel HCCI/LTC Application: Harold Sun (Ford Motor Company)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this project addresses problem of surge of compressor with high EGR significant improvement in peak efficiency island and flow. Another reviewer said that diesel HCCI and LTC can lead to reduced burden and cost for clean diesel technology, and thereby can lead to deployment of higher efficiency passenger cars, which will lead to petroleum displacement. Another reviewer noted that the project was developing a technology to enable emissions and efficiency improvements. Another reviewer said that turbo-machinery is an important enabler for improved use of exhaust energy and that improvement in turbo-machinery is cited as necessary for enabling high efficiency concepts. The reviewer added that while that was not addressed in this study, the knowledge discovery from this project could still be relevant.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer stated that there was solid analysis, and good selection of partners. A reviewer said that this was a good project with good progress, adding that the speaker failed to follow DOE guidelines for presentations and did not provide supplemental reviewer slides. One reviewer said that the barrier is that heavy EGR to enable LTC puts the engine into a lower efficiency operating condition. The reviewer continued that both compressor and turbine in the turbocharger suffer efficiency losses with use of EGR, which confounds the effort to improve efficiency and therefore effort needs to be to improve "U/C" for engine efficiency improvement. The reviewer believed the project was trying to improve compressor and turbine efficiency over a wider range through CFD simulation, bench and engine tests.

A reviewer stated that technical barriers were well identified and addressed and that there were many challenges to new turbo-machinery designs. The reviewer commented that this project is doing a good, systematic job of addressing these barriers with innovative designs, but it was not clear if the approach changed from last year based on reviewer comments.

Another reviewer commented that this was literally reinventing the wheel, both the compressor and turbine wheels. The reviewer continued that the approach is a cookbook assignment for a turbo development task and has been done before a few times. The reviewer quoted from the presentation that "Challenging a relatively matured technology turns out to be much more difficult than we had anticipated," and suggested it was time to "stop beating a dead horse."

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said there were impressive improvements in turbo function. Another reviewer commented that there was significant improvement to the turbo for a light-duty drive cycle. A reviewer noted the project had completed four iterations of design. The reviewer noted that the team fabricated compressor wheels, performed flow bench and validation testing, and that there was improved turbo efficiency of 12-18% which translates to 2-3% fuel economy savings (is the cost of the modified turbo and compressor different than the production unit?). The reviewer continued that the project demonstrated improved U/C is desired operating range on the vehicle and noted that further improvement opportunities were identified but remains to be experimentally validated.

One reviewer said there had been good progress overall and nice accomplishments on path. The reviewer continued that the reported benefits from bench experiment will be checked on-engine in next phase. The same reviewer said the results are promising, but noted that the presentation had not included “extra” slides so the reviewer could understand how comments from last year were addressed. It was not clear to the reviewer what is new or what has changed by comparison. The reviewer found it hard to gauge some aspects of progress without that additional information. The reviewer was also curious that there was a request for an additional year.

One reviewer felt that this “technology development” program addresses issues that have been well-covered by diesel engine manufacturers in the USA (HD), and in Europe and Japan (LD). The reviewer continued that the findings so far are merely a confirmation of prior art by established turbocharger manufacturers R&D teams world-wide and the reviewer did not see new ground breaking results so far.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there was a close working relationship with components suppliers on the iterations toward improved turbine and compressor. One reviewer thought that teaming with a turbocharger company is occurring (they think) and that this is very important. The reviewer noted there was not much discussion and no slide on role of collaborators. One reviewer said that there seems to be outstanding work within the group, but the rest of us are outside. The reviewer conceded that this probably can't be avoided due to proprietary issues. One reviewer believed that an established turbocharger supplier should be able to carry out all the suggested tasks, perhaps using Ford as the verifier. The reviewer questioned the use of the turbo supplier only for gas stand testing. The reviewer believed that Ford Europe/England must already have a few of this project’s “new findings” and asked if the Ford NA engineers have reached out for their help.

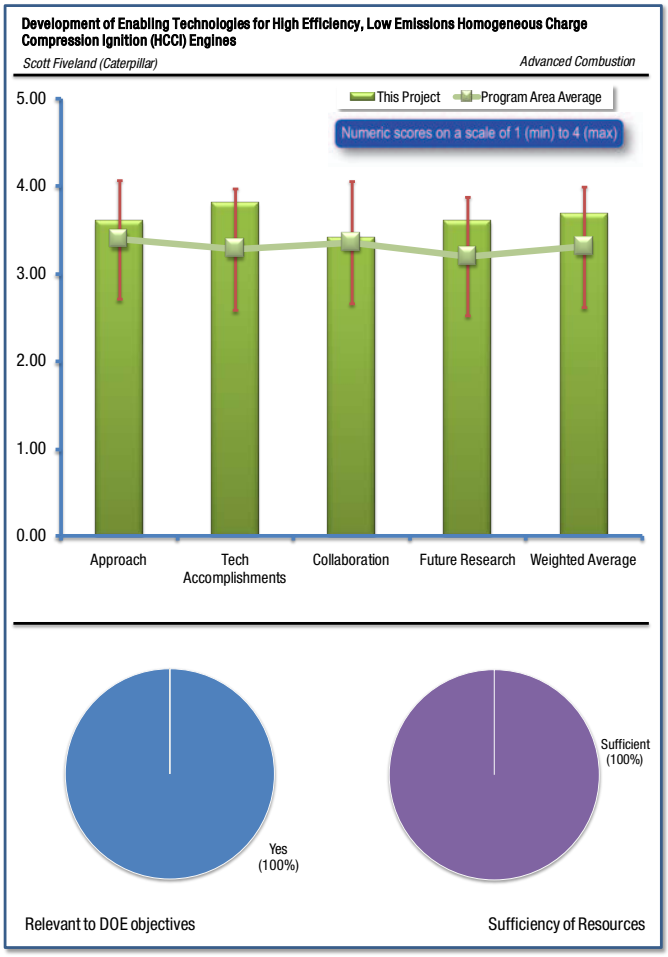
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer noted that the program was ending and this technology is very likely to be implemented in future products and research. Another reviewer said that it was important to get on-engine to see if predicted and bench-scale improvements translate well. A reviewer said that there is remaining work to be done on additional experimental validation of benefits, and to migrate the technology to a small turbo and small diesel engine application. The team expects an additional 6-9% improvement in compressor efficiency. One reviewer described this as an exercise that is really neither needed nor likely fruitful. The reviewer alluded to the presentation's summary comment: “The reviewer said that additional technologies have been identified and numerically validated to fill the gaps,” numerical validation is elusive.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that if in the end, if 2-3% (potentially more) fuel economy improvement in a vehicle can be achieved with low cost design changes (geometric design changes which should result in minimal cost change), then this project will yield a significant public benefit and represent a valuable technology investment by the VTP. One reviewer said there was appropriate funding, but another suggested further investment in this project be reduced.

Development of Enabling Technologies for High Efficiency, Low Emissions Homogeneous Charge Compression Ignition (HCCI) Engines: Scott Fiveland (Caterpillar)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that high efficiency clean combustion engines will lead to reduced emissions and reduced fuel consumption and thereby displace petroleum. Another reviewer described it as a good enabler for higher efficiency. One reviewer said that PCCI was demonstrated with low NOx/PM and fuel economy improvement.

A separate reviewer suggested that HECC does not offer a substantial reduction in fuel consumption in heavy-duty applications relative to other technologies, but is significant for reducing aftertreatment complexity and pollutant emissions.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that there was a good approach for integrating technology building blocks. Another reviewer commented that the scope is broad enough, but spread across a significant cooperative network to achieve success. One reviewer said there was a clear identification of issues to be addressed and analysis of means to move forward.

A reviewer felt that despite the perceived impracticality of gasoline/diesel blends, it is appropriate R&D. Another reviewer said that lately the project had been focused on fuel blending.

One reviewer commented that barriers to HECC involve mixture preparation, air utilization, heat rejection, load capability and combustion control. The reviewer noted that the project was using a systems approach to improving efficiency, and that this project focuses on combustion improvements by shortening combustion duration and engine out emissions. The reviewer continued that they were characterizing the HCCI combustion process to identify technology gaps, extend load range by optimizing spray injection and developing local premixing.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer said there was solid research, implemented in hardware effectively. Another reviewer said that the accomplishments are significant over the course of the program, but it is not terribly satisfying to see how much remains yet undone.

One reviewer said that they had studied lifted flame combustion and plume to plume interactions in the SCORE facility to achieve smokeless combustion, the reviewer added that the project defined requirements to achieve smokeless combustion. The reviewer noted a greater number of orifices reduces the ability of the sprays to breathe in air, which shortens lift off length and that they were moving

lifted flame combustion into smaller bore engines. The reviewer continued that using fuel blending to push the load range of PCCI to higher levels shows promise and the team has experimental evidence to demonstrate the concept. There remains a challenge of dealing with pressure rise rate limit on maximum load capability.

A reviewer said that overall progress is very good and the latest report is OK. The reviewer asked why the project team was reporting on SNL work and why the last two slides were from 2009 AMR. The reviewer also questioned if there were no new reviewer comments from last year.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said the project involves collaboration with Sandia, ORNL and Exxon-Mobil and exploits the unique capabilities of the national labs. The reviewer added that the labs provided valuable input to help achieve the project objectives. Another reviewer said that the collaboration has been outstanding all around for a DOE-industry partnership. One reviewer said that they seem to have formed a very good team–OEM, suppliers, academia, labs. A reviewer asked if they were funding SNL for the work there.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

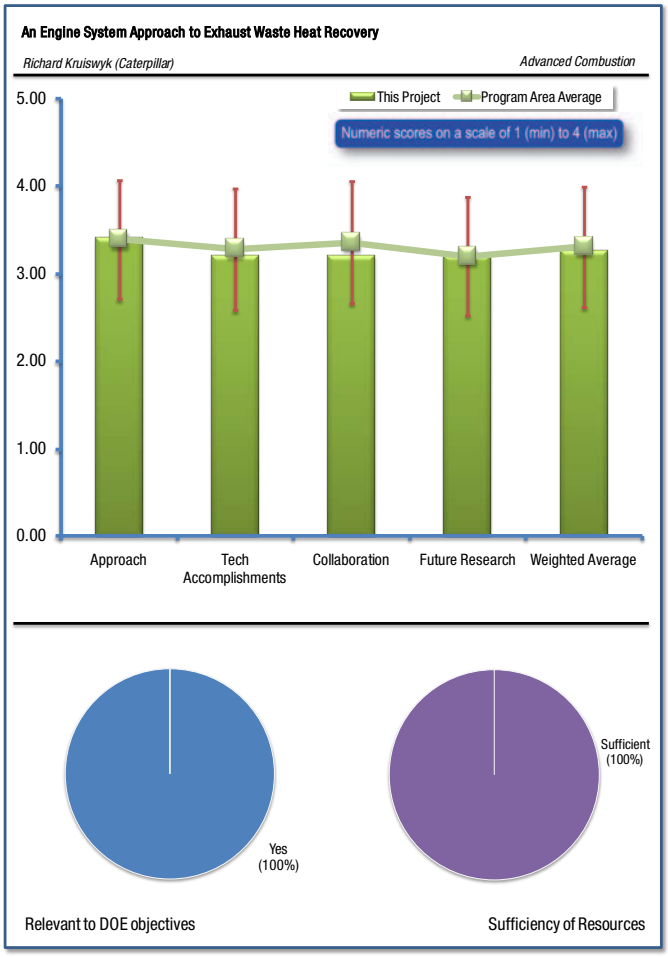
A reviewer said that this line of research will lead into future contracts and product development and that this was a nice example of bringing far-out research closer to production. One reviewer said that the project was continuing work to develop solutions to the remaining limits on implementation of the PCCI strategy.

One reviewer thought that work in this area would continue, even though the project had ended. Another said the project was in wrap up stage. One reviewer said it would be more encouraging to see a concrete plan for addressing the remaining barriers in future work.

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

A reviewer said the project has been successful in overcoming and identifying remaining barriers. Another reviewer said there were appropriate funding levels.

An Engine System Approach to Exhaust Waste Heat Recovery: Richard Kruiswyk (Caterpillar)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that waste heat recovery can directly reduce fuel requirements and thereby improve fuel economy and displace petroleum. Another reviewer said that an assessment of bottoming cycles is critical for heavy-duty applications. One reviewer described a direct means for efficiency improvement. A reviewer described the project as being focused on fuel economy improvements.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said there were interesting ideas approached with appropriate computational and experimental tools, adding that the work has adapted appropriately, as system evolved through the project. A reviewer said that barriers include cost effectiveness, packaging and efficiencies of components for waste heat recovery. The reviewer continued that a systems approach to try to achieve 10% improvement in engine thermal efficiency, based on compound turbocharging with heat recovery via heat exchange between the intake air and the exhaust and a focus on production viable technologies to improve practicality. One reviewer said there was thorough consideration of the means to address the major losses, but it was unclear where turbocompounding will head at the conclusion of this effort. One reviewer agreed with reviewer comments made last year that the followed approach constitutes a revisit of previous technologies and an attempt to marginally improve them. The reviewer continued that the reported work is a routine developmental work that should be carried out by CAT without DOE support or involvement. The reviewer also wondered about where the total system integration effort was.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said that the development of improved, "production-possible" HECC turbocharging hardware is significant. A separate reviewer commented that this was good work and saw solid opportunities for efficiency improvement.

One reviewer said that the project had demonstrated progress toward program goals, though the program is ending to make way for SuperTruck program. The same reviewer stated that the focus has been on procurement of components to test different concepts. The reviewer continued that for HP turbine the team had targeted 2% thermal efficiency increase just through improvement of turbine design, and achieved equivalent of 1.5% net thermal efficiency improvement and demonstrated 2-3% efficiency improvement at some speeds and loads in a test engine.

The reviewer continued that for LP turbine, they had targeted +1% engine thermal efficiency, and demonstrated about 2/3 of that target on a flow bench. The reviewer also noted that more modest gains had been targeted for compressors, and they had demonstrated about 60% of that target on a gas stand.

A reviewer said that turbo system design enhancements should be left to the specialists. The reviewer also felt that the overall results fall short of addressing the end objectives of the DOE program goals.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that component suppliers closely integrated in the project and the team had worked with a university and ORNL for test support. A separate reviewer commented that there was good collaboration with suppliers. One reviewer suggested that the project some collaboration with component suppliers, beyond what they doing now.

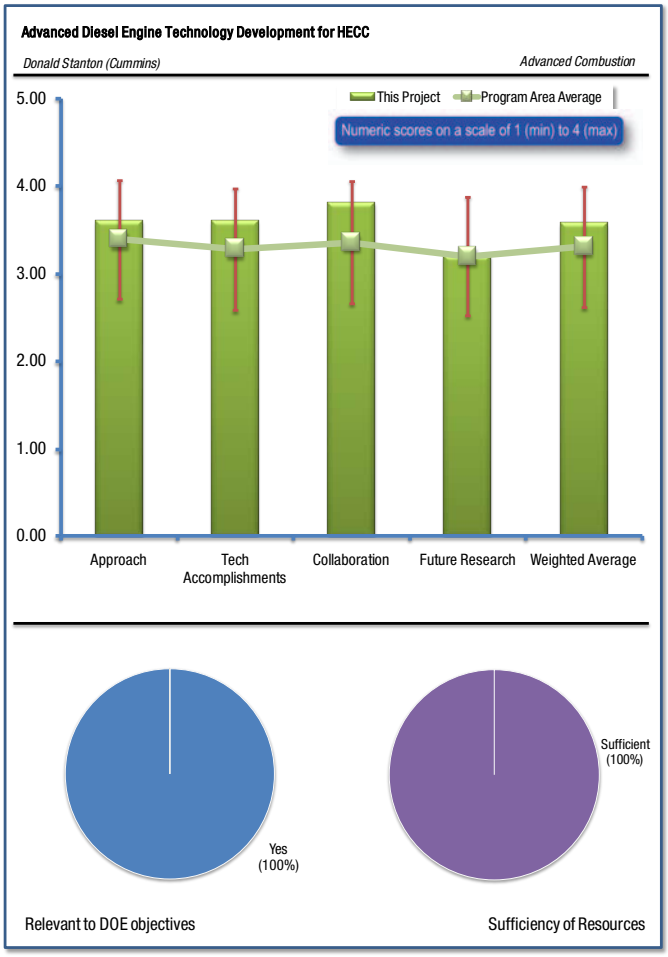
Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that the team had stated plans to continue the work internally as this project ends. Another reviewer said that the project was transitioning to SuperTruck and that some of the work will continue in the new program. The reviewer noted that they will test a Gen2 version of their turbogenerator design. One reviewer felt that the proposed future research had not fully been explained.

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

One reviewer said that the project objectives had been completed within project timeframe. Another reviewer felt that to answer to this question they required some clear metrics that are not well-defined as far as this reviewer is concerned. One reviewer said there had been an appropriate level of funding.

Advanced Diesel Engine Technology Development for HECC: Donald Stanton (Cummins)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said there had been solid development of high efficiency technology. Another reviewer noted that high efficiency clean combustion could provide diesel efficiencies with reduced engine out emissions, thereby reducing the burden of aftertreatment from a cost and efficiency perspective. The reviewer added that HECC can lead to petroleum displacement. One reviewer said that fuel economy is in focus. Another reviewer said that the objectives are in line with DOE.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that efforts have included research on achieving 10% efficiency improvement, fuel interactions with the combustion process and enabling subsystems. The reviewer continued that extended PCCI operating range and incorporated lifted flame combustion and that ether was a two pronged approach to work in concert with SCR NOx control and to work to eliminate NOx aftertreatment. A reviewer noted that the project team had worked in both HD 15L engine and LD 6.7L engine.

A reviewer said that the project was a nicely conceived program that included several key technologies. The reviewer added that there was a good combination of modeling, optical engine, and metal engine development. Another reviewer said that this was a good, comprehensive and well thought out approach.

A reviewer commented that for many programs including this, it will be useful to check the appropriate base, asking "what if their base engine is very poor (not that I think it is, but what if?)."

One reviewer felt that last year's presentation was focused on light-duty and wondered if Cummins has switched to MD/HD in mid-stream.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said there had been great progress; better results than they would have expected at the outset. One reviewer said the project had achieved both targets for NOx (external and internal), but robustness in the engine out PM remains an issue for in-cylinder NOx control strategy. The reviewer continued that the project team had achieved 10.2% thermal efficiency without NOx aftertreatment. The reviewer described other technical barriers that include cavitation damage to the injector orifice passages. The reviewer said that for HECC with high efficiency SCR, packaging, weight and DEF derived deposits remain challenges. The reviewer added that for the 6.7L engine, moving to HECC mode permitted removal of the NOx adsorber catalyst from aftertreatment system. The reviewer also said that for HECC and biodiesel compatibility achieved with sensing biofuel presence and active control.

One reviewer said that there were nice accomplishments but the presenter was only able to get through half of his slides. The reviewer continued that review of the remaining slides indicates progress is being made, but a response to last year's comments would have been useful to understand what guidance and action was taken. The reviewer believes that was a required slide.

A reviewer felt there were many recycled developmental tasks giving the examples of slides 13 and 14. The reviewer described this as not good. The reviewer described early PCCI combustion, early lifted flame combustion, reduced parasitic and increased CR piston as good. The reviewer described slides 15 and 16 as routine work for an engine company's R&D team.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said there was great collaboration drawing from industry, national laboratories, and universities. A separate reviewer noted extensive partnerships with ORNL, Purdue, BP and partners and that these partnerships led to significant contributions from the collaborations. One reviewer said there was a balanced team of national labs, academia and industry and that the project was well done. Another reviewer said there was nice teamwork with OEM, suppliers, labs, academia.

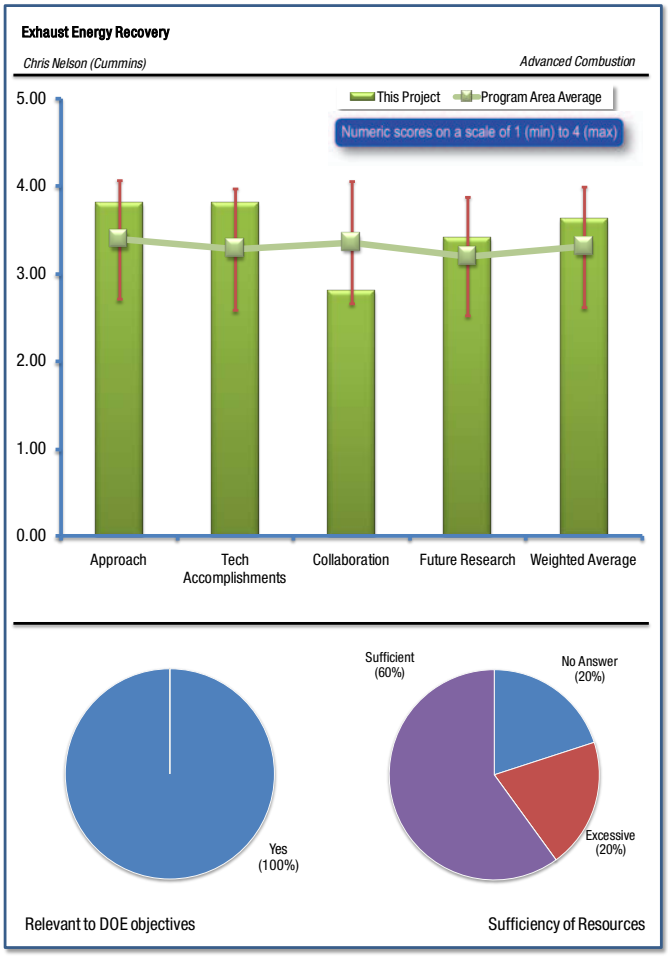
Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that one program is complete and another is on its way. The reviewer added that plans forward look good. A separate reviewer commented that the HECC program is closing out and targets were achieved. One reviewer said it seems that the work will continue in future programs. One reviewer said the LDECC program is continuing, but targets exceeded for thermal efficiency (15.5% demonstrated versus 10% target). Another reviewer said that nothing was revealed except a verbal statement that things will continue under the SuperTruck program. The reviewer suggested more focus on higher risk, higher payback research areas.

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

A reviewer said that the program appears to have been quite successful. Another reviewer said that there was a sizeable budget compared to many other projects, but results are commensurate with funds expended, adding that the project showed excellent work and results. One reviewer said that there was appropriate funding.

Exhaust Energy Recovery: Chris Nelson (Cummins)



Reviewer Sample Size

This project had a total of 5 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that the organic Rankine cycle WHR system is a complex, high-risk, and difficult to package system, and is appropriate R&D area for DOE funds. The reviewer added that Cummins has done an outstanding job developing a system that will very likely be produced and deployed on new and possibly in-use engines for very real petroleum savings. A separate reviewer said that the project is well aligned with DOE objectives.

A reviewer said that the recovery of exhaust energy directly can lead to fuel savings and thereby petroleum displacement. Another reviewer said that waste heat utilization is focused on energy recovery and improving fuel economy. One reviewer observed high efficiency technology development.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said this was a nice approach and an interesting idea and that there was good use of simulation and analyses. The reviewer continued that the program has adjusted appropriately as situations change, partly due to its own earlier results.

A reviewer said this was a solid approach and well thought out. The reviewer added that energy recovery is a viable approach, especially for HD vehicles. Engine system changes caused a re-evaluation. The team responded well.

A reviewer said that the program was targeting a 10% improvement onto top of the advanced engine being developed in the HECC and LDECC programs and that an organic Rankine cycle strategy was being pursued.

One reviewer suggests that WHU approaches have been investigated a few times during the last 40 years and that ORC R&D should be available from the DOE historical reports, from the "Big-3", and U.S. HD diesel engine companies of old (CAT, Cummins, and DDC). The reviewer continued that this project provided an update on the state-of-the-art and that the practical implementation and the likelihood of production release must be undertaken as a priority, and updated continuously.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said that the project had demonstrated incremental improvements including Rankine generator and more electric accessories, and achieved 9.4% efficiency improvement by last year. The reviewer added that further improvements gained another 1.4% efficiency improvement, for an overall >10% improvement and with the low NOx system with less/no EGR reduces system capability to 6.2% efficiency improvement.

One reviewer observed nice analysis and results. Another reviewer stated that the project met its goals even with a major change to the engine system. The reviewer was disappointed to not see some of the mandatory slides related to response to reviewer comments. The reviewer added that these slides help the reviewers to know what, if anything, was changed based on comments.

One reviewer commented that many technical barriers have been addressed and that more secondary work and peripheral activities have been undertaken. The reviewer continued that it was not clear if Cummins will seek partial or full release of the ORC WHU system even in limited production.

The same reviewer noted that the integration of the WHU system into the engine design was a very good effort. However, it seems that much "claptrap" is added to a very complex and ever-expanding engine sub-systems and components. The reviewer wondered what this will do to cost, reliability, and other important parameters. The reviewer added that they did not know if FMEA, both design and manufacturing, have been carried out or reported in prior years, stating that there was no reference to it here.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that this has been primarily an internal program, but this is not seen as a problem. Another reviewer noted they were working with Cummins component divisions on system development. Another reviewer said that this was all internal collaboration and that while this is good, there may have been other opportunities missed.

One reviewer said that it is difficult to collaborate with others, especially during a wrap-up phase. The reviewer also suggested that DOE may want to change "Close, appropriate collaboration with other institutions; ..." to include collaboration with industry partners as well: this might have been included in prior AMR's a while back.

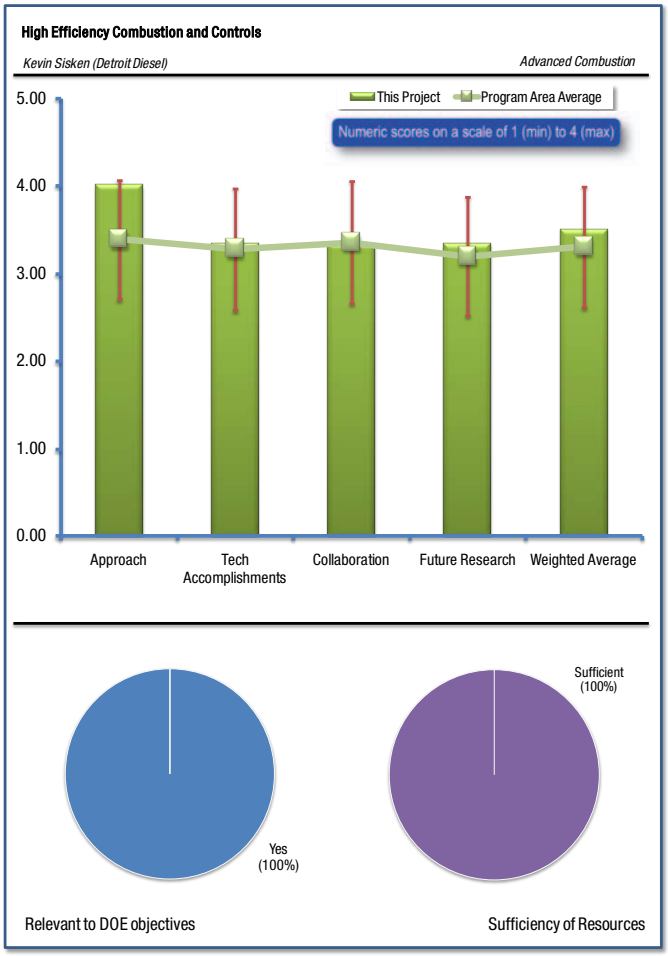
Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that the program is ending but carrying over into the SuperTruck program. A separate reviewer said that the work will carry on in the next program. Another reviewer said that the merits of continuing this work under the SuperTruck should be examined. The reviewer added that there can be higher priority items that would warrant funding preference. One reviewer stated that despite the project being complete, Cummins laid out plans for continuing this work and taking this technology to production. One reviewer noted the project was complete and they were not sure how to rate because of this.

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

A reviewer said that there was a large budget but results commensurate with funding, adding that this had been excellent work. One reviewer said there had been appropriate effort. One reviewer stated that the funding this past reporting period seemed to be on the high side for the reported progress during this shut-down task of the program.

High Efficiency Combustion and Controls: Kevin Sisken (Detroit Diesel)



Reviewer Sample Size

This project had a total of 3 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that high efficiency combustion and controls to achieve high efficiency combustion reduce fuel utilization and thereby lead to petroleum displacement. A separate reviewer said that the project was a demonstration of high efficiency technologies.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer commented that there was a good selection of technologies, nice use of simulation and experiment. A reviewer said that the target is to 10% fuel economy improvement through combination of refining a conventional combustion process, dual spray injection (low pressure and high pressure injection), transient controls and air system refinements. One reviewer said there were excellent project and results, although the reviewer felt that the speaker did not follow DOE presentation guidelines.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer said there had been solid results with more to come. A separate reviewer commented that roughly 2% BSFC improvements were seen through conventional strategy. The reviewer added that control improvements target cycle to cycle variations reduction and cylinder balancing via ion or pressure sensing, but remains at the concept stage. The reviewer also said that the dual spray approach consists of one injector with two distinct spray modes, but durability of the injector is a problem and this approach is being dropped. The reviewer also said that predictive control shows more promise thus far by predicting current system behavior, and is being used for optimization which shows lower NOx and 3% FE improvement. The reviewer said that air system improvement showed 1% FE increase and is being migrated into production.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said there was a partnership with ORNL where experimental studies were performed, leveraging ORNL expertise in advanced combustion and controls. Another reviewer cited OEM, lab and suppliers.

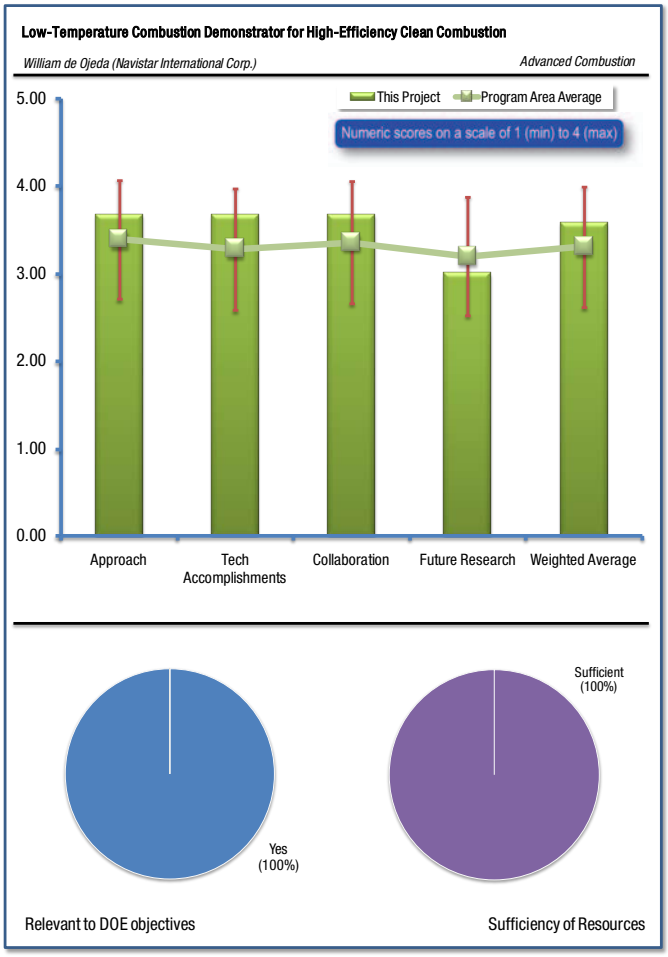
Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that combustion system and controls work will continue in SuperTruck, the injector system will be dropped, and the air system is being put into production. The reviewer added that they will show the 10% improvement in demonstrator. A separate reviewer commented that they plan to continue in the next program.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said there was appropriate funding. Another reviewer was uncertain about the budget as the speaker did not follow DOE presentation guidelines. The reviewer added that the project had shown excellent results, so the budget is apparently adequate.

Low-Temperature Combustion Demonstrator for High-Efficiency Clean Combustion: William de Ojeda (Navistar International Corp.)



Reviewer Sample Size

This project had a total of 3 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said the project was quite focused on fuel economy improvements. A separate reviewer commented that there was development of high efficiency technology. A separate reviewer noted that enabling the use of HECC approaches can reduce the emissions burden for diesel engines and thereby provide petroleum displacement.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that starting with Navistar's state-of-the-art production technology, the project focused on addressing technical barriers. The reviewer added that a systematic approach was used to tackle a difficult problem under stringent emissions complex. The reviewer continued well focused on in-cylinder combustion improvement and enhancements. The reviewer concluded that they covered the basis and this phase harvested a consistent multi-year approach.

A reviewer said the project was attempting to meet 2010 emissions without NOx aftertreatment and improve efficiency by 5% using 2007 DPF strategy. The reviewer added that the platform is a 6.4L V8 engine and the work includes development of enabling component technologies. The same reviewer stated that they were considering the range of fuels, in particular the FACE fuels. The reviewer added that barriers include UHC, fuel economy, stability, load range, transients and fuel tolerance.

A reviewer said there was good use of simulation and experiments. The reviewer was not convinced that high efficiency can be obtained without any NOx aftertreatment, and attempting to do so may be limiting the concepts. The reviewer also said that for many programs including this, it will be useful to check the appropriate base. The reviewer asked “what if the base engine is very poor (not that I think it is, but what if?)”

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said that progress is substantial, considering the challenge of improving the efficiency while maintaining the low NOx and PM combustion strategies such as high EGR rates. The reviewer added that Navistar’s pursuit of minimizing the engine-out NOx to avoid aftertreatment “backed them into a corner.” The reviewer continued that pragmatic adherence to production-viable approaches is a strength that deserves an honorable mention.

A reviewer noted that previous phases of project included engine improvements, such as VVA system. The reviewer added that reduced instability and extended operation range through VVA and feedback control was achieving >5% FE improvement with

additional reductions in emissions. The reviewer also said that using different injection strategies in different speed-load regimes and that they had showed that EIVC strategy allows 95% reduction in PM and 5% FE improvement at constant NOx.

A reviewer said that there had been good combustion results. The reviewer also said that assuming that fuel properties will be optimized to deliver nearly half the target efficiency improvement is risky and unlikely to happen.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said there had been extensive collaboration with component suppliers, fuel supplier, national labs and university. A separate reviewer noted that there was a great team, coordinating with multi-faceted partners and a national lab. One reviewer commented that LLNL's help with CFD and Chemkin is an astute move for Navistar to supplement what has been an anemic in-house competency. The reviewer added that the results reflect a well-coordinated collaboration effort. A reviewer said that the collaboration included an OEM with suppliers, academia, and labs.

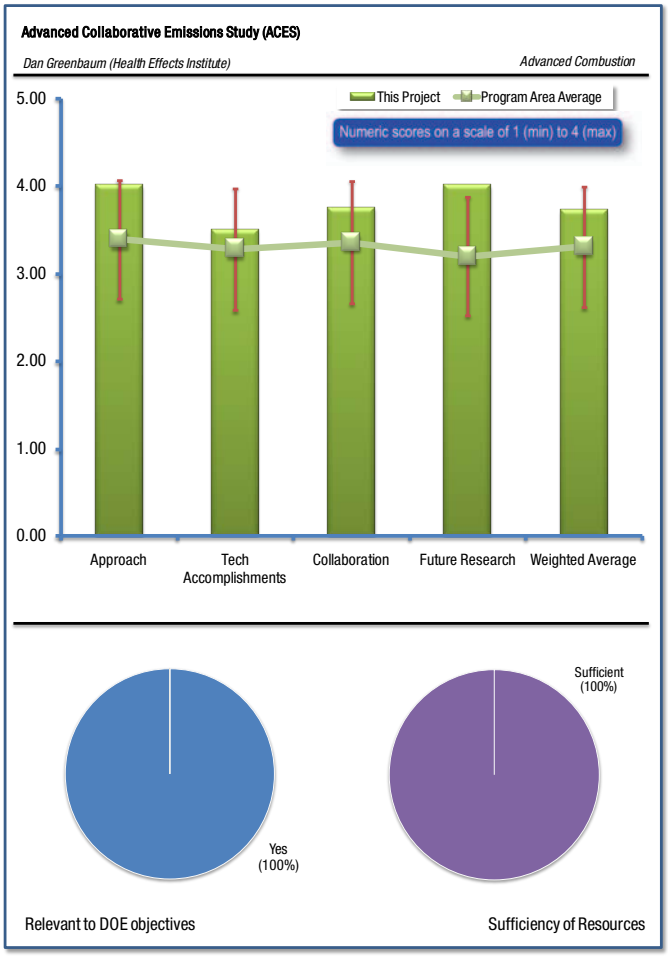
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

One reviewer commented that the program is ending with no indication of future plans. The reviewer assumes this work will continue in future projects and suspects that much work is needed to come to a competitive efficiency given their apparent program assumptions. Another reviewer said that the presentation was not clear as to what/how the future work will be carried out, presumably under the SuperTruck program. The reviewer said that the presentation had only mentioned “fuel reactivity.” The reviewer said it would be interesting to see how an industrial company will deal with this topic, obviously with the support of the national labs, and without double dipping in the DOE budget. A reviewer said that the program has ended.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said this was a good wrap up effort. A separate reviewer said there was appropriate funding

Advanced Collaborative Emissions Study (ACES): Dan Greenbaum (Health Effects Institute)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that avoiding adverse health effects is the reason for emission standards, and meeting emission standards is a prerequisite for efficient powertrains, so these studies are critical to the DOE VT mission. A separate reviewer said that to understand what level of pollutants may affect humans by looking at effects on mice and rats can help define the aspects of pollutants that may affect humans. One reviewer says that this work is to determine toxicology from heavy duty diesel exhaust using new generation combustion technologies.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

One reviewer says these are complex, difficult studies with their controls and they appear to be well-designed and getting useful data. A separate reviewer commented that while they are not a health effects expert, it is apparent that this group has top skills and has developed a most comprehensive and authoritative program. One reviewer says that this is consistent with the work done in the past. The reviewer adds that there is no reason that this study should not identify toxicological effects from the new generation of diesels. The reason that there could new effects occurs because the new combustion technologies could produce different exhaust gas emissions even at low concentrations.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer says that at this point the tests have been initiated and no results have been reported. A reviewer says the results of the study are eagerly awaited. A separate reviewer says that so far there are no final results, but there is little to distinguish the controls from the mice exposed to pollutants. The reviewer added that the PM created by the mice themselves would appear to complicate the study of PM effects.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that this project has many appropriate partners, possibly more than any other ACE project. A separate reviewer said that all the necessary players are well represented and this is critical in order for the results of the project to be widely recognized as valid. One reviewer said that the advisory board for the Health Effects Institute is well staffed. The same reviewer was concerned that at least one of the people on the board is no longer with the listed institution and suggested it would be helpful if the staff listing was properly updated.

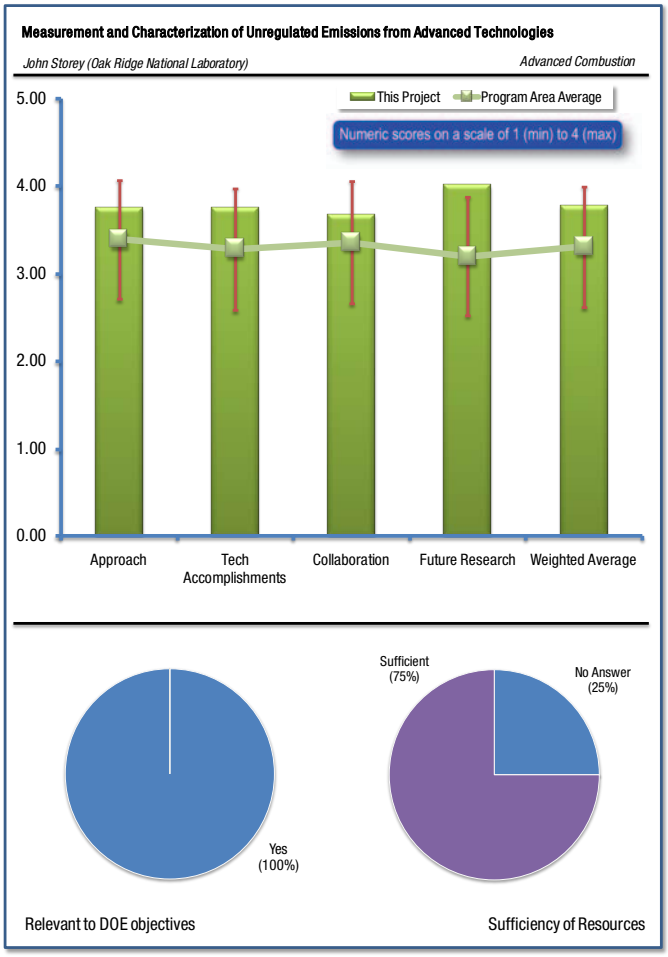
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that the schedule for future work is excellent to follow through with current efforts for the coming year. One reviewer said that this project has the same focus as past tests and should be equivalently effective in identifying problems. A separate reviewer said that if the study shows no impact of pollutants on mouse and rat health, that will be a useful result. The reviewer added that this is not the goal of this project, but one can always hope that ultimately this family of research will find the "silver bullet" that leads to understanding of the characteristics of particles or what is adsorbed on them that may cause disease in humans exposed to large amounts of particulate matter. One reviewer said that the program continuation to completion is at hand. The reviewer hoped that consideration will be given to further testing of 2010 level systems, adding that it seems that Phase 3 is running 2007 level systems and they not heard a plan to do animal exposure of the later systems.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the project seems to be well funded from a variety of sources.

Measurement and Characterization of Unregulated Emissions from Advanced Technologies: John Storey (Oak Ridge National Laboratory)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this work is critical to the implementation of lean gasoline systems, both direct drive and hybrid. A separate reviewer said that it is important to know and understand unregulated emissions from fuels that may reduce our dependence on imported fuel. One reviewer said that this work is necessary to assure there are no unpleasant surprises in new technology. Emission controls are done to reduce health issues caused by older systems; we need to be sure we do not replace some problems with others.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the approach was well designed to determine the emission species from these alternatively fueled vehicles. A second reviewer said that characterization tools and means of operation to obtain samples are well-thought out and probably unique in their breadth. One reviewer said that this group is recognized for leadership in analyses of this kind and that there were good plans and facilities.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer said that understanding the change in emissions as the ethanol component is increased in fuels is crucial. The reviewer continued that it is anticipated that the ethanol component will increase from today's 10%, and that often this increase is done for supply reasons. The reviewer added that it is necessary to understand the impacts of mandated increases in the ethanol component of gasoline fuels. A reviewer commented that there was excellent progress in a wide area of research, especially the E10, E20 blends which are of great interest. A second reviewer also noted the excellent results.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that a good range of collaborators is used. Another reviewer stated that the collaborations are cross cultural as they should be in this type of project adding that these collaborations seem to be well designed. The reviewer also said that from the presentation it is not clear how involved each of the partners is. A separate reviewer stated that the PI has good contacts at many industry locations and that in this work, more involvement from industry would help with experiment setup and implementation of the learning.

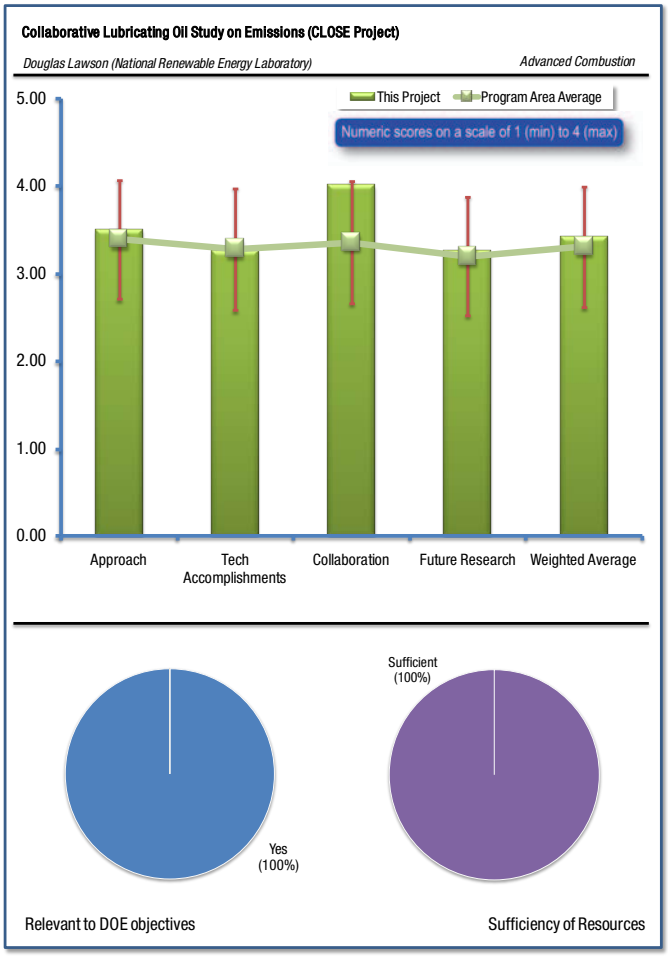
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

One reviewer is looking forward to seeing the results. A separate reviewer said the project is headed in the right direction and is achieving results that are not generally carried out elsewhere. A reviewer said that these are vehicle designed applications and this is as it should be for this type of project.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that this seems like an appropriate level of effort.

Collaborative Lubricating Oil Study on Emissions (CLOSE Project): Douglas Lawson (National Renewable Energy Laboratory)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that identifying possible toxic components in diesel soot is necessary to provide safety for incorporating high volumes of these vehicles on public roads. A second reviewer commented that the impact of emissions from lubricating oil vs. those from fuel-based species is an important piece of knowledge to improve overall emissions. One reviewer noted that understanding the sources of emissions is important to enable further reductions, and to understand the source apportionment for future regulatory actions.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the approach seems very appropriate for the measurements needed. A separate reviewer described carefully designed experiments with statistically valid analyses, supported by the important parties to the issue will result in quality results that are accepted widely. One reviewer said that there has been considerable discussion on the health effects of particulates emitted by gasoline vehicles; the reviewer added that it appears as if there is insufficient data to evaluate that effect. The reviewer continued that lean burn gasoline engines are available in Europe. There is discussion about the health effects of those particulates.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer commented that good progress has been made. A second reviewer felt that there was relatively little data presented here, and that the accomplishments seem to be to simply start taking data. The reviewer continued that the jury is out for accomplishments. Progress seems to be acceptable. One reviewer said that no real progress was reported, although much of the data has been taken. The same reviewer said that the results are still being reviewed by the partners in the work.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that this work is well coordinated with the relevant air quality groups. Another reviewer said that the group of partners seem very appropriate, adding that it might be interesting to have more than one lubricant source/provider in the team, because of the importance of lubricant impact for the project. A separate reviewer said that all the necessary groups are actively involved in planning and executing this program.

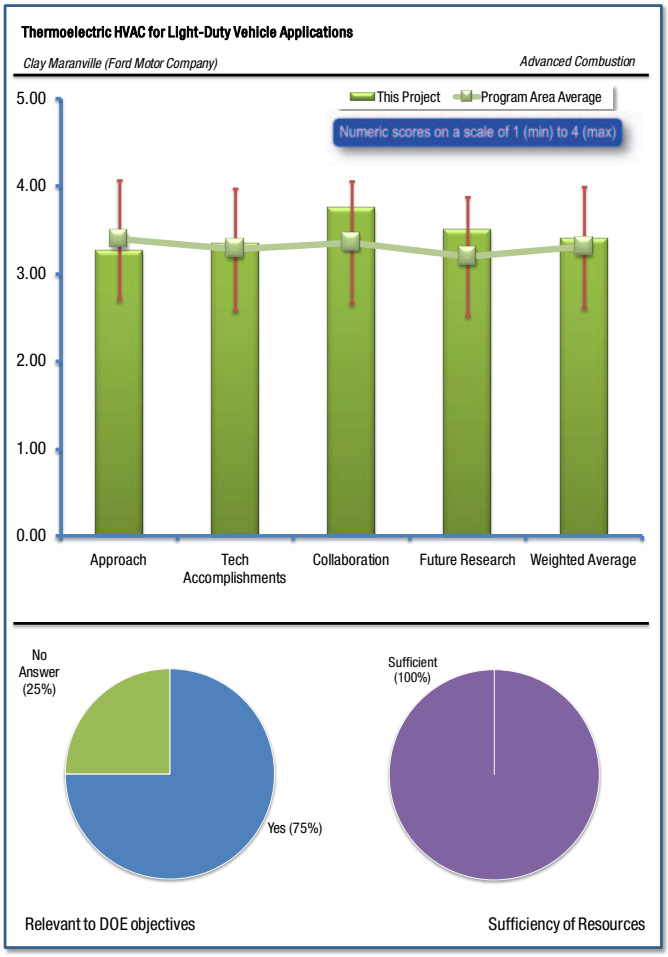
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that the project is scheduled to end this year and that it seems like some future work on related topics would be useful. The reviewer is not sure we don't know all about the issues involved. A reviewer said the project is 80% complete and will present results with suggestions for future work. A separate reviewer hoped the project is done on time in November.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said the project seems to be adequately funded from several sources.

Thermoelectric HVAC for Light-Duty Vehicle Applications: Clay Maranville (Ford Motor Company)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this project does support DOE objectives of petroleum displacement. The reviewer added that the results of this research will make the vehicles become more fuel efficient and lighter in weight by not carrying many parts and components as with conventional HVAC systems. One reviewer said that the project concerned vehicle efficiency opportunities.

A reviewer said that this project concerns integrating thermoelectric coolers in HVAC systems in automotive systems. The reviewer continued that the project began in 2009 and is on track and that the essence of the work is to develop a way to package thermoelectrics in the HVAC system to address the accessory loads of which the HVAC systems are a part. The reviewer added that the technical and commercial approaches which are needed to bring TE to HVAC in automotive systems are the basic effort of this project and in the process the PI wants to eliminate (long term) redundant systems.

A reviewer commented that the approach that the project is taking appears to support the overall DOE objectives of displacing petroleum because of their development of advanced HVAC technologies and capabilities that enable hybrid and plug-in hybrid vehicles development and commercialization. However, the reviewer added, it is not clear at this very early stage of the program how well their choice of bismuth telluride thermoelectric materials will actually perform in achieving the program goals. The reviewer also said that bismuth telluride materials are generally not capable of achieving COP's > 1 in cooling applications, unless temperature differentials are closely controlled and minimized. The same reviewer said that there was no discussion on how they would accomplish this in this presentation. The reviewer also said that the fact that they have a parallel pathway / aspect of their program to develop advanced TE materials to incorporate at a later date is critical to the ultimate success of this system.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that this was a good team with good analytical methods. A separate reviewer said that the milestone time line is well developed with deliberate go/no-go targets and the project is a bit early and the range of results is understandably limited. The reviewer added that the project is intended to reflect “real world” operation in specific geographical locations. The reviewer also said that the tasks include to the following: develop test protocols, use a range of modeling approaches to enable high efficiency systems, and to design, integrate and ultimately validate performance in a demonstration vehicle. The reviewer continued by saying that collaborations with NREL and Visteon will take advantage of simulations tools they have developed to optimize such things as number of TEDs, location of vents, air temperature, flow rates, and so forth.

The same reviewer noted that the testing will leverage Ford's experience in designing climate control systems and that collaborations with BSST will further facilitate developing computer models to predict TE performance and design optimizations. The reviewer

ended by saying that some effort is also being directed toward improving ZT of commercial TE materials such as Bi_2Te_3 (especially for P-type materials and this effort is being pursued in collaboration with Ohio State.

They have a strong team that gives a high probability of success in addressing the goals and potential issues with bismuth telluride discussed above. It is not clear at this point how their team intends to create the compact, high-performance TE systems that will be required to enable this zonal-system concept. They are early in their design phase, so perhaps this will develop as the project matures. Their team progress in this regard will have to be monitored closely and their solutions to this issue must be evaluated closely. The project plans appear to be thoroughly developed at this stage. One reviewer said that the approach can be improved to be more effective.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

A reviewer said that they have done as much as one would have expected given their early design stages. It was good to see that they have created a set of bounding design conditions and environments that will guide their design efforts. A separate reviewer stated that there were good initial results and that a solid plan is in place. A different reviewer said that the project is making progress toward the final objectives.

One reviewer said that the results presented were somewhat of a broader, nonspecific level. The reviewer believed it would have been better to focus on a specific result and discuss that in some detail. The reviewer continued, commenting that the effort has focused on a more real-world performance evaluation of a specific test platform (automobile model). The reviewer added that the Ford Fusion HEV was selected in the demonstration program around which integration of TE devices is being evaluated. The reviewer also noted that the Fusion is a flexible platform. The reviewer also said that a study of population density centers and driving patterns in a range of locations is being conducted to prove the efficacy of the concept and to minimize a test protocol.

The reviewer also said that Visteon is carrying out the baseline simulation and the results are being used to develop an understanding of thermal sensation (in a minikin). The reviewer continued by saying that BSST is developing a liquid look design to reduce the size of TE pellets. The reviewer also said that OSU efforts have centered on materials evaluation for TE.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that the project has a strong team that can address the challenges and issues that are associated with this project. The reviewer added that there appears to be very good collaboration with Visteon and NREL at this point, but it is not clear how much collaboration is on-going with BSST. A separate reviewer said that the collaborations are excellent, covering a full spectrum of issues as noted above. One reviewer stated that there was a good team assembled with complementary capabilities. One reviewer noted that this project has a good group of collaborators and good results can be expected via well coordinated work.

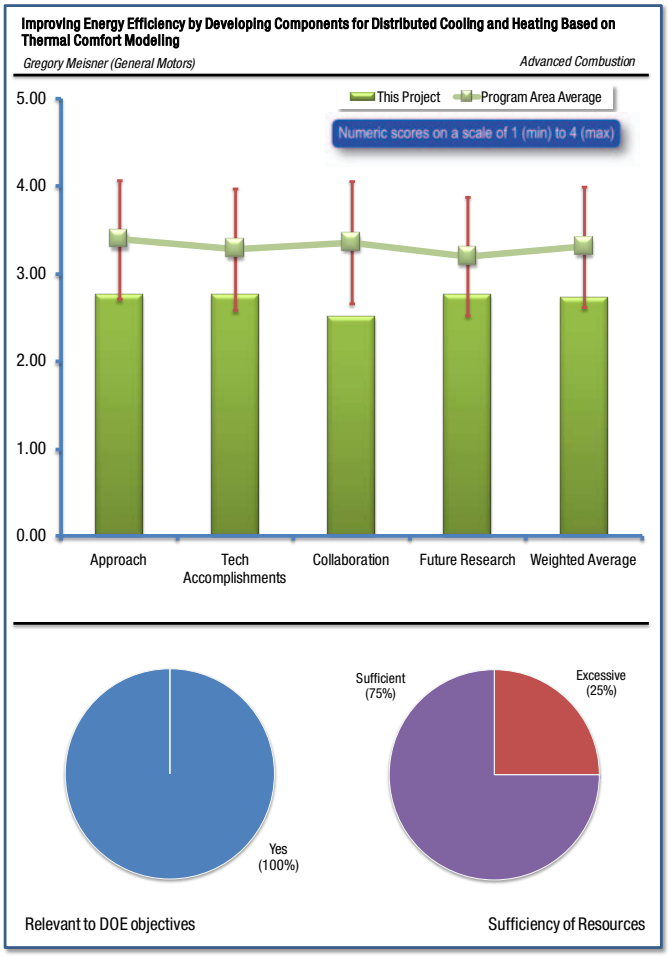
Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

A reviewer said that the test plan for the way forward is well developed. One reviewer said that there was a solid plan with realistic stretch targets. A separate reviewer noted that the project's plans are logical and rationale, with a good emphasis on the barriers to overcome and mitigating the risks. Their demonstration vehicle selection is very good. One reviewer said that the proposed future work is reasonable and technically sound.

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

A reviewer said that the resources for this project are sufficient for the project to achieve the objectives in a timely fashion. A different reviewer said that the resources allocated are appropriate for the range of tasks being carried out. A separate reviewer stated that there was appropriate funding.

Improving Energy Efficiency by Developing Components for Distributed Cooling and Heating Based on Thermal Comfort Modeling: Gregory Meisner (General Motors)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this project does support DOE objectives of petroleum displacement by reducing the weight of the HVAC system by using thermoelectrics. One reviewer commented that this project does support the DOE objective of petroleum displacement, as it is a key enabler of hybrid and plug-in hybrid vehicle technologies. The reviewer continued by saying that the project appears in early stages of development however, so progress on achieving DOE objectives must be monitored closely as their project matures. A different reviewer said the relevance was vehicle efficiency improvement.

One reviewer said that this effort focuses on waste heat recovery for improving fuel economy and that as such it is relevant to DOE's interest. The target is to reduce HVAC consumption by 30%. The reviewer added that the partners include Berkeley, Delphi Thermal Systems and University of Nevada, and the overall objectives are to reduce HVAC components that employ TE materials to improve COP to a level greater than 2. The reviewer continued by saying that included is a component to understand the physiological response of passengers to heating and cooling cycles.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the project had a good team with solid analytical approach and the correct skills mix to approach the problem. A reviewer said that the tasks include prioritizing a list of potential distributed heating and cooling components, complete selection of a suitable GM vehicle, and complete definition of a design approach. The reviewer continued by saying that these sorts of efforts, important as they are, probably do not deserve to be offered as major accomplishments (unless there are some special considerations that would give an appreciation for them). The reviewer added that Phase 1 concerns applying a "thermal comfort model" to determine how vehicles respond to heating and cooling, and the team will carry out wind tunnel testing in the Delphi wind tunnel. The reviewer also noted that Phase 2 will concern developing an initial prototype of HVAC components and evaluate performance on a demonstration vehicle. The reviewer also stated that additional phases were presented.

One reviewer said that in the presentation GM discusses the objective to "Develop new thermoelectric materials to improve the efficiency of thermoelectric generators for engine waste heat recovery." The reviewer continued by saying that this project is not about improving thermoelectric (TE) generators for waste heat recovery, it is about improving the performance of TE cooling systems and their application to zonal cooling in automotive passenger cabin cooling. The reviewer suggested that GM should be focusing on TE materials for improving TE cooling system performance. The reviewer added that University of Nevada - Las Vegas is not well known for TE materials research, so it is not clear how well this aspect of their project will progress. The reviewer also commented that there is no discussion of thermal manikin evaluations, only discussion of human subject testing. The reviewer felt that this can be

quite subjective and may give ambiguous, vague results that will be difficult to interpret in guiding their design work. The reviewer also said that Phases 2, 3, 4 and 5 were only briefly described in the presentation, so it is difficult to assess the overall project plan except to say there are some uncertainties on how the phases fit together. The reviewer continued by saying that Phase 5 looks completely out of place in this project.

A reviewer felt that the thermal comfort model has not been clearly explained. The reviewer continued by saying that the presenter seemed to not having a good understanding of the concept and that the model has to be set up with appropriate boundary condition for validating a tri-zone system as said during presentation.

Question 3: Characterize your understanding of the technical accomplishments and progress toward overall project and DOE goals.

One reviewer said that the program is just starting and there were good initial plans and results. A separate reviewer said that technical accomplishments and progress are not significant as presented and so therefore, it is still early to tell whether or not the project will be successfully carried out toward DOE goals.

A reviewer said that the tasks were presented in rather general terms, which made it a bit difficult to get a better sense of the accomplishments over the past year. The reviewer suggested that in the future, the PI should ask the collaborators to supply one slide that best illustrates the results of their effort over the year. The reviewer continued by saying that as it stands, the results presented were somewhat general and hard to judge, which perhaps may unfairly bias the perception of the progress made and the significance of the effort.

One reviewer said that the team members have started to develop their plans at this point, but they appear to be early in their project. The reviewer continued by saying that in 2010 the project plans to develop a mule vehicle for thermal comfort evaluations and those plans are good, but they must be integrated with results from UC-Berkeley's Thermal Comfort Model. The reviewer stated that this model must be updated quickly, but there was not discussion of what updates are necessary for this project. The reviewer also suggested that the project's work also needs to be integrated with the results from the mule vehicle thermal comfort evaluations, but GM did not discuss how this will be accomplished. The reviewer asked why UC-Berkeley is identifying the initial set of heating and cooling components for development and what Delphi's role was in this task effort.

Question 4: What is your assessment of the level of collaboration and coordination with other institutions?

A reviewer said that the collaborations are very good and the PI is leveraging their expertise to meet project goals. One reviewer said that the collaboration team is good; however, there are little results of the collaborative effort shown and explained during presentation. The reviewer added that a more aggressive collaborative effort needs to be demonstrated besides just mentioning what other collaborators have been developed for their own purposes.

A separate reviewer said that the project has a good team, but it is not clear whether it is as strong as the other team on this program. The reviewer continued by saying there is some collaboration occurring, but it is early in their project and this must be monitored going forward. The reviewer believed that there seems to be some collaboration on develop operating parameters and how these are related to the HVAC component design, but once again an incomplete list of specifics were given so it is difficult to judge what level of collaboration and what specific technical parameters are being discussed between the team members. One reviewer said that this was a good team with broad skills, but wondered if UNLV will contribute materials specifically for HVAC and if not, what their role is.

Question 5: Has the project effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways?

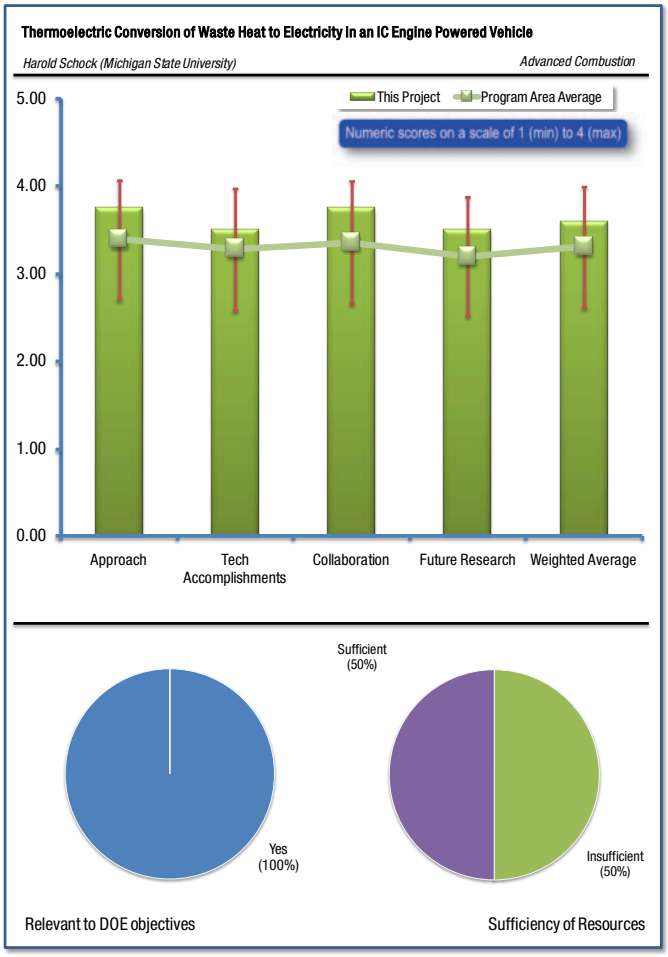
A reviewer said that it was a good plan that was just getting started. A separate reviewer noted that additional human testing will continue at Berkeley, and human testing will be performed at Delphi. One reviewer said that the plans may lead to improvements, but need better co-ordination and focus on the problems. A separate reviewer commented that Phase 5 looks to be completely out of place

and suggested that this project should focus on developing TE materials for enhancing TE cooling performance, not focus on developing TE materials for waste heat recovery.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said there was appropriate funding. A separate reviewer stated that the resources are adequate for the effort described, adding that it would help the PI's case to show more in the available time to justify the investment in this effort. Another reviewer noted that the resources seem to be more than what it needs to achieve the objectives and suggested that GM does better planning and become more aggressive in executing this very important project.

Thermoelectric Conversion of Waste Heat to Electricity in an IC Engine Powered Vehicle: Harold Schock (Michigan State University)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that this project is relevant to DOE's interest by its focus on exhaust waste heat recovery from automobiles and the associated gains in fuel economy that could potentially result. A separate reviewer noted that this project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and at the same time less pollutants. The reviewer added that using thermoelectrics as a way to harness the energy from waste heat is an excellent choice. The reviewer continued by saying that it will also reduce the weight and maintenance of vehicles by not having to carrying auxiliary power sources.

One reviewer said that this project on heavy vehicle waste energy recovery is particularly important because the amount of power that can be produced is much higher than in light-duty vehicles. The reviewer continued saying that the TEG system weight penalty on vehicle performance is also much less, if any at all, on a heavy vehicle than in a light-duty vehicle. The reviewer added that a 3-5% increase in BSFC is quite significant to the trucking industry and would have a significant impact on heavy vehicle fuel usage nationwide. One reviewer commented upon vehicle efficiency improvement.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the project had a good plan with appropriate team skills and systematic approach. The reviewer noted that the approach has been adjusted as the vehicle market moves. A separated reviewer stated that the presenter clearly demonstrated that the project's approach is working since they understand the technical difficulties and they have the solution to effectively solve the problems.

One reviewer noted that the approach is reasonable and covers a lot of elements. The reviewer added that the team assembled is wide-ranging and includes a range of expertise and capabilities. The reviewer believes that the problem has been addressed from a broad perspective, covering as it does materials development, modeling, metrology for performance, module design and integration. The reviewer continued by saying that the PI has also noted the importance of interfaces as an issue that needs to be addressed and they apparently have a solution (which was stated to be proprietary). The reviewer added that the project has targeted skutterudites as material with attractive properties for TEGs.

A reviewer said that they have taken a good approach to this project. The reviewer noted that the thermal cycling test that shows a 20% reduction in power output after 10 cycles is of concern, given that these systems must cycle 1500-2000 times per year in a typical vehicle application. The reviewer continued by saying that the project's work on advanced power electronics to integrate with this

system is very good and their systems approach incorporating thermal transport solutions, TE materials analysis, TE module assessments, power electronics and their vehicle-level analysis impacts is quite good.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

One reviewer believes the project team has made excellent progress in achieving their goals. The reviewer added that they have addressed many of the technical challenges in thermal management, advanced TE materials, TE devices fabrication, system fabrication, and system analysis on limited funding throughout their project timeline. The reviewer continued by saying that the module and power scale-up studies are very good and shows the progression that has been made. The reviewer added that the work with advanced TE materials is also quite good and shows a pathway to higher power systems.

A separate reviewer said that there have been many good results, but component failures are a concern. The reviewer added that the vehicle application seems to have shifted to what the reviewer believes is a more attractive target.

One reviewer commented that it was an excellent presentation with many facts and figures. The reviewer continued by saying that the team is making lot of good progress toward the goals of the project and that this suggests that the barriers will be overcome. The reviewer recommends that this project be allowed to continue with funding since they have well demonstrated their effort in meeting DOE objectives.

A reviewer said that the project appeared to review several years of work and that it is evident that a large number of tasks have been included in the research over the year. The reviewer also commented that in the oral presentation of results, it was difficult to determine which results were for the most recent reporting year and which were part of earlier efforts, though the PowerPoint slides were clearer on this point. The reviewer suggested that in the future, the PI should attempt to stick with the most recent reporting year (since that is what is supposed to be evaluated) and to minimize background and past accomplishments. The reviewer suggested that the PI can be aided in this effort by simply requiring from his collaborators one slide that summarizes what they have done (in the past year) and perhaps one graph to show a representative quantitative result and an identifier of some sort on each of the supplied slides from a collaborator.

The reviewer also said the approach to materials taken by the PI is that skutterudites are attractive for TE modules and that his efforts have shown significant gains in thermoelectric efficiency (ZT=1.6 at around 800K).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that they have a strong team that is well coordinated and quite knowledgeable in addressing this project's challenges and issues. The reviewer continued by saying that the project team's analytic and experimental integration of thermal system design, TE system design, advanced power electronics design, and advanced TE materials (i.e., skutterudites) is very good and their module and power scale-up studies are also very good and show the collaboration within their team. The reviewer also said that this project team has accomplished as much or more than any of the other contractors on this project with somewhat limited funds compared to the other contractors.

A separate reviewer stated there were solid relationships with a number of groups. A separate reviewer said that this project shows an excellent collaboration between these groups and their efforts are well coordinated. The reviewer strongly believes that collaboration is the key to successfully achieving the objectives.

One reviewer said that the collaborations are good and the team is extensive. The reviewer also said that what specific contributions could be attributed to specific partners was not always evident, and that perhaps in the future the PI could be more specific on this point.

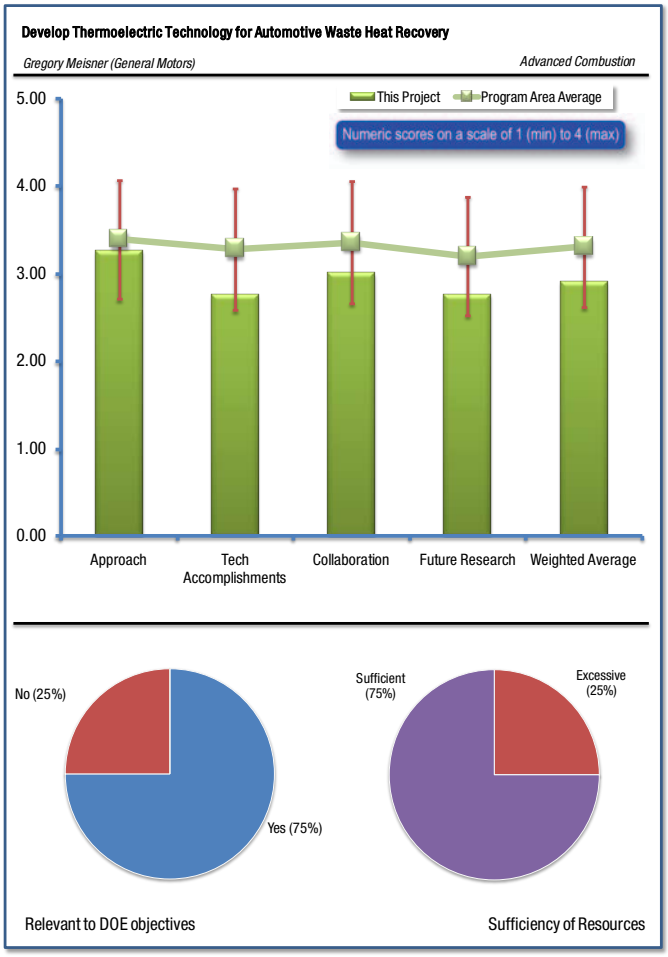
QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

One reviewer says that the team has a very good plan that is clearly based on their understanding of the barriers and the tasks. The reviewer strongly recommends that the MSU project continue to be funded so that they can successfully finish this very important task. One reviewer said that the way forward seems to focus on further material development with some work on interfaces. It was unclear to the reviewer what tasks would be continued given the apparent reduction of funding. A separate reviewer believed that the program is being scaled back and plans are uncertain. One reviewer said that the program's plans for building a 1 kW TEG prototype are very good and exactly the right step. The reviewer added that it builds and leverages nicely on their current progress and accomplishments.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that this was an excellent presentation. The reviewer added that the presenter as well as the team has well demonstrated their efforts in successfully achieving the objectives. The reviewer believes that the resources seem to be insufficient for the MSU team to achieve the goals in a timely fashion. The reviewer strongly recommends to DOE that this project should continue to be funded at a higher level of funding until we have a final product that can be used on any IC engine powered vehicles. A reviewer said that the resources are adequate for the funding allocated to this project, adding that there has evidently been some scale-down in funding but still a lot of work is being pursued. A separate reviewer said that there was an appropriate level of funding.

Develop Thermoelectric Technology for Automotive Waste Heat Recovery: Gregory Meisner (General Motors)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

One reviewer suggested improved vehicle efficiency as an aspect of relevance. A reviewer stated that this project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and lower emission, adding that using thermoelectric as a way to harness the energy from waste heat will also cut down the weight of vehicles by not carrying auxiliary power sources. One reviewer commented that they are currently only using bismuth telluride in their thermoelectric generator (TEG) design to demonstrate their system design. The reviewer believes that this bismuth telluride system will not perform at high enough power levels to impact fuel economy and taking this approach will not bring this TEG system to a commercially viable product fast enough. The reviewer added that the team is generally making only small, evolutionary progress compared to other teams.

A separate reviewer stated that this project began in 2005 and thus far about $13 million has been invested. The reviewer added that the overarching goal is integration of TE modules into automotive systems for waste heat recovery. The reviewer continued by stating that the specific objectives have included completing construction of a TEG, modifying a specific vehicle to accommodate a TEG, and fabricating TEG modules. The reviewer also noted that the effort also includes improving ZT and other thermo-mechanical properties of skutterudites (which appear to be the material targeted), though Bi_2Te_2 seems to be integrated in the TEG constructed.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said that the approach is reasonable and can be improved to overcome some barriers such as weight, size and volume. The reviewer believes these are very important in making the waste heat recovery TEG unit acceptable. A reviewer said that there was a good approach with initial modeling, material development, and now vehicle demonstration. A separate reviewer commented that the project began with developing a model to design TEG and to use the model to design, fabricate and assemble a prototype TE generator. The reviewer continued by saying that power electronics for power conditioning, algorithms for controlling thermal to electrical conversion and improved TE materials (skutterudites) constitute the main work of the effort. The reviewer added that in the module developed, Bi_2Te_3 was used.

A reviewer said that using a Chevy Suburban as a demonstration vehicle is a good approach and the team's thermoelectric (TE) system sectioning approach is a proper design approach. The reviewer continued by saying that the presentation gave no details on the energy flows in each section and the exhaust temperature profiles that justify why this approach was taken or what the benefit is from this approach in their application. The reviewer suggested that with a power output of only 350 W average, there is some question as to whether this sectioned design is truly optimized.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer stated that the project had shown solid accomplishments, but unfortunately, real world operation of LD vehicles has low exhaust energy availability and original program goals are not likely to be met. A separate reviewer said that a thermoelectric generator design was fabricated for an exhaust system using Bi_2Te_3 TE materials and that the details were shown of the design in a particular model car. The reviewer added that the TEG modules were fabricated by Marlow. The reviewer continued by saying the skutterudites with ZT of 1.6 at 800K were shown. The reviewer also said that the collaboration with UNLV examined how formation of nano precipitates could reduce thermal conductivity.

A reviewer said that GM needs to show some concern about the weight of the TEG even at the initial design level, since weight is a very important factor in determining the fuel efficiency as well as the applicability of the TEG. The reviewer added that a big and heavy TEG unit will defeat the purpose of improving fuel efficiency when it is used on vehicles.

One reviewer felt that the team has told little in this presentation and that it is difficult to assess their progress and accomplishments. The reviewer is quite concerned that they do not know the TEG weight and impacts of that weight on vehicle performance. The reviewer adds that if this system is too heavy, then any net fuel economy impacts will be small and possibly negligible. The reviewer felt that the project had relayed very little on their systems design, thermal design, TE design, and weight impacts on vehicle performance. The reviewer added that there is no energy diagram showing the details of temperatures and heat flows in the two sections, nor any discussion of the tradeoffs between energy flows, exhaust temperatures, and power in the two sections. Because of this the reviewer found it difficult to assess whether the average power of 350 W is the best that can be achieved with their system. The reviewer added that even after reviewer questions on the second section design, GM offered no further explanation on the design specifics. There was little or no discussion on how much fuel economy improvement was possible with a 350 W system and how weight impacts factored into that evaluation.

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that the team of collaborators is extensive, with most concerned with the materials and fabrication concepts. A separate reviewer stated that it is a large, well-integrated team. A separate reviewer commented that they have a strong team with reasonable collaboration and coordination. However, given the strong team on paper, there seems to be (relatively-speaking) less progress on this project. The fact that they lost General Electric on their team has been a detriment to their project. One reviewer suggested that the coordination between partners could be improved to provide a means for a better design of TEG.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer said that future work will provide test results for an initial TEG, assembly of a second generation TEG with full electrical system components, perform dynamometer tests for a vehicle equipped with a TEG, and finally demonstrating fuel economy gain. For the latter, the reviewer said, even without any weight optimization of the TEG, the PI's results have shown a 5% improvement of fuel economy. The reviewer continued that the plan is to continue to examine skutterudites and suggested that the team should consider their availability to meet potential demand. The reviewer feels that future presentations should mention this issue.

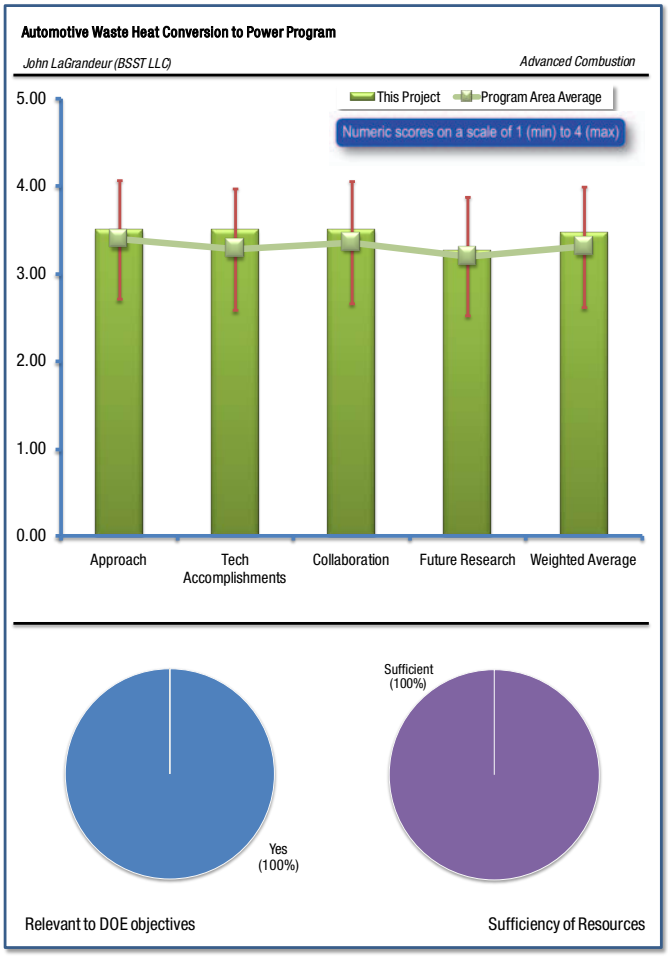
A separate reviewer felt that plans for incorporating higher performance skutterudite materials are too slow. The reviewer added that their average power output is relatively small, and it is not clear that this power output will impact vehicle performance all that much or this team's approach will ultimately achieve close to the VTP project goals. The reviewer adds that the system design shows only a fair amount of innovation and the fact that they do not know their system weight at this point (or would not answer the question) is not a good indicator.

One reviewer recommended that GM should look at a more practical TEG design for their proposed future research. They need to pay attention to size, weight and volume for the TEG as well as the cost. The separate reviewer suggested that program be finished.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

A reviewer said that the funding was appropriate. One reviewer felt that the investment of $13 million is quite extensive over the past five years and that from the information it was unclear if there was sufficient return on this investment. The reviewer suggested that perhaps GM's overhead is very high which would account for the high costs. One reviewer felt that the resources provided for the project are excessive. The reviewer recommends that funding should be adjusted to reflect the progress has been made by the GM team.

Automotive Waste Heat Conversion to Power Program: John LaGrandeur (BSST LLC)



Reviewer Sample Size

This project had a total of 4 reviewers.

Question 1: Does this project support the overall DOE objective of petroleum displacement? Why or why not?

A reviewer said that the project supports the overall DOE objectives of petroleum displacement by making the vehicles more fuel efficient and less pollutants, adding that using thermoelectric as a way to harness the energy from waste heat and will also cut down the weight of vehicles by not requiring auxiliary power sources.

A reviewer said that this project began in 2004 and includes a range of collaborators (Ford, BMW, Visteon, JPL, Caltech, NREL, Virginia Tech, Faurecia). The reviewer added that the emphasis is on waste heat recovery, which is consistent with DOE's emphasis on improvement in fuel economy in automobiles.

A separate reviewer said that while the project does support DOE objectives, it is only a reserved "Yes" because their power level is only barely large enough to start impacting fuel economy. Their build and test of a 500 watt TEG system at NREL is quite significant in moving the technology forward. While their power output is starting to become large enough that they can impact the fuel economy in a light-duty vehicle, it is concerning that they are not planning to go above 500 watts. This represents a significant reduction / retrenchment (~33% reduction) from the 750 watt power level this team was proclaiming and committing to earlier in their project. There was little or no discussion in the presentation on why they had to degrade their power output. One reviewer noted improved vehicle efficiency.

Question 2: What is your assessment of the approach to performing the work? To what degree are technical barriers addressed? Is the project well-designed, feasible, and integrated with other efforts?

A reviewer said there was a good approach with appropriate modeling, component level testing, and system plans and a useful improvement had been shown in each phase. A reviewer said the project objectives include developing a TEG architecture that improves manufacturability of TE engines and assemblies, evaluating and optimizing TE interfaces, and simplifying the TEG vehicle system including a reduction in the overall size and weight. The reviewer added that the project effort also includes testing interfaces (brazes, solders, liquid metals, etc). The reviewer continued by saying that this year a 500W TEG was build and tested (some experimental difficulties were noted that included leaks, which pushed back the milestone schedule for dynamometer testing), adding that the circular TE module was evaluated in a bench scale arrangement. The reviewer continued that the testing included evaluating interface materials and determining the temperature drops across the module. Cartridge heaters provided precise control of the heat input. The reviewer added that both individual TE elements testing and module testing of the hoop arrangement were carried out.

A reviewer said that the project team has a good understanding of the thermal and TE system problems and challenges of developing and fabricating the TEG system. The reviewer continued by saying that the validation of the robustness of thermal and electrical interfaces was very good and the team's use and consideration of half-heusler materials and TE element segmentation is very good. The reviewer said this will ultimately help to increase their power output. The reviewer felt that the presentation lacked a system-level

discussion of how much a 500 watt TE power system could ultimately impact fuel economy. The reviewer noted that they had showed in 2009 that this impact could be 1.5 - 3.3% with ZT's ~ 1.25 and would only get to a 4.5 -5% level if ZT's ~ 2. The reviewer felt there was no plan apparent for achieving material ZT's ~ 2, so the only conclusion is that their impact on fuel economy with system is in the 1.5 - 3 % range, and this is low compared to the VTP goal.

A reviewer said that the approach can be improved not only by paying attention to the mechanical design of the heat exchanger but also on the TE materials development. The reviewer suggested that better TE materials that can be used at higher temperature are important in vehicle applications. The reviewer felt that the presenter did not sufficiently address the question of substrate material at high temperature. The reviewer continued by saying that the coefficient of thermal expansion, thermal conductivity as well as electrical conductivity all are important factors in selecting an appropriate substrate material for high temperature applications. The reviewer would like to have a rather clearer explanation from BSST on how they choose the substrate, especially on the high temperature side.

QUESTION 3: CHARACTERIZE YOUR UNDERSTANDING OF THE TECHNICAL ACCOMPLISHMENTS AND PROGRESS TOWARD OVERALL PROJECT AND DOE GOALS.

A reviewer said that there was good understanding of the importance of weight in the overall fuel economy requirement and the problem of back pressure had also been addressed. A separate reviewer commented that there had been good results so far.

A reviewer said the project's transition from a planar TEG design to a cylindrical system was particularly important, adding that the thermal cycling of their devices/assemblies at 100 to 1000 cycles is very good. The reviewer continued by saying that the TEG modeling and integrated TEG / vehicle modeling has been effective and quite helpful in enabling their team to move forward on their designs. The reviewer added that the fact that their TEG system weight is around 10 kg is quite good. The reviewer found it somewhat disappointing that the project team is only targeting about 500 watts in their final system. The reviewer stated that this represents a significant reduction / retrenchment from the 750 watt power level this team was proclaiming and committing to earlier in the project. The reviewer felt there was little or no discussion in the presentation on why the power output was degraded. The reviewer also said there was little or no discussion in the presentation concerning what impact a 500 watt system could have on fuel economy. The reviewer acknowledged that it was shown in their 2009 review. The reviewer believes the impact on fuel economy is small compared to VTP goals over an entire drive cycle. (Some of the results reported were from past years which was a bit distracting, though nonetheless interesting to see, to evaluating the work over the past year.)

One reviewer said that the Phase 3 planar form was redesigned into a cylindrical form to improve manufacturability and that this design is potentially significant. The reviewer added that a predictive model for TEG performance was developed and compared with measured I-V measurement and that design requirements and modeling of TEG temperature was also addressed. The reviewer continued by saying that exhaust system modeling was performed to achieve back pressure (an effort of Faurecia).

QUESTION 4: WHAT IS YOUR ASSESSMENT OF THE LEVEL OF COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS?

A reviewer said that this was a strong team and they have demonstrated very good collaboration and coordination in developing and testing their 500 watt and 125 watt systems, and developing and optimizing their engine and exhaust system interfaces. A separate reviewer said that this was an excellent team that combines two OEMs, suppliers, and academia. The reviewer added that it sounds like production will launch in a couple of years.

One reviewer stated that collaborations include teaming with Ohio State, Northwestern for materials characterization, adding that the PI has done a lot of work with the team he has assembled.

A reviewer said collaboration with a car company such as BMW and Ford is a good chance for this team to transition the technology directly to the consumers. The reviewer also noted that the cost analysis as well as TE materials availability and low cost manufacturing process were not discussed in the presentation.

QUESTION 5: HAS THE PROJECT EFFECTIVELY PLANNED ITS FUTURE WORK IN A LOGICAL MANNER BY INCORPORATING APPROPRIATE DECISION POINTS, CONSIDERING BARRIERS TO THE REALIZATION OF THE PROPOSED TECHNOLOGY, AND, WHEN SENSIBLE, MITIGATING RISK BY PROVIDING ALTERNATE DEVELOPMENT PATHWAYS?

A reviewer suggested that the team keep going adding that future production plans are encouraging. A separate reviewer suggested that future research should focus not only on the technology but also on low cost material and low cost manufacturing process. The reviewer felt that these should be included in the presentation along with the cost analysis One reviewer said that their plans for vehicle performance testing at BMW, Ford, and NREL are logically thought out and their timing is good for commercializing this technology more quickly than other teams. The reviewer added that their retrenchment / reduction to a 500 watt system is cause for concern, especially with little discussion as to why the project incurred the power reduction and what might be done to re-claim the power reduction in the future. The reviewer felt it was not clear how the team plans to achieve a higher impact on fuel economy (closer to VTP goals) with their current system. One reviewer noted that the program ends this year and dynamometer testing still remains to be done. The reviewer added that this would constitute a phase 4 effort and a phase 5 objective would include TEG installation and evaluation in BMW and Ford Fusion Vehicles.

QUESTION 6: HOW SUFFICIENT ARE THE RESOURCES FOR THE PROJECT TO ACHIEVE THE STATED MILESTONES IN A TIMELY FASHION?

One reviewer said that the project is indicated as being completed (this phase) in October 2010. A separate reviewer said that the resources are sufficient for the BSST team to carry out the project in a timely fashion. A different reviewer felt that current funding was appropriate.