
2005

MERIT REVIEW & PEER EVALUATION REPORT

FUELS TECHNOLOGIES PROGRAM

*Less dependence on foreign oil, and
eventual transition to an emissions-free,
petroleum-free vehicle*

F R E E D O M C A R A N D V E H I C L E T E C H N O L O G I E S P R O G R A M



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**
Bringing you a prosperous future where energy
is clean, abundant, reliable, and affordable





Department of Energy

Washington, DC 20585

August 2005

Dear Colleague:

This document summarizes the comments provided by the Review Panel for the FY 2005 Department of Energy (DOE) Fuels Technologies Program Merit Review and Peer Evaluation Meeting, held March 7-9, 2005 in Golden, Colorado. The goal of this document is to provide the reader with a summary of the comments and scores from over twenty reviewers from industry and government on these fuels technologies projects.

The format used in this report is similar to that used in the long-running Advanced Combustion and Emission Control Merit Review and Peer Evaluation for DOE National Laboratory Projects. Information is provided both on a quantitative basis (through project review scores) and a qualitative basis (through reviewer text comments) to outline reviewer opinions on these activities.

Thank you for participating in the FY 2005 DOE Fuels Technologies Program Merit Review Meeting. Please feel free to provide suggestions for improving this meeting in the future.

A handwritten signature in blue ink, appearing to read "Steve Goguen".

Steve Goguen, Team Leader
Fuels Technologies
FreedomCAR and Vehicle Technologies Program

A handwritten signature in blue ink, appearing to read "Kevin Stork".

Kevin Stork, Technology Manager
Fuels Technologies
FreedomCAR and Vehicle Technologies Program

cc: Ed Wall
Connie Bezanson
Tien Duong
James Eberhardt
John Fairbanks
Roland Gravel
Rogelio Sullivan
Phyllis Yoshida

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Introduction

This report is a summary and analysis of comments from the review panel at the FY 2005 DOE Fuels Technologies Program Merit Review and Peer Evaluation, held March 7-9, 2005 in Golden, Colorado. The work evaluated in this document supports the FreedomCAR and Vehicle Technologies Program. The results of this merit review and peer evaluation are major inputs used by DOE in making its funding decisions for the upcoming fiscal year. The objectives of this meeting were to:

- Review and evaluate FY 2005 accomplishments and FY 2006 plans for DOE programs in fuels technologies.
- Provide an opportunity for industry program participants (engine manufacturers, emission control manufacturers, vehicle manufacturers, etc.) to shape the DOE-sponsored R&D program so that the highest priority technical barriers are addressed. The meeting also serves to facilitate technology transfer.
- Foster interactions among the national laboratories conducting the R&D.

The Review Panel members, listed in Table 1, attended the meeting and provided comments on the projects presented. They are peer experts from a variety of related backgrounds including automobile and truck companies, engine manufacturers, emission control system manufacturers, fuel producers, universities, and other U.S. Government agencies. A complete list of the meeting participants is presented as an appendix.

Table 1: Review Panel Members

Member Name	Affiliation
Brent Bailey	Coordinating Research Council
Rodica Baranescu	International Truck and Engine Corporation
Ewa Bardasz	Lubrizol Corporation
Loren Beard	DaimlerChrysler Corporation
Norm Brinkman	General Motors Corporation
Tom Brotherton	CALSTART
Vinod Duggal	Cummins Inc.
King Eng	Shell Global Solutions (US) Inc.
John Farrell	ExxonMobil Corporation
John Gordon	John Deere Power Systems
Henry Hogo	South Coast Air Quality Management District
Steve Howell	MARC – IV Consulting (representing National Biodiesel Board)
Shang Hsiung	U.S. Department of Transportation
Jeff Jetter	Honda R&D Americas
Yury Kalish	Detroit Diesel Corporation
Vance Kopp	Suncor Energy Inc.
Ken Murphy	Mack Trucks, Inc.
Harry Sigworth	ChevronTexaco Corporation
James Simnick	BP America
Jerry Wiens	California Energy Commission

Analysis Method

As shown in Table 1, a total of twenty advisory panel members participated in the merit review. A total of 22 project presentations were given at the meeting (excluding two overview presentations from DOE staff), and a total of 337 review sheets were received from the review panel members (not every panel member reviewed every project). Review panel members were asked to provide numeric scores (on a scale of one to four, with four being the highest) for five aspects of the research on their review form, a sample of which can be found as an appendix to this report. The five aspects were:

- Relevance to overall DOE objectives;
- Approach to performing the research and development;
- Technical accomplishments and progress toward achieving the project and DOE goals;
- Technology transfer and collaborations with industries, universities, and other laboratories; and
- Approach to and relevance of proposed future research.

The numeric scores given to each project by the reviewers were averaged to provide the overall score for that project for each of the five criteria. An overall average on the individual criteria for all the projects presented at this review was also developed.

Reviewers were also asked to provide qualitative comments on the five research aspects, as well as on the specific strengths and weaknesses of the project and any recommendations for additions or deletions to the work scope. These comments, along with the quantitative scores, were placed into a database for easy retrieval and analysis. These comments are summarized in the following sections, with an indication of how many reviewers provided written comments for that project and that question. All reviewers of a given project provided a numeric score for each of the five criteria, but did not necessarily provide qualitative comments.

Organization of the Report

The main body of this report begins with a summary page with the average scores for each of the five criteria for all of the projects, highlighting the highest scores for each of the five scoring aspects and the category average for those aspects. A brief description of the research being performed is also presented.

The remaining pages present the results of the analysis for each of the projects discussed at the merit review. Graphs showing how the particular project compared with other projects in this review are presented, showing averages, highs, and lows for the set of review projects overlaid on each given project's average score. A summary of the qualitative comments is also provided to summarize the important points made by each reviewer relative to the project's activities.



Fuels Technologies Program R&D Projects

The Fuels Technologies Program at the Department of Energy FreedomCAR and Vehicle Technologies Program has two main goals. First, by 2007, identify fuel formulations optimized for use in 2007-2010 technology diesel engines that incorporate use of non-petroleum-based blending components with the potential to achieve at least a 5 percent replacement of petroleum fuels. Second, by 2010, identify fuel formulations optimized for use in advanced combustion engines (2010-2020) providing high efficiency and very low emissions, and validate that at least 5 percent replacement of petroleum fuels could be achieved in the following decade. Projects in this program are geared toward meeting these goals in both petroleum fuels and non-petroleum fuels arenas, and are working toward identifying fuel properties important to advanced combustion engines and toward identification of viable fuel formulation for advanced combustion engines.

Below is a summary of average scores for 2005 for the 22 projects in this program, along with the average, minimum, and maximum score for all projects in this report. The highest score in this category for each question is highlighted. Projects are grouped first by the presenting organization, then alphabetically by title.

Summary of Scores for Projects

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score
5	<i>Natural Gas Vehicle Activities-Infrastructure Development:</i> Dennis Smith (U.S. Department of Energy)	2.93	3.00	2.93	2.93	2.60
8	<i>On-board Fuel Desulfurization Filter:</i> Ron Rohrbach (Honeywell)	3.00	3.06	2.81	2.81	2.81
11	<i>Advanced Petroleum Based Fuels – Diesel Emission Control (APBF-DEC) Study:</i> Shawn Whitacre (National Renewable Energy Laboratory)	3.60	3.53	3.20	3.93	2.60
14	<i>Biodiesel Quality and Stability:</i> Bob McCormick (National Renewable Energy Laboratory)	3.57	3.21	3.00	3.36	3.14
17	<i>DOE's Gasoline/Diesel PM Split Study:</i> Doug Lawson (National Renewable Energy Laboratory)	3.25	3.50	3.38	3.63	3.00
20	<i>Evaluation of Fleet Operating Experience with Biodiesel:</i> Ken Proc (National Renewable Energy Laboratory)	3.56	3.25	3.06	3.00	2.88
23	<i>Gaseous Fuels Technology Transfer and Industry Coordination:</i> Richard Parish (National Renewable Energy Laboratory)	3.20	3.07	2.93	3.27	2.73
26	<i>HCCI with Synthetic Fuels of Varying Boiling Range and Ignition Quality (with Volvo/Mack/Sturman):</i> Joshua Taylor (National Renewable Energy Laboratory)	3.38	3.13	2.94	3.25	3.00
29	<i>Next Generation Natural Gas Vehicle (NGNGV) Activity:</i> Richard Parish (National Renewable Energy Laboratory)	3.06	3.25	3.19	3.63	2.94
32	<i>Performance of GTL Fuels: Fuel-Engine Compatibility and Achieving Low Emissions:</i> Teresa Alleman (National Renewable Energy Laboratory)	3.13	3.07	3.07	3.53	2.87
35	<i>Relating Fuel Molecular Structure to Ignition Properties in Advanced Engines:</i> Joshua Taylor (National Renewable Energy Laboratory)	3.25	3.19	3.06	2.44	3.13
39	<i>Testing of Biodiesel Fuels and Blends in a Modern Production Medium-Duty Engine:</i> Bob Hayes (National Renewable Energy Laboratory)	3.31	3.31	3.06	3.00	3.00
42	<i>Weekday/Weekend Ozone Studies:</i> Doug Lawson (National Renewable Energy Laboratory)	3.21	3.64	3.50	3.57	3.07
45	<i>Effect of Fuel Sulfur & Engine Operating Parameters on Corrosivity Associated w/EGR in HD Dsl Eng.:</i> Mike Kass (Oak Ridge National Laboratory)	3.00	3.21	3.07	2.86	2.79
48	<i>Fuel and Emission Control System Effects on Unregulated Emissions in APBF-DEC:</i> John Storey (Oak Ridge National Laboratory)	3.20	3.60	3.33	3.47	3.33

Page Number for Project Summary	Research Project Title	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score
51	<i>Fuel Effects on Gasoline-Based HCCI Performance and Emissions:</i> Bruce Bunting (Oak Ridge National Laboratory)	3.06	3.00	3.00	2.71	2.71
55	<i>Fuel Property Effects on Diesel High-Efficiency Clean Combustion:</i> Scott Sluder (Oak Ridge National Laboratory)	3.20	3.13	3.00	2.53	3.00
58	<i>HC-SCR with Fuel-Borne Reductants:</i> John Thomas (Oak Ridge National Laboratory)	2.47	2.67	2.80	2.33	2.53
61	<i>Rapid Aging of Lean NOx Traps for Diesel Applications:</i> Todd Toops (Oak Ridge National Laboratory)	3.07	3.27	3.13	3.13	3.07
63	<i>Transportation, Fate, and Impact of Lube Oil Phosphorus:</i> Bruce Bunting (Oak Ridge National Laboratory)	2.94	3.19	2.94	2.88	2.75
66	<i>Optical-Engine Studies of Fuel Effects on Low-Temperature and CIDI Combustion Processes:</i> Chuck Mueller (Sandia National Laboratories)	3.06	3.38	3.38	3.25	3.25
69	<i>Advanced Technologies in Real-World Use:</i> Nigel Clark (West Virginia University)	3.07	3.36	3.43	3.14	3.14

Overall Program Scores

	Q1 Relevance Score	Q2 Approach Score	Q3 Technical Accomplishments Score	Q4 Tech Transfer Score	Q5 Future Research Score
<i>Overall Program Average</i>	3.16	3.23	3.10	3.12	2.92
<i>Overall Program Maximum</i>	3.60	3.64	3.50	3.93	3.33
<i>Overall Program Minimum</i>	2.47	2.67	2.80	2.33	2.53



Fuels Technologies Program

Natural Gas Vehicle Activities-Infrastructure Development, Dennis Smith of the U.S. Department of Energy

Brief Summary of Project

This project involved several natural gas infrastructure activities, including a safety analysis of FuelMaker's home natural gas refueling appliance, a project with SunLine Transit in California to use a hydrogen-CNG blend in transit buses, and a project to capture, clean using a CO₂ wash technology, and use landfill gas in natural gas refuse trucks.

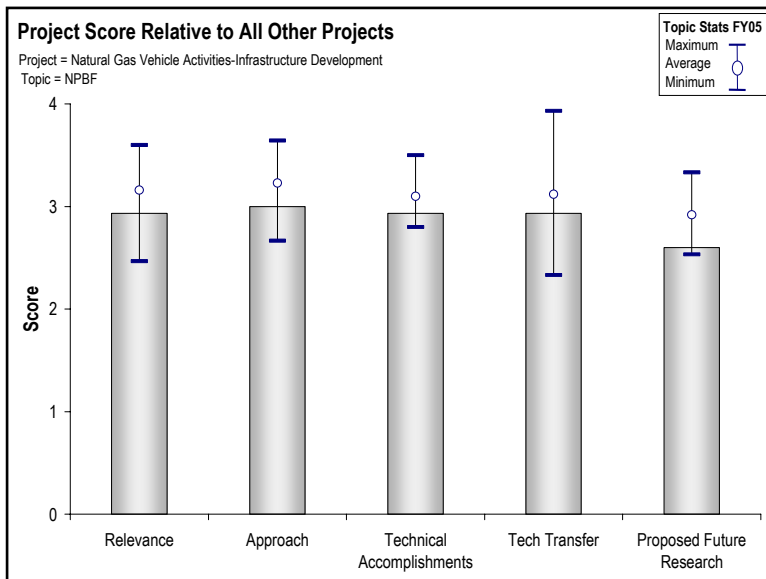
Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 15 reviewers)

The reviewer comments regarding relevance of this research to the overall DOE objectives were mixed. One person said that this project has a good focus and is an area where it makes clear sense for DOE to take the lead. One person thought that

understanding, promoting and developing infrastructure for natural gas seems beneficial to ensure that it can be used in a safe, reliable manner. A comment was made that landfill gas usage was a potential "home run." One reviewer noted that this project is addressing the safety of natural gas and the refueling infrastructure. Another reviewer mentioned that the presenter did not show how the project applies to the DOE objectives, but the application is good. One person commented that after more than 15 years of CNG, there seems to be a movement away from this alternative. Another added that the infrastructure cost remains a major hurdle for heavy-duty fleets, one that will not change, not only for the refueling station, but also for the modifications to any existing facilities to bring them up to code. He added that this is a classic case where the commercial market has not adopted the technology. A comment was made that natural gas research might not be a viable path to a hydrogen economy. One reviewer did not see over-the-highway operation as a good application for natural gas. He added that centrally fueled fleets make much more sense. Finally, a reviewer offered that this is an excellent and well-run program, but that natural gas engine development does not fit in with stated goals and intentions of the FreedomCAR Fuels technology program that are totally focused on diesel technology. Natural gas is also not renewable, noted this reviewer, although the program can work on non-renewable fuels. This work appears not to be a fit with this program at all, although this reviewer believed it is important for the natural gas industry and believed we will need every fuel available to meet future needs. Perhaps other DOE programs would be better suited for this work.

Question 2: Approach to performing the research and development (Written responses from 8 of 15 reviewers)

A few reviewers expressed concerns about the approach of this research while other agreed with the approach. One reviewer felt that this project provides the needed leadership to expand natural gas applications. Another person thought that the tech transfer for infrastructure development is important for reaching DOE commercial impacts goals. One person thought that it was good to see coupling with hydrogen efforts. To one reviewer it was not clear if hythane is the best segue to a hydrogen infrastructure. He said that natural gas reforming at the point of fueling is another approach, but was not mentioned in the presentation. He also added that natural gas reforming and co-generation have the potential for application at individual businesses and homes. Someone thought that the long-term commercial aspects look bleak. Another reviewer felt that the approach to the research was not well discussed and that this was more of a "position" talk. Someone thought that centrally fueled fleets would be a better fit. He added that except for landfill gas, natural gas is not a "renewable" resource and it looks like a significant amount of it will be imported. Finally, a reviewer said issues associated with CNG infrastructure are being addressed in a thoughtful and scientific manner. The missing component seems to be consumer and user education, but the reviewer was not sure whether this was the purpose of this particular piece of the efforts.



Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 15 reviewers)

The comments were generally positive regarding this question. One reviewer complimented the results and made a note of the 3.6 million gallons/year displacement of diesel fuel. Another offered an opposing view that the program has made good progress toward barriers, but 3 million gallons of fuel displacement is a pretty poor return on dollars spent. Another agreed with the assessment of results and said that good progress was shown. One person liked the work because landfill gas is renewable. It was asked if it is true that the ICTC is being used to warrant the investment made or is it more similar to the case of the electric charging station network established in the Los Angeles basin area that is now mostly unused. This reviewer added that the current California Hydrogen Net is focused on light-duty vehicles whereas the ICTC is focused on heavy-duty fleets, and questioned if those will be compatible. One person mentioned that not much was discussed in regard to technical accomplishments.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 9 of 15 reviewers)

The reviewer comments were positive regarding the technology transfer and outside collaboration. One reviewer liked the broad industry involvement. Another stated that the project is focused on technology transfer and close coordination with end users. One person mentioned that landfill gas work has some value and collaboration with Waste Management and Mack the right approach. Another reviewer agreed that collaboration with major fleets (and smaller light-duty fleets) would be very useful. He added that perhaps this is already in the works. According to the same reviewer, collaboration with Honda on home refueling projects would be a good fit for the DOE's objectives, especially when looking ahead to hydrogen infrastructure challenges. A comment was made that the interaction among stakeholders is good. However, someone mentioned that he did not hear of any stakeholders' input from the energy sector. A comment was made that the focus should be on landfill gas because it's renewable, could impact the Clean Cities program, and involves centrally fueled fleets. A reviewer said that technology transfer is premature to assess at this time; it should be good for this niche application (waste management resources and vehicles). The last reviewer said that coordination with industry has been excellent, but to spread this word to users and consumers would take a lot of effort and dollars: if this is not the intent of this particular program, this reviewer's ranking would be higher.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 15 reviewers)

Reviewers generally thought that there were no proposed future plans. One person felt that continuation is appropriate, but it is a scattered application of limited funds. One reviewer felt that this question was not covered. Another agreed and said that the extent of future work was not entirely clear. According to him, projects related to natural gas could use more funding, given the short-term potential for diesel fuel displacement and the long-term potential for distributed energy (including hydrogen). One person mentioned that the funding is targeted for zero and that it should reach that target. Another reviewer liked the future hydrogen home refueling appliance idea. A reviewer said that he had not seen where the project is heading, but that it could be a niche application for landfills.

Specific Strengths and Weaknesses (Written responses from 10 of 15 reviewers)

- Specific Strengths
 - Excellent program to promote the NGV.
 - Hydrogen CNG mixtures are interesting, but probably not a near term source for petroleum reduction in 2010.
 - Good industry involvement.
 - Good application of technology to reduce conventional fuel use and diversify supply.
 - Work on reducing petroleum savings by substitution of non-petroleum fuel.
 - Demonstration of process for clean methane from landfill.
 - Safety study of Fuelmaker.
 - Great opportunity to reduce reliance on petroleum-based fuels.
 - Landfill gas portion is of significant interest.
- Specific Weaknesses
 - Economic incentives not demonstrated in the presentation.
 - Blending hydrogen and natural gas was not conducted in a well-thought-out way; was the reduction in

- NOx emissions related to a change in combustion phasing that could be easily accomplished without hydrogen blending? This approach would have a negative impact on range, which is already a barrier.
- For natural gas light-duty vehicles, Fuelmaker did not address key barrier: cost of fuel tanks and customer acceptance of the technology.
 - Working on natural gas vehicles when OEMs have stopped building them. Diesel engines can be made cleaner, cheaper, and more efficient than any natural gas bus engines.
 - Not enough emphasis on centrally fueled fleets.
 - Other than landfill gas portion, comes across as a rather superficial lobbying effort for NGVs. More info to better judge credibility of the extremely positive TIAX FEMA safety analysis of home refueling appliance would be helpful. This would be helpful because historically, TIAX has had a reputation of overselling alternative fuels and lacking balance in its analyses.
 - No weaknesses, per se, but real questions about whether this work fits within the FreedomCAR program. I think it is good work and needed, but just doesn't fit in very well with the stated goals. Much more consumer and user education is needed for this to make significant market penetration.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 15 reviewers)

- Funding of these activities does not appear to fit well with the FreedomCAR program goals so, while these efforts are good and needed, it might be a better fit to place them in other programs.
- Cease work on natural gas.
- Need non-road natural gas applications.
- Show technology penetration and potential market development along with appropriate incentives necessary for broader commercial development.
- DOE needs to give greater recognition and support of natural gas issues and technologies if it expects to achieve real progress towards hydrogen.
- Focus on centrally fueled fleets and LFG. Many cities have their own landfills and could run city refuse, construction, and other municipally owned vehicles off the landfill. On the other hand, they could use GTL technology to create liquid fuels for the same purpose.
- "Acrion" process for scrubbing and recycling natural gas seems promising, if there is a net energy/environmental benefit to the process.
- Include economics of NGVs versus diesel and gasoline alternatives. This is typically the key factor in what fleet buyers and consumers look for, and helps a lot in explaining NGV "lessons learned," and does not appear to have been considered in this work.



Fuels Technologies Program

On-board Fuel Desulfurization Filter, Ron Rohrbach of Honeywell

Brief Summary of Project

The goal of this project is to develop a proof-of-concept desulfurization filter for use onboard a vehicle. This would remove sulfur from diesel fuel as an enabling technology for NOx adsorber technology. Researchers have developed filters at a one-gallon size and proved their functionality, and plan to make larger filters for engine testing.

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 16 reviewers)

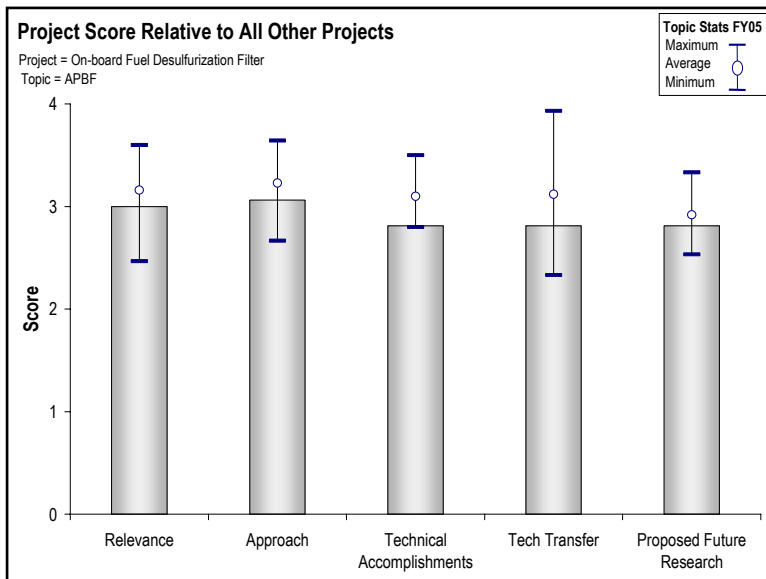
Several reviewers had positive comments, speaking of this project as addressing a practical problem, one noting the good alignment with DOE objectives to reduce petroleum consumption by allowing higher-sulfur fuel or by providing a polishing filter to protect catalysts. This reviewer said, however, that this work was needed three years ago before the US EPA diesel rulemaking. Others commented that this is a good fuel enabling technology with good alignment on systems to protect advanced emission control devices. Another commented that this is an interesting concept to solve the diesel fuel contamination problem. Another commented that the project is sharply focused because it is concentrating on a single important issue. Another person stated that the technology is only valid with ULSD fuels. This was echoed by a reviewer who said that this is a solid project, but is more related to the use of ULSD and its drawbacks than on the stated goals of replacing 5% with non-petroleum fuels. The work does provide further background which is useful knowledge in developing these replacement fuels, however. A reviewer understood the need for on-board cleaning of a fuel contaminated in the pipeline but wondered about the efficiency of a small on-board reactor and the effect on engine operation (thermal issues, packaging, etc.) The final reviewer added that contamination of ultra-low-sulfur fuel is anticipated to be a problem for some time. This technology offers a way to succeed with LNT technology.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

One reviewer felt the team used a solid approach, while another described the technical approach as “Edisonian.” Another said that the approach to accomplish the stated goals of the project is excellent, and that the investigators did a good job in screening potential candidates down to something manageable and then testing that subset in more detail. This was also seen in the remarks of a reviewer who commented that there was a good plan to screen candidates for absorbents, but another felt that the restriction to commercially available samples is a limitation. One reviewer had detailed comments regarding “distributed desulfurization,” noting it is not logical and should be done at the refinery. On-board desulfurization is problematic, due to challenges regarding packaging, durability, efficiency, practicality, etc. The EPA is unlikely to accept mandatory regeneration at low intervals such as 20,000 miles. Desulfurization at the refinery level will increase cetane number, assuming traditional methods are used. Another reviewer commented that the work is focusing on vehicles, but could also be done at fueling stations. The final reviewer felt that the presentation provided very few details on the approach and results, so was difficult to rate.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 10 of 16 reviewers)

One reviewer stated that the results look promising, while another added that there has been good progress, but the results reported indicate a lack of a sound assessment of the performance of the selected hardware. Others had questions about the results. One person commented that there was no explanation of the fuel property changes after filtration (specifically a huge increase in cetane number). Another felt that the “chemistry #1” is intriguing, but cautioned that the results look “too good”; resulting fuel properties are excellent. If this fuel analysis is



accurate, what were the downsides to this particular process? Other reviewers commented that a hypothesis was developed, but the limited data and the early stage of the project make it hard to rate. Another reviewer commented that 1% is too low capacity. The final reviewer commented that there are clearly proprietary issues that weren't communicated during the talk including the identity of the wonderful material they identified. Finally, a reviewer said that he felt the numeric scores are really a 4 for some areas and a 2 for some. A score of 4 reflects that some concrete reasoning was provided for narrowing the possibilities. A score of 2 reflects the fact that the best option is too big, the disposal costs of the collected sulfur compounds have not been addressed, and the removal of the sulfur has also destroyed the lubricity of the fuel to the point the fuel going into the injection system would no longer meet newly adopted ASTM standards. The researcher did not seem to know this was the case, which was very surprising to this reviewer: one of the biggest concerns of sulfur removal is lack of lubricity.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 12 of 16 reviewers)

Generally the comments were favorable, with many reviewers noting the good team of industry stakeholders being involved at all levels. One person felt it was positive that Honeywell led the project instead of a national lab. One reviewer commented that there must be huge intellectual property issues with this program, which could restrain technology transfer. Another agreed, adding that proprietary issues appear to be getting in the way. Another person commented that the researchers need much more input on confirming performance of the hardware. A reviewer said it is premature to think about integration before the validity of the concept can be proven. This reviewer noticed a drop in lubricity as sulfur is trapped; what does one do for this? Another suggested that feedback from a broad cross-section of OEMs should be solicited. Finally, one said that there was good collaboration with industry, but that more work is needed to share information.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 16 reviewers)

Many comments focused on the need to further develop future plans. One reviewer stated that the future plan needs help and oversight. Another stated that the researchers need more focus on future goals. A reviewer noted that the team needs to include lubricity testing after sulfur removal and include sulfur compound disposal costs. A reviewer said the team has the correct assessment; need to prove concept first, and need to design the hardware and integrate it with the engine. The final comment was that no investigation of fueling-station size units or their potential efficiency was planned.

Specific Strengths and Weaknesses (Written responses from 13 of 16 reviewers)

- Specific Strengths
 - Excellent DOE appropriate fuel study.
 - Solid approach.
 - Novel approach to protect vehicle catalytic systems.
 - Approach to the problem is really good.
 - Supports the NOx adsorption technology.
 - A solution to a very real problem. Lots of good “chemistry.”
 - Investigation of a large number of chemical approaches.
 - 6-Sigma approach, extensive screening.
 - Major sulfur reduction can benefit any sulfur intolerant aftertreatment solution. It is beneficial to show relevance to how contaminated fuel may be experienced.
 - Good work developing this concept, selecting adsorbent, and integrating into real systems.
- Specific Weaknesses
 - Need economic application for broad use, need to show all feasibility issues including how to dispose of the materials and fit the hardware in the engine.
 - Needs to show economics and integration into engines and vehicles.
 - Lack of actual data.
 - Limited data so far.
 - Screening/feasibility testing will likely lead to useful new technologies, regardless of the point of application.
 - Application requires vehicle maintenance in order to maintain performance of emissions control system.
 - Presentation gave no information on the adsorption capacity of the material or the breakthrough of sulfur



- as the filter accumulates sulfur.
- Not clear this moves toward the 5% replacement program goals, and lack of lubricity of fuel after sulfur removal makes the value of this work questionable.
- Still premature to assess feasibility.
- The main weakness is that open communication is hampered by proprietary issues. This work, as performed, could have been done in a National Lab (at least it seems to me). Simply screening the performance of all available materials doesn't require significant heterogeneous chemistry expertise. This research should include a much greater emphasis on fundamentals, such as why is material X better than the others? If this is understood, perhaps a new material could be identified with ten times the performance. The way this research is set up, one would never know. In summary, this work suffers from a lack of fundamental focus.
- Fueling station approach ignored.
- Presentation did not address performance in special situations. For example, how does the system perform with biodiesel blends; oxygenate additives being proposed by some; very low temperatures; very high temperatures, etc?

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 16 reviewers)

- Work on efficiency and cost. Understand the full material balance of materials in and out of the hardware.
- Because of the maintenance issues and volume required, this work should be directed toward taking sulfur out of the fuel at the refueling station or somewhere upstream of the vehicle.
- How will the vehicle owner react to another maintenance item? Some of the fuel data presented indicates that more than sulfur species are being absorbed (see fuel properties table).
- When is engine testing and field verification appropriate?
- Establish parameters for the proof of concept: sulfur removal domain; temperature range; size; engine effect.
- Include fueling station unit size study. Could be just a paper study at first.
- Proposed scope is good, but I suggest addressing performance in special situations. For example, how does the system perform with biodiesel blends; oxygenate additives being proposed by some; very low temperatures; very high temperatures, etc?
- Measure lubricity levels after sulfur removal, get clearer costs on disposal options, work proposed on vehicles is good... This is a necessary project for ULSD, but if one goes strictly by the program goals of 5% replacement it should not be funded by FCVT—it should be funded by some other DOE program.



Fuels Technologies Program

Advanced Petroleum-Based Fuels – Diesel Emission Control (APBF-DEC) Study, Shawn Whitacre of the National Renewable Energy Laboratory

Brief Summary of Project

APBF-DEC is a large industry-government collaboration among many key organizations, including vehicle and engine OEMs, emission control suppliers, energy companies, and government entities. The goal of the program is to identify combinations of fuels, lubricants, engines, and emission control systems to meet upcoming emission regulations while improving efficiency and durability, and meeting customer expectations for performance, and considering the potential for meeting additional constraints (like currently unregulated emissions). This project is wrapping up this year, with no current plans to develop follow-on efforts.

Question 1: Relevance to overall DOE Objectives (Written responses from 6 of 15 reviewers)

Reviewers mostly agreed on the importance of this project. One reviewer commented that this is very important work that has shown the limitations of NO_x adsorbers and the need for engine manufacturers to reduce engine-out emissions as part of meeting 2007/2010 emissions levels. Another mentioned that by providing a basis for reducing emissions and maintaining performance this project will help ensure that petroleum-based diesel and diesel engines can continue to operate and compete with other low-emission technologies. One noted that this is a textbook example of useful research for current engines and fuels. Another stated that it may not remove all the barriers, but at least many will be identified. One reviewer found the scope amazingly broad. One reviewer did not see the exact connection of results with program goals. Another thought that focusing on emission reduction, though important, doesn't support the objective of petroleum displacement.

Question 2: Approach to performing the research and development (Written responses from 7 of 15 reviewers)

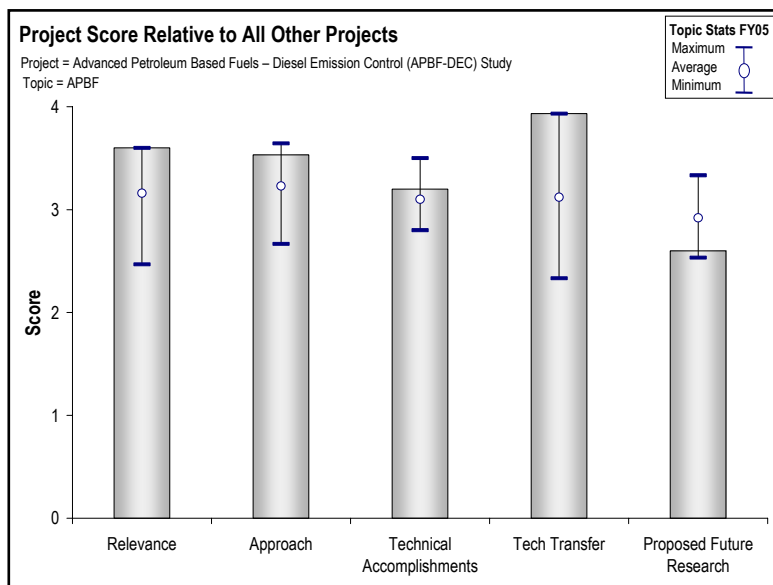
The comments regarding the approach were very positive. One reviewer stated that the objectives of the project were clearly met due to a well structured project. Another added that systems approach is the correct way to proceed and that they need to consider how to account for hybridization as well. One reviewer commented that this is a good approach to dealing with current diesel emission issues. One simply said that cooperation with industry partners is excellent and necessary. However, one reviewer was not sure how this program will reduce petroleum energy consumption. A reviewer commented on the multidimensional scope for precompetitive investigation (engines, emission control, fuel, and lubricants) and that the findings were transferable to OEMs for competitive development.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 15 reviewers)

Almost all of the reviewers agreed that this is excellent work, one saying that results were very impressive. One said that the work has pointed out that engine-out emission levels need to be reduced. Another felt that the project has provided a good basis for meeting the 2007 regulated standards. One reviewer stated that this is a world-wide recognized project. On the other hand, one said that this project has certainly identified issues, but not necessarily solutions. Another did not see what the calculated impact is on energy consumption.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 5 of 15 reviewers)

Reviewers were impressed by the collaboration with the industry. One comment was that there seems to be very



broad and engaged industry involvement. Another agreed and added that this project is well coordinated with industry as shown in the presentation. A third reviewer noted the large set of collaborators and felt this aspect of the program to be excellent. One reviewer was impressed that they were able to work with so many partners.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 11 of 15 reviewers)

Reviewers acknowledged that this project is ending and there is no future research plan. One reviewer added that since this project is just being completed, final reports are needed for all to review and provide feedback. To one reviewer it was not clear what the future work is or if it will continue. He acknowledged that APBF is ending and asked what is next in this area. One said that very little future work is planned, seemingly regardless of what stakeholders desire.

Specific Strengths and Weaknesses (Written responses from 12 of 15 reviewers)

- Specific Strengths
 - A nicely run program that has produced useful information.
 - Leading study on extremely important ultra-low-sulfur diesel fuel and NO_x aftertreatment issues, extremely valuable to diesel engine manufacturers.
 - Good real-world test of available technology.
 - Covered the main technologies (DPF, NO_x adsorber, and SCR) being considered for 2007/2010.
 - Identified and quantified lots of issues across a broad range of engines.
 - Relevance and timeliness; broad scope for emission control approaches, platforms, vehicular applications.
 - Aging tests for LNT systems with desulfation.
 - Collaboration of many stakeholders is a strength, working on real fuels with real engines today.
 - Collaboration with industry a real strength, durability testing is excellent.
 - Close cooperation among DOE, the Labs, and full industry.
 - Partnerships are good.
- Specific Weaknesses
 - Project will end.
 - From questions by the OEMs, additional efforts may be needed in this area.
 - Not clear how these efforts contribute to the program goals quantitatively.
 - What are the specific conclusions and recommendations sufficient to justify \$33 million spent?
 - Has been going on so long that what was pre-competitive has become competitive and potential solutions to some of the issues (new catalyst formulations, blending with combustion modes and control strategies, lube formulations, etc.) will be buried within each company and leave the picture incomplete.
 - Aftertreatment systems were “black boxes.”
 - It would have been good to compare urea and LNT on all systems.
 - DPF was not included.
 - More work in the area of NO_x aftertreatment and lubricant effects for Tier 2 Bin 5 LDDs would be welcome.
 - What other fuels would help? B20, FT, etc?
 - Not clear how the work ties back specifically to fuels--seems more of an aftertreatment technology study.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 9 of 15 reviewers)

- Expand research to nonroad engines and the Tier 4 regulations.
- Need better quantification of the technology performance and assessment of chances of commercialization and economic impacts or gaps that will prevent the utilization of the technology.
- Presentation was an overview of multiple projects. I'm not deeply familiar with all of these projects, so it's difficult to judge.
- In Steve Goguen's opening presentation, he mentioned that APBF will “issue new solicitation to identify fuel property requirements for post-2010 advanced internal combustion engines.” Does this mean that APBF will be extended beyond this fiscal year?
- Can this program provide clean input to facilitate decisions between SCR and NO_x adsorbers?
- Review decision to end the work.
- Additional comment - this project is one of several that originated many years ago; none of the historical context was provided, so for those like me who were hearing about this for the first time, a lot of the context

was missing. I know time was short and a prescribed format was used, but it would have been nice to see this slipped in.

- Make reports as complete as possible. This work is a prologue for 2010 and beyond.
- Need more information on impact of other heavy metals not currently monitored or controlled, which may be catalyst de-activators, with particular emphasis on metals that may be picked up in the petroleum transportation system from pipeline to terminal to dealer to the user. The platforms and testing would be a good model for B20 testing which is needed.



Fuels Technologies Program

Biodiesel Quality and Stability, Bob McCormick of the National Renewable Energy Laboratory

Brief Summary of Project

The purpose of this study is to survey the quality of in-use biodiesel supplies and address any quality issues that are identified. Researchers are also pursuing basic work in biodiesel stability and stability test methods. To date, much testing of B100 and B20 has been performed: most B100 met ASTM standards, but B20 splash blending has been identified as an issue causing variation in actual biodiesel concentration through insufficient mixing.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 14 reviewers)

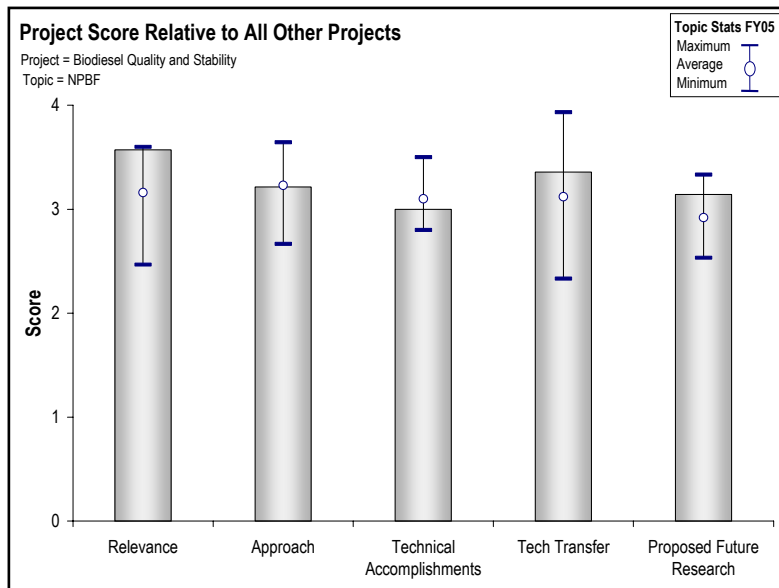
The majority of the reviewers felt that biodiesel quality and stability is an important area within non-petroleum based fuels (NPBF) and that this project is very relevant to the overall DOE objectives in regard to NPBF. A reviewer commented that biodiesel does appear to be a valid means to achieve the 5% replacement of petroleum fuels. A reviewer stated that this is an important area with good potential for petroleum displacement. Another commented that biodiesel stability/compatibility is a key component of the NPBF activities. Another reviewer added that this project is of key relevance to the overall DOE objectives of incorporating non-petroleum-based blends in diesel fuel. He added that biodiesel is renewable and the fuel properties lend themselves to blending with petroleum diesel. Fuel stability is by far the most critical issue in biodiesel compatibility with diesel fuel. One reviewer commented that this project will help integrate biodiesel into the commercial diesel fuel market by providing valuable data on production and stability. He also mentioned that identifying quality issues will help the technical community set the appropriate standards to ensure the fuel will perform in the commercial marketplace. Most of the reviewers agreed that this is a good project focused on a new fuel entering the market and that key technical questions are appropriate for DOE funded work. One comment was that there is a lot of stability work in this project, but asked about cold flow issues.

Question 2: Approach to performing the research and development (Written responses from 8 of 14 reviewers)

The reviewers recognized the importance of the project and provided some advice for future work. One said the approach was solid. One reviewer noted that the identification of structural differences between conventional and biodiesel fuel strongly supports the project rationale. Another commented that more specifics on the approach are needed to demonstrate how the approach will help meet the DOE goals. A reviewer advised the team to correlate the results from actual fleet operations and maintenance data with out-of-specification fuels. He also mentioned the need to address varying sources of biodiesel feedstocks and any correlation with operational issues, and that the blending issue needs to be tied also to fleet operations data for operations and maintenance. Another person felt that the scope should be expanded. It was not clear to reviewers what feedstocks were surveyed and if feedstock has an impact on stability. It was also mentioned that the project needs some energy companies on its collaborator team. A reviewer emphasized that the cold flow issues should be addressed.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 9 of 14 reviewers)

Reviewers' comments regarding technical accomplishments were mixed. One reviewer commented that overcoming the stability and quality issues with biodiesel will allow an opportunity for this fuel to integrate with petroleum based distillate products. He went on to say that for the fuel to have broad acceptance and distribution it is critical that stability and other properties are understood so that they can be managed properly. A reviewer said that the researchers achieved very good results with minimal funding compared to other Fuels Technology programs. Another complimented the technical work on understanding the oxidation of biodiesel. One felt that



the results to date have identified issues which would seem to be intuitive or readily apparent and that there is a lack of possible solutions at this stage. Another reviewer thought that this is a great start and the program should continue to collect information, especially from the material compatibility standpoint (CRC AVFL tie-in is valuable). One reviewer stated that the project accomplishments include some understanding of antioxidant content which affects the biodiesel fuel stability, but questioned how ambient temperature exacerbates the stability, which is an issue for the users. A comment was made that the chemical structures of biodiesel on early slide were shown as ketones, not esters. One reviewer emphasized that he realizes that it takes time to develop information, but more and more biofuel is finding its way into the market and it is important to avoid getting a “black eye.”

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 14 reviewers)

Reviewers acknowledged the collaboration with NBB and other parties (oil companies and OEMs). One reviewer mentioned that the cooperation with industry is critical and seems to be on track. Another reviewer stated that the key biodiesel quality issue concerns the fuel system and that the fuel system suppliers, most diesel engine companies and NBB appear to be actively engaged. He went on to say that strong industry participation will drive to address practical issues and facilitate technology transfer and applications quickly. Good interaction with Howard Fang at Cummins was acknowledged. One person mentioned that it is not a good sign that this work is receiving priority in the heavy-duty engine industry only at Cummins. Another reviewer thought that greater coordination with actual fleets using biodiesel is needed to correlate operating and maintenance data to fuel formulation issues. One commented that the input from Asian OEMs should be solicited. It was also mentioned that the disagreement over Rancimat test could slow things down. One simply said that collaboration with industry was excellent.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 14 reviewers)

Reviewers generally agreed with the proposed future research plan to expand the quality surveys and extend the detailed data analysis. A reviewer stated that the project seems to have focused on the critical items that (if not managed properly) could keep biodiesel from effective integration into the petroleum-based diesel market. He also said that once these items are understood and there is reasonable economic justification for the use of biodiesel, it should integrate very well. Another thought this is a good plan for the future of work on biodiesel. One reviewer stated that the future research is good, but should include ultra-low-sulfur fuels as well as other likely fuel components which are not well studied yet such as oil sands and Fischer-Tropsch diesel. This program should be funded at the middle level, or potentially the high level, instead of the low level, in this reviewer’s opinion.

Specific Strengths and Weaknesses (Written responses from 11 of 14 reviewers)

- Specific Strengths
 - Addresses a specific option for meeting the volume replacement goals.
 - Biodiesel survey starts the process of getting biodiesel to be an acceptable commercial reality.
 - Focus on key issue and develop fundamental understanding.
 - Researchers’ understanding of market needs.
 - Real-world work.
 - This research is on a fuel component that is in the market today. There are mandates for its use in certain markets.
 - Attempting to relate bench tests for stability to field performance. In depth stability work.
 - This is a significant issue for the biodiesel industry (whether they want to admit it or not), and Bob’s group is about the only group working here, and they are doing some very good work. It is very important to identify and correct problems before biodiesel really takes off; it may even cripple the biodiesel effort if problems are not addressed. The testing survey is an important effort. Also, Bob’s team plays a “tiger team” role in troubleshooting biodiesel. This really needs to be supported at an even higher level.
 - Understanding the basic chemistry and development of stability methods is excellent, as is the sampling of product from the field and cooperative work with the OEMs and National Biodiesel Industry.
 - Topic relevance, timeliness, industry coordination.
- Specific Weaknesses
 - Little information on how biodiesel will meet the cost goals.



- Correlation of fuel survey results with fleet durability/performance; making the conclusion that “operational problems are rarely caused by oxidative deposits,” without data supporting that.
- Fundamental understanding of biodiesel stability issues.
- Doesn’t identify fuel resource materials.
- Industrial partners do not include an energy company nor fuel manufacturer, serious weakness of this project.
- Not clear that cold flow issues are being addressed.
- Not enough scope allowed to really dive into troubleshooting specific biodiesel problems. Now is the time to better understand these issues, and Bob’s group is the team to do it.
- Need more data on S15 or ultra-low-sulfur fuels, need better correlation and understanding of impacts of fuel degradation which occurs in actual operation.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 12 of 14 reviewers)

- Need to define the stability requirements for biodiesel (ASTM specification). I'm not sure the chemical representation is correct in the presentation (slide 3). Cold temperature properties not emphasized.
- Need involvement of actual fleets using biodiesel and to relate analysis and data to real operating and maintenance issues that are being fuel-quality-driven.
- I recommend an expanded program with increased funding around fuel quality/durability-performance issues:
 - Regularly analyze fuels developed in fleet tests and compare durability/performance results with analysis results.
 - Detailed study of biodiesel oxidation from manufacture through blending throughout its life in the vehicle.
 - Oxidation pathway may be much different with B20 than normally seen in the food industry due to the presence of diesel fuel hydrocarbons and also due to the environment seen by the fuel in vehicle fuel tanks.
 - Involve OEMs in joint studies to investigate impact of poor quality biodiesel on vehicle durability and performance. Include winter issues in surveys and analysis.
 - Investigate and coordinate with European experience.
- Care should be taken to sample fuels on a representative basis, whenever possible; e.g. avoid over-sampling from a single source.
- Emphasize additive technology and test methods development.
- Needs to add focus on winter blending and any ethyl ester effects: needs to clearly spell out conclusions and recommendations.
- Add an energy company(s) to the industrial collaboration team.
- I'm curious whether there are interactions between biodiesel and regular diesel fuel composition (aromatics, PNA, etc). Maybe this work has been done before but I'm not a specialist in this area.
- Cold flow bench vs. field. Technologies to deal with potential cold flow issues with greater than 5% blends.
- This work merits even higher levels of funding; it is critical to the ultimate acceptance of biodiesel as a widespread fuel.
- Significant increase in correlating the stability data to field results in use, increase needed in evaluating various anti-oxidants with both B100 prior to blending and with B20 and B5 blends with more diesel fuels (i.e., F-T, oil sands, ULSD), continue efforts with specifications and fuel survey and double the total number of samples in fuel survey, more data collected and correlated with Europe.
- Project findings need to be leveraged to biodiesel industry’s quality implementation.
- In the future focus also on blends with ULSD.



Fuels Technologies Program

DOE's Gasoline/Diesel PM Split Study, Doug Lawson of the National Renewable Energy Laboratory

Brief Summary of Project

The overall objective of this work is to quantify the relative contribution of gasoline and diesel engines to particulate emissions in the South Coast air basin in California in order to verify emission inventories that are used to develop air quality management strategies. This project involved both vehicle dynamometer testing of light-duty and heavy-duty vehicles as well as ambient air quality sampling.

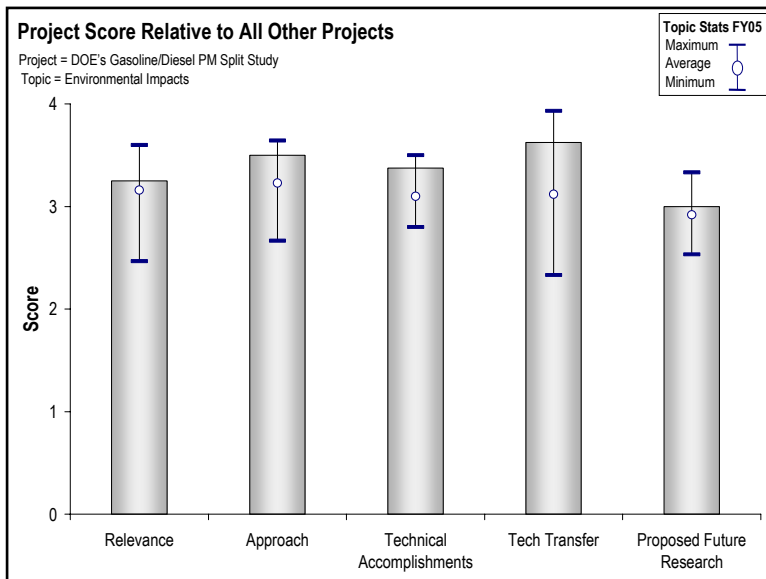
Question 1: Relevance to overall DOE Objectives (Written responses from 14 of 16 reviewers)

Many reviewers approved of the relevance of the project to DOE objectives, while a few questioned its relevance. One person thought that addressing potential environmental and health hazards of new fuels early in the process is the right approach.

Another added that distinguishing between particulates from gasoline and diesel is important. To one reviewer this seemed a thorough approach to the long-standing, contentious issue of source apportionment. One felt that this is an interesting research into PM and real-world air quality. He added that as emissions inventories are used to develop air quality management programs, these inventories should be verified to ensure that the best controls are put in place. Another felt this was really solid work and was necessary to make sure that proper impacts of diesel technology for the FCVT are treated appropriately. This is an important project for correct assessment of the contribution of gasoline and diesel engines to emissions, said a reviewer. Another stated that this is groundbreaking work to understand PM apportionment. It was also mentioned that this research has a good focus. One reviewer said that if one defines "technical barrier" as unreasonable or unjustified regulated PM levels, then this certainly has the potential to remove or reduce a "technical barrier." Another commented that the focus on understanding emissions characteristics will help in understanding fuel composition. One reviewer felt that this is an important topic and worthy of DOE funding. He mentioned a concern about the veracity of the conclusions, which do not seem to be widely accepted in the air pollution control community. This reviewer also made a general suggestion for DOE to put some resources into promoting and supporting peer review to either corroborate the findings or figure out if there is a problem. A comment was made that this is good work, but it is not clear how it relates to DOE goals of reducing petroleum consumption because future diesel/gasoline vehicles are much different than those on the road now. To one reviewer this seemed an interesting study, but this reviewer also noted that the subjects of the study are existing vehicles that very likely are different from the technologies being developed by the FCVT. One thought that this was good work but was not sure how it fits with the DOE objectives. Another stated that this study appears to be retrospective and the link to FCVT technologies is not clear.

Question 2: Approach to performing the research and development (Written responses from 9 of 16 reviewers)

In general, the reviewers felt that this research had a sound approach. One person thought that this was a good and sound approach. Another added that it is a good approach for existing air quality assessment, but application to future technology is not clear. A comment was made that the instrumentation was good. One person stated that advanced, real-time PM measurement techniques (number and mass) would have been nice, but would have been overkill for many of the tested vehicles. He added that this would be beyond the scope of this project, but data would be useful for other purposes. Another reviewer felt that this was a great approach using leading research capabilities. Another echoed the previous comment and added that the research is impressive. One asked if the PAHs were extracted from the samples that were then reported as elemental carbon. However, he said, the results are very interesting. To one person it was not clear how background ambient emissions from non-mobile sources are accounted especially in the port areas as well as other areas. A reviewer asked how a correct apportionment for old and new technology (for both gasoline and diesel) can be done. Would a gasoline engine deteriorate faster than



a diesel? Finally, a reviewer said that the project design and conception is excellent.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 6 of 16 reviewers)

Most of the reviewer's comments were positive regarding technical accomplishments. To one reviewer this seemed good work, but the link to barrier progress was not clear. Another thought that more work needs to be done in this area, but this project added greatly to the knowledge base. It was mentioned that the current data is very interesting and the work needs to continue to ensure our pollutant inventories are properly quantified. One felt that his research certainly shows that there is more than one contributor out there. According to him, the presentation would be a little more credible if the scales on the PAH emissions rates charts were comparable. One person was not sure how this fits with DOE objectives. Finally, a reviewer said the results are clear and concise, and that it was interesting that heavy PAHs are more from gasoline than from diesel: this could be a very important finding that is not generally thought to be the case.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

All of the comments regarding this question were positive. One person liked the good coordination with emissions regulating agencies. Another thought that there was good coordination in some respects, but better coordination could be accomplished. One commented that involvement of CARB and EPA is good. Another felt that this project involves an outstanding group of stakeholders and researchers. It was echoed that such collaborative effort is hard to beat. One person commented that the researchers need to present this to the regulatory agencies and are advised "to duck afterwards." One reviewer said that publishing the data in peer-reviewed literature is crucial, and meetings with regulatory agencies to share information even more so, especially the data on gasoline heavy PAHs and how diesel and gasoline compare in that arena which is not largely known or understood; in fact, this is misunderstood because most people believe heavy PAHs will be more with diesel fuel. A reviewer said that the nature of this work is fact finding for correct modeling and inventories: industry collaboration is mostly in providing hardware and basic data.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 7 of 16 reviewers)

Reviewers acknowledged that the project is completed. They suggested publishing the reports prior to meeting with regulating agencies. Reviewers were not sure what future work is needed. It was not clear to one person how this relates to future fuels and engine development work. One reviewer stated that comparison to other research results is an important and often ignored step. One person asked what the future work plans are, but another said that the planned follow-up is right on track.

Specific Strengths and Weaknesses (Written responses from 12 of 16 reviewers)

- Specific Strengths
 - Good study plan.
 - Well thought out and detailed plan that was executed well.
 - Good focus, high level of detail, collaboration with those having specialized expertise.
 - Collaboration of world-recognized researchers.
 - Very useful results for the determination of regulatory direction and priorities.
 - Groundbreaking work to identify sources of ambient pollutants based on composition of pollutants.
 - Inclusion of old and new vehicles and appropriate driving cycles.
 - Opens eyes to the fact that properly controlled diesels are not the ogres they are thought to be.
 - Lots of detailed information that may be more relevant to air quality regulatory policy development than to energy policy development.
 - Excellent care in getting credible data and correlations, and experimental design.
- Specific Weaknesses
 - Don't see how it fits DOE Goals.
 - Not sure how it applies to DOE goals at this time.
 - Project has taken a long time to complete.
 - Be careful to present results in a "fair" comparative manner.
 - Applies only to present gasoline and diesel engines on the road now.



- It would be nice if there was additional research in this area to corroborate the findings here. The conclusions are based on atmospheric science hypotheses that do not seem to be agreed upon in the air community. The implications of the findings are so significant that it warrants a better understanding of where the experts in this arena stand on the topic. This fundamental understanding is the basis of our air control strategies, and implicitly is driving technology decisions.
- The only potential weakness in this project was lack of up front EPA involvement—I imagine that was by design rather than an oversight.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 16 reviewers)

- None. Great project.
- Demonstrate the application to current DOE goals.
- Needs to identify conclusions that can be implemented in engine R&D and/or regulatory policy.
- Continue work.
- Can you identify other sources from the atmospheric samples (railroads, power plants, etc.)? What about silicates?
- Follow-on work using the same care is beneficial. More characterization of non-automotive particulate sources and their fractions would be helpful as further work. Also, integration with engine or vehicle work with other fuels, such as natural gas, advanced engines with DPF equipment, HCCI, and hydrogen ICEs and characterizing the ambient effects of large numbers of these types of engines and fuels would be useful. This would be predictive rather than measurement centered, perhaps using data on this project as a starting point.



Fuels Technologies Program

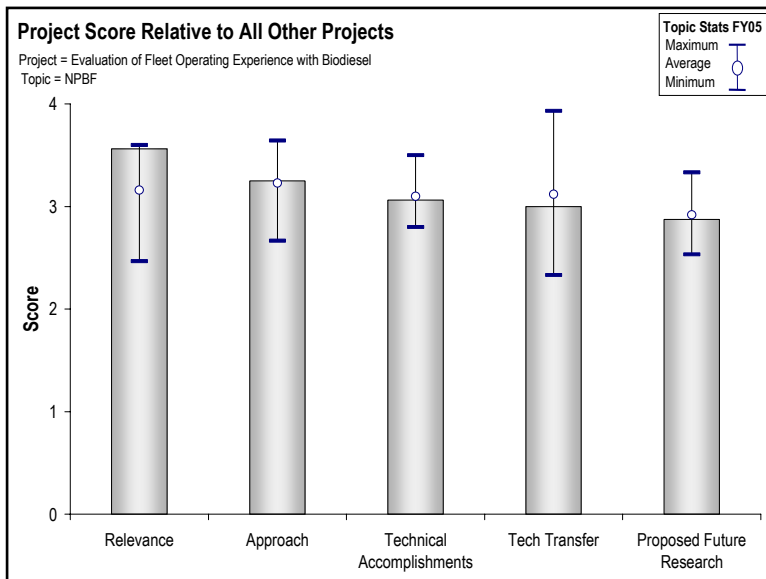
Evaluation of Fleet Operating Experience with Biodiesel, Ken Proc of the National Renewable Energy Laboratory

Brief Summary of Project

The goal of this activity is to examine the experience of several fleets with biodiesel, to provide detailed technical analysis of B20 data to understand durability and performance implications of using biodiesel. The researchers are working with the Postal Service, the transit property in Denver, and a public school system in the Denver area. The data collection includes fuel use information, emissions testing, and engine teardown analysis.

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 16 reviewers)

A few reviewers noted the good alignment with DOE goals and objectives. In one reviewer's opinion, the program provides much-needed statistical and real-life info on bioblends in use. Others noted that biodiesel has potential for meeting petroleum displacement goal, but more data are needed and there is a need to examine impact of this upcoming fuel that could replace a significant amount of non-renewable energy. One reviewer summarized the project goals as obtaining in-use fleet data, identifying issues, and developing durability and performance information. In-use information on B20, or other fuel replacement technologies for that matter, is absolutely critical in one reviewer's opinion in moving from the "niche market early adopter" stage to the mainstream. This is best done by "independent, unbiased" sources like NREL so the data is as credible as possible. The final reviewer stressed that understanding long-term operations is a key element in the growth of biodiesel usage.



Question 2: Approach to performing the research and development (Written responses from 11 of 16 reviewers)

One reviewer simply stated that this appears to be a good approach, while another characterized this as excellent work. Another agreed that it is a good approach, but somewhat limited from a fuel perspective given that the B20 was apparently sourced from a single supplier under controlled conditions. One reviewer suggested a need to tie evaluation data to fuel analysis studies of biodiesel, and to continue to track long-term effects on engines. Another suggested the need to include non-road applications. One reviewer noted that a range of engines and applications is included in the work. Some of the applications may not log many miles (school bus). Ambient temperature may also play a part in various applications. A reviewer suggested that some attention to fuel-system-critical issues be added in the future, such as water separation, fuel filters, tank cleanliness, fuel quality, etc. (these issues may be monitored already). One person felt that the study fleets are adequate, but another was not clear if the chosen fleets address all the potential problems, such as cold weather operation, water contact issues, oxidative stability (how long was fuel in storage before use, for instance), combustion chamber deposits over 435,000 miles, etc. The final reviewer commented that it seems hard to improve the project given level of funding.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

One reviewer stated that this is a good start, and another said it should continue. Another added that there was good analysis of repairs and vehicle history, but this reviewer did not understand the NOx decrease here when every other study shows the opposite effect. One reviewer summarized that the results show no discernable wear differences between diesel and biodiesel. Emission levels and fuel economy trends seem to be in the anticipated ranges for older technology engines. Field data may need longer time to draw trends /conclusions. One person suggested the need to determine causal factors for results from the field trials. Close coordination and collaboration with fuel analysis work would enable this to happen. Another reviewer stated that the researchers still need units with more mileage/hours, while still another said that the results tell the story, but more fleets are



needed. The final reviewer cautioned that the results only show that there were no problems under the fleet test conditions for the time of the test, and does not show that there are no possible problems with biodiesel under all conditions.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 11 of 16 reviewers)

Several reviewers noted the good collaborative team of participants, including industry. Another reviewer commented that there was excellent contact with users. Several reviewers suggested that light-duty diesel OEMs should be contacted for potential participation and input from other OEMs is deserved. However, one reviewer acknowledged that it is difficult to expand the number of engine manufacturers participating, since this is not at the top of anyone's priority list. One reviewer noted that there is a variety of engine technologies and ages in this project. Some of the manufacturers, who might contribute to provide insight, are not in the mix of participants, so the data will be fleet- or use-specific. A reviewer commented that Blue Sun Biodiesel is a fuel partner; however, since most of the fuel is petroleum, where is the input from a petroleum fuel producer? Another reviewer backed this comment up, stating that additional fuel suppliers should be considered. A reviewer offered that OEMs need to be informed especially on problems or issues, so that learning can occur. A final reviewer said that the information collected so far is good, but the team needs much more data and needs to place more focus on drivability and cold starts than currently in data collected.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 8 of 16 reviewers)

One reviewer agreed with proposed future plans, while another just proposed continued study of fleets. Another said that the team needs as many fleets with as much data as possible as fast as possible. One reviewer suggested improving the synergy between fuel analysis work and the in-use fleet demonstrations. Another person commented that the future plans are to complete the current path, but the plan does not connect with the fuel quality or variations. One reviewer suggested that perhaps trying to list the issues and then trying to find fleets that operate under conditions that would test those issues would be a better approach. The final reviewer commented that engaging engine and/or fuel system suppliers might provide more reliable analysis. Reliable trends need to be established.

Specific Strengths and Weaknesses (Written responses from 12 of 16 reviewers)

- Specific Strengths
 - Good start.
 - Good summary.
 - Good long-term data to support the use of biodiesel.
 - Work is first rate--keep it up.
 - Adds to biofuel experience/database.
 - Real world application to meet DOE goals.
 - Relevance of real operational issues.
 - Demonstration that fuel economy, emissions and engine wear are not a concern with a limited scope of B20 quality.
 - Field test are where the customer sees the pros and cons of the technologies. Fleet practices, length of field test can play an important variable. The fuel consumption loss is about the same for both fleets.
 - Durability information for any alternative fuel that will be used by medium- or heavy-duty engines is critical. A major consideration for this type of vehicle/engine purchase is durability. This data will help extend the use of biodiesel by removing the durability roadblock. Also the fuel economy and emissions study is useful.
 - Good pairing of test and control vehicles.
- Specific Weaknesses
 - No mention of cold flow properties and impacts, need more analysis of the fuels; sketchy details in the report.
 - Fuel properties not monitored in detail.
 - Lacks non-road applications.
 - Limited geographic areas and biodiesel supply sources.
 - Need more extreme condition data. Also, need to clarify how or if some repair and routine maintenance



cost differences will be attributed to fuel-related causes. Should also compare fuel cost of biodiesel to conventional diesel.

- Need to expand effort for more fleets in varying climates and operations to maximize unbiased assessment of real world impacts so that biodiesel blends can contribute substantially to the 5% overall replacement goals.
- Is the fuel consumption decrease consistent with the energy density change between diesel and biodiesel? How do ambient conditions impact the performance? RTD fuel economy results for month of Dec[ember] seem reverse of previous months? Does not relate to fuel quality being used in each test site.
- Not directly addressing key OEM concerns on B20 including fuel quality & injector deposits,
- Do effects on older diesel engines predict effects with future advanced diesels?
- Does not necessarily prove biofuel is OK under all circumstances. We find that our customers do things with our products that we never imagined and that may be the case with biofuels.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 9 of 16 reviewers)

- Economics need to be addressed and estimates of total penetration.
- Expand to include future engines with aftertreatment.
- Extend program to other fleets.
- Continue efforts, expand the effort to include more fleets (total per year funding of \$2MM is recommended), place more attention on diesel issues like drivability and cold start.
- Continue evaluations to mileage intervals typical of the useful life of this class of vehicle, e.g., >500,000 miles.
- Include one or more light-duty diesel vehicles. An appropriate fleet is likely unavailable, so this might require different approach.
- Broaden fleet study to include pickup trucks, particularly those with plastic fuel system components that might be sensitive to oxidized B20.
- Evaluate all possible biodiesel formulations (soy, rapeseed, animal fat, etc.) that will be available in the U.S. (as practical).
- Consider including one B20 fuel that is partially oxidized, or otherwise “aged,” to represent a real-world fuel.
- Measure detailed fuel properties including peroxides, oxidation stability, and cloud point on fuels being pumped into fleet vehicles and fuels sampled from fleet vehicles.
- Survey engine/component manufacturers to make sure program addresses their concerns for warranty coverage of B20.
- The maintenance practices may be different in different fleets as well as ambient environment. Include engine/equipment and fuel supplier to bring in their experience and length of field test may/may not be adequate.
- Existing plans are good; suggest incorporating more extreme condition data. Also, need to clarify how or if some repair and routine maintenance cost differences will be attributed to fuel-related causes. Should also compare fuel cost of biodiesel to that of conventional diesel.
- Try to find fleets that could generate known problems to help find ways to fix them. Just showing that under certain circumstances everything is OK is not enough. That can promote a false sense of security. Rather, let's try to find the problem areas and solve them before there is extremely wide ranging usage and we have a mess on our hands.



Fuels Technologies Program

Gaseous Fuels Technology Transfer and Industry Coordination, Richard Parish of the National Renewable Energy Laboratory

Brief Summary of Project

This project is focusing on verification of natural gas engine capabilities, information exchange with the NGV industry, coordination of state vehicle and infrastructure development, and provision of assistance to fleets who are new implementers of natural gas technology. Activities include publication of technical information, emission testing of current technology engines and vehicles, and cooperation with hydrogen representatives on codes and standards issues.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 15 reviewers)

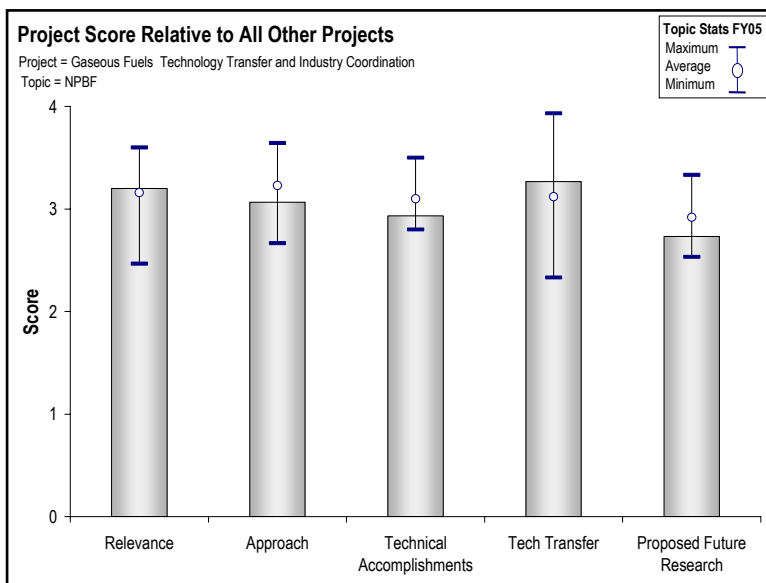
Two reviewers noted that the project is very good and is aimed at DOE goals. Another added that this is key to promoting natural gas usage in engines/vehicles. Another reviewer noted they had the same issues with regard to natural gas within the overall DOE portfolio of projects. This specific effort must carefully avoid illegal lobbying efforts. If the budget request for this area has been zeroed, the only effort should be to manage earmarks in the areas such that it supports and is relevant to the current priorities. One person commented that natural gas is a niche market, and that the objectives would be better served developing economic solutions for centrally fueled fleets rather than over-the-road infrastructure. CNG does not fit in with 5% replacement in diesel engines and new combustion regimes in one reviewer's opinion, but this is an excellent project and must be repeated with the promising replacement fuels and serves as an excellent model for doing so. Another person commented that the development of codes and standards is needed and a government agency (e.g., NREL) has a much greater role and impact. The engine and fuel supply industry cannot serve this infrastructure need. Operational and in-use emissions data can solidify and prove the contributions of these technologies to emissions reduction as well as diverting petroleum fuel use. Another person noted that information transfer is a key to any new technology, and that a process that can facilitate this is always beneficial. The final reviewer suggested the need to clarify how LNG imports to meet future natural gas incremental demand will improve U.S. energy security.

Question 2: Approach to performing the research and development (Written responses from 7 of 15 reviewers)

One reviewer noted that the workshop approach is good. One person suggested the need to expand user groups to include other vocations, but the reviewer recognizes resource constraints. Another reviewer felt the team had taken a sound approach as evident from excellent results in progress of CNG engines in production. A reviewer noted that information and standards are a good thing. One reviewer simply stated that this is not a research and development project. The final comment was that hydrogen has unique characteristics that must be accounted for, so natural gas codes and standards cannot simply be adopted for hydrogen.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 15 reviewers)

One reviewer felt that this work shows that natural gas engines are viable as an alternative to diesel in specific applications. Another reviewer cautioned that the critical measuring stick is the adoption and deployment of natural gas vehicles. This does not seem to be happening on a broad commercial scale because of the lack of the business case for natural gas vehicles. Others felt that there needs to be more emphasis on the outcome of workshops and identifying key opportunities and on the economics. Finally, a reviewer said that the program showed good results, and that the team should really keep a focus on the Fuel Codes and Standards development. This is a function which government is uniquely suited to do and which industry tends to either not do or spend



the minimal amount of time needed until it is too late and an uninformed local agency has already banned the product.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 15 reviewers)

One reviewer noted that there are nine partners involved with this project; however another reviewer suggested a need for greater OEM (vehicle body) involvement. One person commented that the workshop approach and publications are good technology transfer. Another commented there was good focus on the niche markets and locales where there is interest. One stated that technology collaborations are really solid. The final reviewer suggested developing landfill gas usage in collaboration with the Clean Cities Program.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 15 reviewers)

Two reviewers felt that the plan was good in maintaining future work that continues existing efforts with no new initiatives. One said that future plans are solid and would be rated at a score of 4, but CNG doesn't fit in with stated program goals. One reviewer noted that NREL continues to provide the leadership needed in the gaseous fuels area. Another commented that codes and standards need to be practical and data-based. Development of these codes and standards need to be focused and meet national requirements. The last reviewer commented that until gas becomes economically viable, it will not take hold in the U.S.

Specific Strengths and Weaknesses (Written responses from 9 of 15 reviewers)

- Specific Strengths
 - Excellent program for DOE energy diversification.
 - Results speak for themselves.
 - Timeliness and relevance.
 - Really solid work, some excellent learnings which should be applied to the replacement fuels which are developed as part of the FCVT program.
 - Making fleet operators comfortable win CNG.
 - Meeting a national need. U.S. codes may be transplanted in other countries, there by creating export potential, jobs in the U.S.
 - Standards development. Information dissemination.
 - Good summary of work, provides a service to NGV users.
- Specific Weaknesses
 - Outcome of the workshops is not well described.
 - Market growth is still limited. How can this be addressed?
 - No research involved in this activity.
 - Not enough focus on economics.
 - Seems rather like a somewhat duplicative NGV lobbying group & somewhat removed from the DOE's R&D charter. Might a lot of this be more logically done by industry and fuel supplier groups? Also need to clarify how LNG imports to meet future natural gas demand will improve U.S. energy security.
 - Doesn't fit well with program goals.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 11 of 15 reviewers)

- Assert more leadership and focus on economics and advantages for NGVs and include fuel penetration to the transportation market and local/national codes and standards.
- Work should continue, especially the work with the Codes and Standards for CNG, but perhaps in another program area than FCVT based on the stated program goals.
- It is extremely important to maintain collaboration between NGV stakeholders, since the engine and vehicle manufacturers are not necessarily committed to this market.
- Look for CNG growth in on-road and non-road applications.
- Refresh industry involvement (NGNGV), forward looking portfolio (less than 2010 emissions, better life cycle costs, etc.).
- Consider higher level of activity, if budget available.
- Consider potential synergies of working with Honda on light-duty CNG issues.

- Ensure all stakeholders have access to pertinent information.
- Comment in general about natural gas work - it seems that there are some issues related to NG use in advanced combustion engines that are not being addressed by DOE. What are the implications for natural gas use in HCCI? What about H₂ and natural gas for ultra-lean burn applications? Seems as though some fundamental combustion studies are warranted.
- Many cities have landfills. What about collaborating with them on landfill gas energy conversion?
- Suggest critical review of real benefit of all aspects of this program and consider scaling down & transfer of much of this work to industry groups.
- I recommend dropping this program because the technology is available and proven.



Fuels Technologies Program

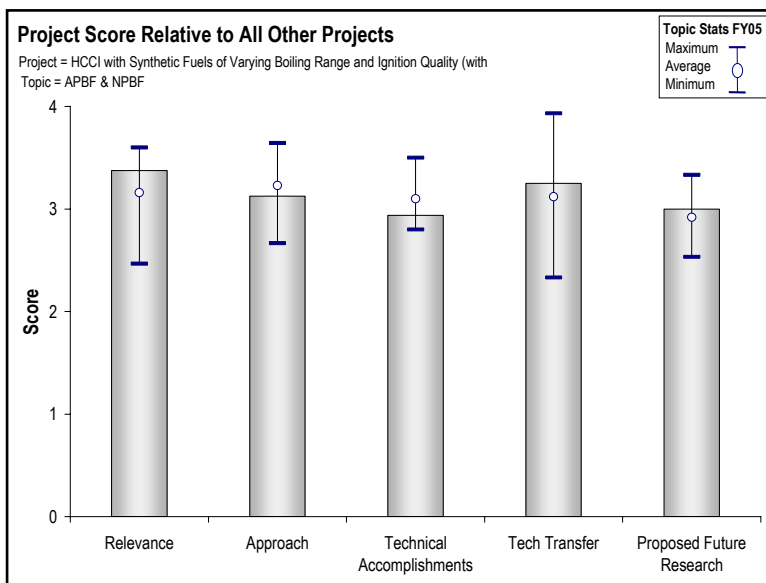
HCCI with Synthetic Fuels of Varying Boiling Range and Ignition Quality, Joshua Taylor of the National Renewable Energy Laboratory

Brief Summary of Project

These researchers are investigating the fuel properties that impact performance in an HCCI engine, identifying the trade-offs of fuel properties of HCCI and diesel engines, and developing a ranking system for HCCI fuels. They have developed a heavy-duty engine with flexible valve timing to test these fuels, and have looked at a variety of fuel formulations at a single load-speed point.

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 16 reviewers)

Almost all of the reviewer's comments were positive regarding the relevance of this research to the overall DOE objectives. One reviewer stated that HCCI technology is very important and this project is assisting in defining the fuels needed to support this technology. Another said that this is a critical and promising area for research. A comment was made that there is good alignment with the FCVT goals. One person thought that this is interesting work on fuels for HCCI. Another agreed and added that understanding the fuel effects on HCCI is clearly an important issue for DOE. A reviewer offered that the fuel characteristics are very relevant for HCCI. One person commented that the setup used is a great test bed for better understanding the interaction of HCCI and various fuel formulas. To one, HCCI technology seems interesting but the final connection to DOE goals was fuzzy. Another person was not overly enthusiastic about specially crafted fuels as emissions control devices unless they are enablers. A final reviewer said that the project objectives are good, but noted a lack of petroleum industry involvement.



Another said that this is a critical and promising area for research. A comment was made that there is good alignment with the FCVT goals. One person thought that this is interesting work on fuels for HCCI. Another agreed and added that understanding the fuel effects on HCCI is clearly an important issue for DOE. A reviewer offered that the fuel characteristics are very relevant for HCCI. One person commented that the setup used is a great test bed for better understanding the interaction of HCCI and various fuel formulas. To one, HCCI technology seems interesting but the final connection to DOE goals was fuzzy. Another person was not overly enthusiastic about specially crafted fuels as emissions control devices unless they are enablers. A final reviewer said that the project objectives are good, but noted a lack of petroleum industry involvement.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

Comments regarding the approach were mixed. One person felt that the approach was very sound. Another stated that from a scientific standpoint, the analytical approach was excellent. He added that regardless of the fuel, knowledge of combustion was enhanced. A reviewer thought that the hardware was flexible and the fuel matrix was reasonable. One thought that the fuel matrix scope was not as clear as it could be. Another pointed out that only one operating point (1300 rpm and 30 bhp) was investigated and that he would like to see similar information at other engine operating points. One person felt that this is a sound technical approach for isolating key factors and that the researchers need to measure particulates across variables. Another said that this project did not include an energy company to help with fuel chemistry. To one reviewer the fuels matrix seemed too small and C9-C14 represent only front end of diesel, and no naphthenes or aromatics were included.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

Reviewers had mixed comments regarding the technical accomplishments of this research. One reviewer said that it is good to have hardware in place and operating. Another added that the analysis was excellent. He also mentioned that if the engine platform had been more capable, the results would have been even more interesting. One person thought that this research identified possible factors for HCCI fuels. Another commented that this is good fundamental research, but there is much opportunity for more work in this area, for both gasoline-like and diesel-like fuels. A comment was made about the need to publish full results in an SAE paper. One reviewer pointed out that the data presented appears to show HCCI is a good technology to meet stringent emissions standards and maintain efficiency. He added that the fuel effects must be understood to take full advantage of this technology. Another stated that there was good engine development but poor fuel development. Another pointed out that

the data are only for a single speed at very low load (10%) and that phasing of all the data was done way too early. To him it seemed that no key insights were gained from this work.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

Comments about technology transfer and outside collaboration were mixed. One person felt that the analysis provides insight into the combustion process. To another it appeared that industry partners are full participants in the research and are actively involved and contributing. It was added that the involvement of Mack/Volvo Powertrain is very important. Currently, the project as investigative research has good industry participation, noted a reviewer: it is premature to judge industry participation when a fuel profile has not been defined. On the other hand, a mention was made that this project involved only two industry participants. One person said that broader collaboration is needed for a government program. Another stated that he did not hear much about technology transfer. Finally, a reviewer said that no fuel industry players were involved, but it would not take that much to get them involved. This reviewer thought the implications are pretty major (i.e., lower-cetane fuel is better for reducing NO_x in HCCI combustion regimes).

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 16 reviewers)

Reviewers agreed that the goals of the future work should be more clearly stated. One reviewer liked the prospect of quantifying ignition quality for low-temperature combustion. Another mentioned that the opportunity to pursue light-duty diesel research at SwRI should not be lost. He said that approaching the CRC is a positive step. One person thought that more industry involvement is needed. Another stated that specific goals for future work are needed and were not clearly defined. One questioned what the key scientific questions are to be addressed in the next phase of research. The finding that lower cetane reduces NO_x in HCCI seemed to a reviewer to be pretty significant, but the project is coming to a close and little future research is planned. In addition, it does not appear that any computer model or theoretical model from this work has been developed and made available to engine and fuel designers. Continued work at NREL is needed for heavy-duty vehicles, in a reviewer's opinion: this reviewer said that a light-duty program should also be pursued, pending availability of funding.

Specific Strengths and Weaknesses (Written responses from 10 of 16 reviewers)

- Specific Strengths
 - Hardware in place and operating, basic data generated.
 - Nice engine system.
 - Engine set-up and development are excellent
 - Work to correlate fundamental fuel property tests with engine tests.
 - Good work on HCCI parameters using engine test equipment.
 - Partnership with engine manufacturers and suppliers.
 - Matrix to try to separate volatility and chemical ignition effects.
 - Designed experiment of engine parameters that could be used to control combustion.
 - Shows that cetane may not be a critical parameter for future HCCI engines; identifies fuel parameters for future engine R&D.
 - HCCI is interesting engine research.
 - Excellent analysis and good future direction.
 - Relevance and timeliness.
- Specific Weaknesses
 - Need improved goals (more specific) within the program.
 - No input from fuel supplier, quoted "EPA diesel fuel" - EPA does not make fuel!
 - No clear focus.
 - Engine platform not as capable as it needed to be.
 - Would be helpful to bring in more fuels-related analysis similar to Taylor Ignition Properties presentation on 3/6 (presentation #6) and re-verify based on engine tests.
 - Very little collaboration with the fuel industry, follow-up on modeling is needed but not there.



Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 16 reviewers)

- Like to see light-duty engine project go forward.
- Expanded operating range is key to the success of HCCI. Understanding fuel effects is very important.
- Identify the link from steady state to transient operations.
- Analyze in more detail the effect of fuel composition/properties on combustion phasing and correlate these results with ignition quality testing.
- Analyze the results in terms of the compression ratio or other engine properties required to achieve an “optimum” CA50 and correlate these with fundamental fuel properties.
- Pool data and experimental approach with the gasoline HCCI project to find commonalities of fuel properties.
- Bring in a fuel supplier.
- Expand in the future to VVT plus flexible common rail for maximum flexibility.
- Might also include more inexpensive, non-biodiesel, non-oxygenate fuel components in future work.
- The objective of developing a model for ranking HCCI fuels just hasn’t been accomplished yet and needs to get done and this needs to be worked more cooperatively with the fuel industry (petroleum, biodiesel, F-T, etc.)



Fuels Technologies Program

Next Generation Natural Gas Vehicle (NGNGV) Activity, Richard Parish of the National Renewable Energy Laboratory

Brief Summary of Project

This project is focusing on the development of advanced medium-duty and heavy-duty natural gas engine platforms that achieve very low emissions, and the identification of customer demand for such engines in the near term. At least eleven separate engine/platform combinations are being developed, both with spark-ignited engines and diesel pilot-injected engines.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 16 reviewers)

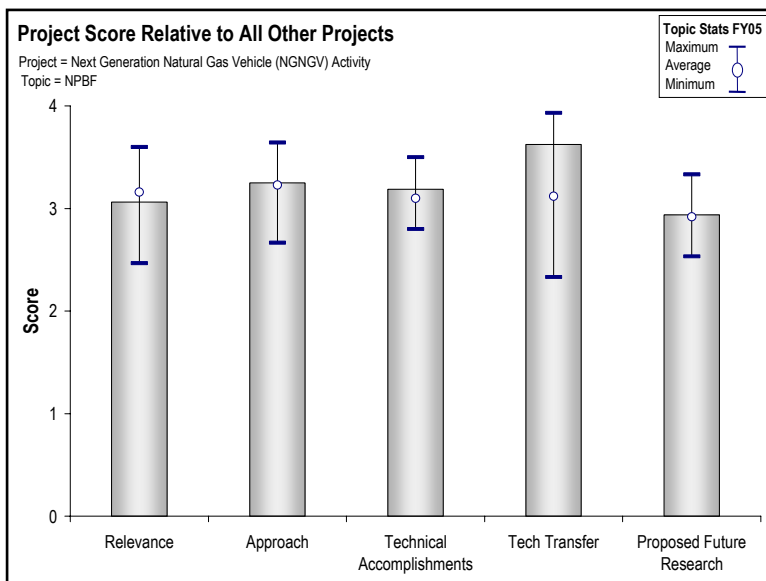
Comments on this question varied widely. Some felt that the project was well-aligned with the DOE petroleum replacement objective and a good fuels application to meet the DOE goals. Others commented that the work helps assure that the necessary technologies will be there if there is ever sufficient market and that the work looks at natural gas technologies needed for both 2007 and 2010 emissions levels. Other reviewers had more critical comments. One person commented that the objectives are to research and develop natural gas on-road vehicles to diversify fuels use as well reduce petroleum dependence. Natural gas engine technologies have historically achieved emissions standards ahead of the diesel platforms. These are niche market technologies. Natural gas technologies may also meet 2007/2010 emissions earlier than diesel technologies and be cost effective. This project provides an alternative solution for urban applications. Another reviewer added that natural gas is not an “alternative” renewable fuel to petroleum-based diesel, and did not see the alignment with DOE goals to reduce petroleum dependence. The final comment was that given the 20 years that natural gas vehicles have had to mature and the fact that they do not achieve the same reliability and performance as diesel engines as well as their significant infrastructure costs, what’s the commercialization aspect? Additionally, once diesel engines meet 2007 and 2010 standards, where are the emission benefits for NGVs? Given that DOE has zeroed this from its budget request, what’s the relevance proposition? Finally, a reviewer said that this is some excellent work, and is to be commended, but CNG does not fit in with the stated program goals of developing diesel engines and advanced combustion engines. This is not to say this work isn’t important—we will need every alternative we have at our disposal if we are to maintain our current standard of mobility in the future and this type of work is critical for CNG and the OEMs certainly are supportive of this work. It just isn’t a fit for this particular program as it is stated.

Question 2: Approach to performing the research and development (Written responses from 8 of 16 reviewers)

Several reviewers stated that the programmatic approach was good, and that the researchers have used a broad base of engines and supporting funding. One reviewer summarized that the technology path is developed with collaboration of industry and government agencies. The technology options include lean-burn spark ignition, stoichiometric EGR spark ignition and in-cylinder NG injection with a diesel pilot. The program is investigating various technology options and some will become a clearer choice. Stoichiometric spark ignition with EGR has become possible with recent availability of these components from diesel platforms. These technologies have the potential to achieve future emissions requirements as well as improve on energy efficiency. Another reviewer felt that the researchers have used a sound approach, though he was not sure how this will lead to commercialization. Another felt that the inclusion of more non-traditional, unproven (2010-targeted) technology would be useful. The final reviewer stated that he did not see much in technical progress description.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

One reviewer felt that there was good progress, while another felt that there was good screening activity, but that it



is hard to detect how efficient this process is. Superb accomplishments, said a reviewer. One offered that the approach is excellent to achieve the goals stated in the project description. One reviewer stated that the final assessment of project success should be based upon the amount of new technology that actually enters production. One reviewer commented that commercial engines have demonstrated the 2007 emissions potential, and as natural gas fuel costs continue to rise (perhaps still less than petroleum fuels) that there is opportunity for life cycle cost reduction. Another suggested that the project move to minimizing emissions levels. Another felt that it was too early to judge results. The last reviewer felt that there was not much technical progress, just demo projects.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 16 reviewers)

Comments were all positive with many reviewers agreeing that there is good team involvement of a multi-functional industry/OEM with all the major players, as well as SCAQMD. Specific comments were that working directly with the OEM is the best technology transfer method. Another reviewer added that the engine and vehicle companies are directly involved with research, development and implementation of these technologies. The technology transfer is happening real-time. A reviewer characterized the work as having excellent industrial partnership. Consumers and purchasers of equipment need to be made more aware of this work, said a reviewer, who also noted that the project has excellent collaboration with the OEMs with high cost shares. The final comment was that cooperation with all stakeholders is critical for increased acceptance of natural gas technology.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 16 reviewers)

A few reviewers felt that the project was right on target, however most reviewers suggested additions/modifications. One suggested the need to add specifics to the future program plan to strengthen the support for this work. Another felt the focus on 2010 is good, but that more complete systems (not just engines on dynos) should be tested, under real-world conditions. Vehicles currently operating under “high-emitter” conditions should be targeted, such as trucks performing port-related duties. As noted by the presentation, durability is a key issue. Another person noted that natural gas engines need to demonstrate 2010 emissions, three-way catalyst durability (heavy-duty engine emissions warranty is 435K miles), and fuel economy improvements. The current use of catalysts in light-duty applications is inadequate for heavy-duty use. One reviewer stated that he did not see the technical direction for future. Another felt that no groundbreaking work was done, and that it could all be done by industry. A reviewer commented that the researchers need to remove barriers to demand by focusing on economics (not emissions incentives) that will pull this technology into the marketplace. Finally, a reviewer said that CNG just doesn’t fit with the stated goals, although the work proposed is solid and should be funded somewhere.

Specific Strengths and Weaknesses (Written responses from 10 of 16 reviewers)

- Specific Strengths
 - Excellent approach and results.
 - Real-world applications with direct input on the goals.
 - Broad base of support with specific and measurable targets.
 - Reduction of petroleum use by substituting natural gas.
 - Evaluating various technolog[ies], technology transfer real time. These technologies can serve as a learning or starting experiences for hydrogen engine technology developments. These technologies ha[ve] significant potential for export in countries such as China, India, Egypt etc.
 - Brings together a wide range of market sectors, industry participants, and engine technologies.
 - Driving emissions to low levels. All the major players are participating.
 - Good summary of progress towards emissions goals with natural gas.
- Specific Weaknesses
 - Need quantitative assessment of how these activities contribute to the 5% DOE goal.
 - Does not move toward stated goals of replacement fuels for diesel and advanced combustion engines.
 - Focused on technology that could easily be taken care of by industry.
 - No weakness; zeroing of future funds will negatively impact this fledgling technology enterprise.
 - Needs policy and program continuity to build and maintain customer and industry confidence.
 - Working on a technology that I think is a loser.
 - No strategy development to pull this technology into the market. Must eventually make economic sense.



- Begin with non-fuel-economy-sensitive markets (bus, refuse, etc.) that are centrally fueled.
- A comparison of natural gas engine efficiency and emissions for 2007 and 2010 vs. advanced gasoline and diesel fueled engines projected for the same time frame would be helpful in understanding the competition.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 16 reviewers)

- If one sticks to the program goals, this work should cease being funded by the FCVT program and should be funded by another DOE program, but it should be funded somewhere in DOE.
- I recommend stopping this project, but if any more lean burn natural gas engine projects are done, they should include lean NOx traps with a target of 0.2 g/hp-hr.
- Stop work.
- Show the overall benefits of the program effort in replacing imported oil while meeting emission standards with a commercially viable, economic technology.
- Evaluate lower than 0.2g/bhp-hr NOx emissions potential with HCNG. Significant resources are planned in H₂ economy and infrastructure development. Limited investments in NG engine technologies can be valuable transition. Create a conduit between natural gas & H₂ technologies. \$2-3 M funding can continue to build upon existing experiences and continue to create national value.
- Policies and program criteria based on emission benefits need to transition to increasing importance of petroleum reduction benefits.
- Economics of reclaiming landfill gas will have to become attractive to drive the economics for this technology.
- Good proposed future work; suggest adding a comparison of natural gas engine efficiency and emissions for 2007 and 2010 vs. advanced gasoline and diesel fueled engines projected for the same time frame would be helpful in understanding the competition to the scope.



Fuels Technologies Program

Performance of GTL Fuels: Fuel-Engine Compatibility and Achieving Low Emissions, Teresa Alleman of the National Renewable Energy Laboratory

Brief Summary of Project

This project's objectives are to research gas-to-liquid fuels with respect to fuel/engine compatibility, fuel impacts with GTLs and catalyzed particulate filters, optimization of a diesel engine to take advantage of GTL properties, and emission impacts of blended GTL fuels with conventional diesel fuels. Thus far, the team has learned that GTL is quite compatible with current fuels and can offer emission benefits.

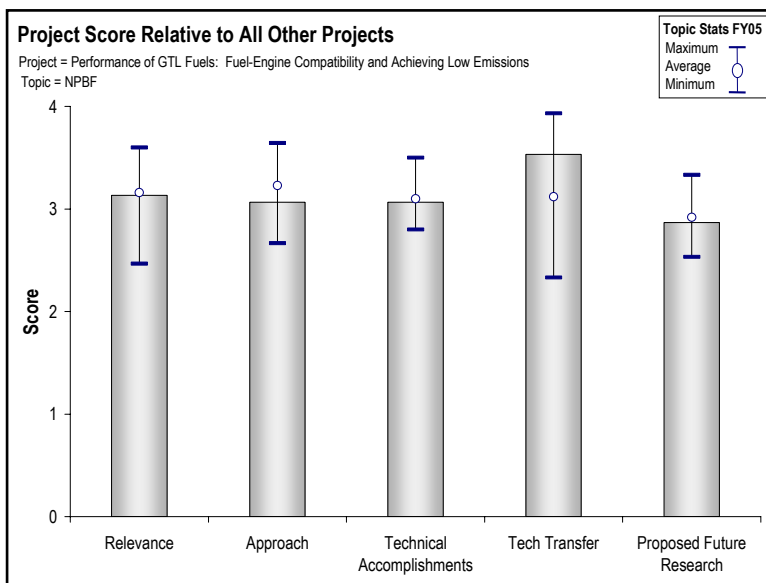
Question 1: Relevance to overall DOE Objectives (Written responses from 11 of 15 reviewers)

Reviewers agreed that the overall project seems in alignment with DOE objectives. One person said that this project includes good testing with aftertreatment technologies. It was noted that GTL seems to be a good replacement fuel. Another

reviewer agreed and was reminded of the great potential for GTL that's worthy of greater study. One person stated that it's important to note that GTL will be imported from outside the US. He also said that the natural gas infrastructure in the US is mature and there is no rationale for building GTL plants in the US; however, BTL has the potential to be produced domestically, and eventually displace petroleum-based fuels to an extent. Another comment was that GTL is a potential home run hitter for expanding potential fuel supplies. A comment was made that the final step in BTL fuel production is a Fischer-Tropsch process, so the fuels should be identical to GTL; therefore, this project is relevant to the DOE objectives, from a long-term perspective. A question was raised why NETL is studying GTL production when GTL is being produced today by energy companies. One reviewer felt that the project addresses important questions, but seems like a lot of money was spent and it's not clear the new insight was worth the investment. Another mentioned that the results indicate commercial promise in GTL fuels, but the cost barriers remain. One said that GTL is very relevant as a future alternative fuel or as a blending agent: the investigation is very timely. A final reviewer said that this project is excellent, well designed and well run. This reviewer added that these were exactly the types of things needed to answer the engineer in the engine companies. While some consider F-T fuels blended with diesel a no-brainer, it will take this type of detailed study to secure the support of the engine community.

Question 2: Approach to performing the research and development (Written responses from 10 of 15 reviewers)

Overall, the reviewers felt that this project will provide good information on GTL diesel fuel performance. One reviewer said that so far, the approach is correct. According to one reviewer the only thing needed is more testing. Another said that the approach is excellent and well thought out, but some questions still remain. One person stated that this project has a good statement of objectives but needs quantitative links to DOE goals. Another noted that a solid comprehensive approach with active partnership from industry participants is indicated by significant cost share from the industry. A comment was made that to complete the fuel and hardware comparison, the performance of CARB diesel with a DPF should have been included. For example, there could be an effect upon trap regeneration frequency. Researchers stated that GTL met D 975 standards, but what about cold flow? The team needs to present whole picture, not just the positives. One reviewer mentioned that high cetane fuels can exacerbate PM formation in LD diesels. He went on to say that the team should look at reduced cetane number (50-55) fuels. According to this reviewer, the results might be more promising. One person said that GTL fuels in the future do not have to distill exactly like today's diesel fuel. He added that the researchers may want to be able to tailor cetane quality depending on targeted combustion mode (like multigrade gasoline).



Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 9 of 15 reviewers)

Comments on technical accomplishments and progress were mixed. One reviewer said that GTL showed acceptability with current diesel engines. Another thought that this project provided a greater understanding of GTL effects. Someone felt that there was a need to show novel results for these fuels including energy efficiency and economic comparisons. A comment was made that the fuel penalty of 4.4% is significant. One noted that so far there is no mention about energy content and lubricity of GTL. One person felt that the key barriers to GTL fuel were not being addressed. He was not sure what barriers this R&D has overcome. Another comment was that the data show that the GTL fuels don't have a detrimental effect on advanced aftertreatment, but it's not clear that they provide a benefit. According to one reviewer a comparison of #2 diesel fuel versus GTL with CCRT would have been illuminating. A final reviewer stated simply that the program has set out to do what it said it would do.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 15 reviewers)

Comments regarding technology transfer and outside collaboration were very positive. One reviewer said that this project includes eleven excellent partners. Another echoed the previous comment by saying that there is a strong industry involvement and active participation of all partners. Another felt it had excellent partners and collaboration, and it was nice to see this, as it doesn't always happen. Others agreed with comments as "good cooperation with many stakeholders," "good buy in," and "lots of outside involvement." One reviewer said that industry is an active participant, and that the project is very well suited to that.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 15 reviewers)

Comments regarding the approach and relevance of future research were mixed. According to one reviewer this project has a very good application to DOE program goals, but commercial viability needs to be shown. Another reviewer wondered what the proposed future work is. Another was not sure there are any key burning technical questions remaining that require significant funding. A mention was made about coal-derived GTL fluids. One person thought that longer-term, real-world in-use deterioration and wear issues need to be investigated. A comment was made that some lead time is needed to bring down the cost of fuel. A reviewer said we need to learn how to use GTL better, so the research should focus on both the fuel and fuel blends. A final reviewer said that the proposed research was good, but some things missing.

Specific Strengths and Weaknesses (Written responses from 12 of 15 reviewers)

- Specific Strengths
 - Broad applicability.
 - Relevance and timeliness; industry participation.
 - Good initial study of GTL emission benefits and actual operating experience in relatively new vehicles.
 - Demonstration of good performance can lead to public acceptance of GTL fuels.
 - Involvement of 11 partners in the study.
 - Collaboration with industry excellent, well designed and executed.
 - Good collaboration with partners.
 - Industry participation is advantageous to potential success.
 - Shows that F-T diesel is a good fuel without significant adverse properties.
- Specific Weaknesses
 - Need to improve the novelty of the research to a higher level; what about the cold flow properties of the GTL fuels?
 - Vehicle fleet study does not tell us much about GTL fuels that we didn't already know or could have guessed based on engineering judgment.
 - Not at all clear that the engine modified by Ricardo took advantage of GTL fuels.
 - Does not address the key issue for GTL: should energy industries invest in GTL plants?
 - A few of the test results indicate irreproducibility.
 - Is it likely that special engines will be produced to take advantage of F-T diesel properties? Industry favors blend market!
 - Does not discuss the cold-flow operability of this fuel. Working on a fuel that is in production today.
 - GTL derived fuels don't have to look exactly like today's diesel. Effect of different feedstocks (bio, coal,



- etc.).
- Data are on new equipment only, misses long term in-use emissions and equipment deterioration issues-- which are as important as emissions reduction characterizations--perhaps more so--to customers, especially since they will have to pay more for GTL fuel.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 11 of 15 reviewers)

- Like to see more long-term vehicle (light-duty, other heavy duty) evaluations of GTL - durability, compatibility, etc.
- Agree with defined future work.
- Need to demonstrate how these fuels can become commercially viable in the U.S. market including fuel cycle energy and emissions of regulated and CO₂ emissions.
- Drop project.
- A LDD fleet study would be useful, including NOx aftertreatment targeted for Tier 2 Bin 5. Also, it would be interesting to incorporate advanced, real-time PM instrumentation into the program, including PM number measurement. This approach might be better than trying to discern a post-DPF GTL effect based on traditional PM mass measurement techniques.
- Cold weather operation and fuel effects.
- What are optimum blend/fuel properties to achieve cost-effective emission and petroleum reduction benefits?
- It would have been very helpful for me to see where this work fits in with all the other work reported on GTL - was there any basis for worrying about GTL compatibility with CCRTs?
- Fuels derived from different feedstocks.
- Continue running in-use fleet to very high miles and document fuels, maintenance, and emissions deterioration issues.
- Planned future work is good. There is still a looming question whether GTL can and will be domestically produced given its economics and BTU penalty--a more complete study of this is needed. If this analysis is negative, then further funding of this whole area will not meet the program goals and it should be terminated (although this was one of the most well-conceived and run programs presented). Need to include lubricity and long term wear and injector analysis implications in future work--this has not been done. Additional areas of concern to the OEMs (i.e. 'sociability') need to be addressed as was brought up in comments such as cold start, white smoke, engine noise, misfire limits vs. cold temperature. More work is needed on GTL compared with ULSD and with biodiesel blends, especially with GTL as a blending component in the 10 to 30% range.



Fuels Technologies Program

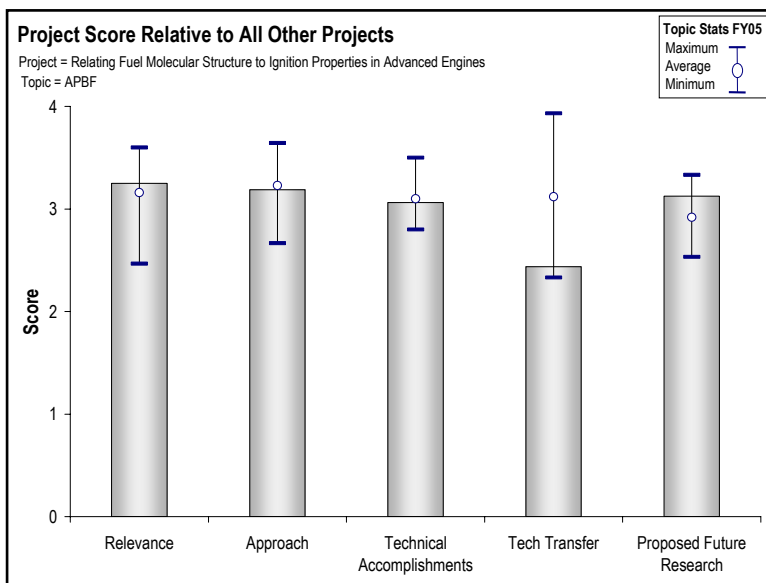
Relating Fuel Molecular Structure to Ignition Properties in Advanced Engines, Joshua Taylor of the National Renewable Energy Laboratory

Brief Summary of Project

Here, researchers are attempting to relate fuel compound molecular structure to how ignition delay varies with temperature. This process involves the use of a test matrix of fuels whose ignition delay properties are measured in an ignition quality tester (IQT).

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 16 reviewers)

In general, reviewers thought that the program is relevant, and the main technical question (that of HCCI ignitability) is central. One person stated that this project deals with one of the barriers to making HCCI technically viable. Another positive comment was that this is very interesting work with the IQT, albeit tangential to DOE goals. Another reviewer added that more justification of the project is needed beyond matching activity relative to DOE goals. A reviewer suggested if fuel properties or even a more relevant bench technique can be developed that will better quantify compression ignition characteristics it would be a huge benefit, not only for current technology engines, but future engines with varying combustion modes. Another reviewer offered that the project title and objectives are a good fit to meet the overall program objectives and is background information that would be helpful to other projects and efforts. A final reviewer said that in itself the project is important for deepening the understanding of ignition and fuel properties.



Question 2: Approach to performing the research and development (Written responses from 11 of 16 reviewers)

Most reviewers felt that the researchers had a good approach. One commented on the validity of testing as it applies to HCCI. Another said this is interesting fundamental research and an important step will be correlation with homogeneous, HCCI-like combustion which the speaker acknowledged would be investigated in the future. The project appears to be on track, commented one reviewer. Another added that good analysis of fuel chemistry is involved. A suggestion was made to expand engine evaluation to include other low-temperature combustion modes beyond HCCI and that the theoretical analysis of current information is excellent. One reviewer felt that a better-defined objective is needed that increases the novelty of the research. Another acknowledged that HCCI is the biggest incentive but was not sure how this test relates. According to him, the IQT is well suited as a CN surrogate technique, but it is not, as constructed, useful for HCCI fuel screening. Another added that significant modifications are required to permit extraction of the type of fuel chemistry effects desired. He went on to say that what's going on in the IQT needs to be understood much more before it can become a useful tool. Another reviewer agreed and said that IQT needs to be re-configured as a research tool, with control of fuel/air ratio, temperature, pressure, mixing time, etc. One reviewer offered the opinion that the approach appears to be more of a shotgun of "let's try some fuels and see what happens" rather than using a fundamental understanding of fuel combustion chemistry, along with some sort of economic or feasibility analysis of fuels or components that could realistically be produced, to choose the fuels for testing and analysis. This reviewer said that there has been very little actual modeling of results based on physical or chemical parameters to yield the most promising fuels as of yet, but the project is still in the data gathering mode. A reviewer offered several questions: is vaporization not a factor in ignition? Any fuel has distillation characteristics (the light components ignite first): can vaporization compensate for lower cetane?

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 16 reviewers)

All the comments regarding technical accomplishments and progress were positive. One person stated that it is a start for ranking fuels. Another noted that the researchers are very active in collecting data on oxygenates. A reviewer added that good data were derived based on cetane number and activation energy. A comment was made that there is good use of chemistry and engineering fundamentals in this project. Many reviewers liked the approach and one suggested that it would be good if it could be as broad as possible. Comments were made that there is lots of data and it is good to see model compounds as well as fully blended fuels. A person added that a more rigorous analysis of the results is needed. Another reviewer stated that the results were showing promise, but the investigators need to make the connection between theoretical values and what really will provide benefits for HCCI.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

Reviewers felt that not much was said about the collaborations and technology transfer. To one reviewer this did not seem to be a problem, as work was well done. Another thought that the industry collaboration could be improved. One person added that now would be a good time to solicit the opinion of auto OEMs. One person said that he did not hear much about technology transfer. Another agreed, saying that it's not clear what the level of industrial/external coordination is. A comment was made that as this goes forward, a new method of characterizing ignition will hopefully result to replace the current cetane number/index. He added that this will require significant engagement of ASTM, CRC and the petroleum industry. A final reviewer said that it wasn't apparent that petroleum industry has been involved in the selection of fuels or oxygenates. More work is needed on "real potential" oxygenates or other compounds to give the petroleum industry some options for making a good HCCI fuel. This reviewer didn't think it would take much time to coordinate, however. One reviewer thought it was too early to assess transferability.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 8 of 16 reviewers)

A reviewer felt that this project enhances the success and understanding of fuels for HCCI. He added that collaborative work with Sandia and SF State is good. A reviewer thought the work should continue to improve understanding. One reviewer liked the idea of expanding the project scope to include biodiesel fuels. Another reviewer thought that future work on HCCI combustion was not clearly presented. A comment was also made that a milestone for a decision on whether this test is relevant to HCCI is needed. One person mentioned that understanding cold-start emissions will lead to reducing these emissions. Another commented that the technique should be made as broad as possible to cover all combustion modes. A reviewer suggested that work with ranking HCCI fuels and more biodiesel blend studies on HCCI makes sense, especially given recent interest in biodiesel and the likelihood that higher commercial volumes will be available. Even if oxygenate work proves out, it was not clear to this reviewer that DPGME and TPGME would be economically produced and serve as a realistic fuel component to get to the replacement goals.

Specific Strengths and Weaknesses (Written responses from 13 of 16 reviewers)

- Specific Strengths
 - Good fundamental look at combustion.
 - Focused on an important problem.
 - Excellent theoretical analysis. Potential for wide ranging applicability.
 - Application to all combustion modes.
 - Good work on HCCI fuel properties, correlations, and better understanding of fuel ranking fundamentals.
 - Interesting research to improve our understanding of effects of molecular structures on combustion efficiency.
 - Good technical and logical approach.
 - Capability established.
 - Simple, automated bench test of ignition quality run on a wide variety of fuels at a wide variety of conditions.
 - Relation of activation energy to molecular structure and kinetic mechanisms.
 - Ability to rank on a performance basis HCCI fuels. Determining the effects of activation energy on ignition



- quality.
- Ranking of fuels for HCCI and development of theoretical models which can be used and then comparing the model results to empirical data would be very valuable, especially with blends of replacement fuels like biodiesel with “conventional” diesel fuel.
- Important investigation of fundamental fuel properties that may help identify future candidate formulations.
- Specific Weaknesses
 - Still a lot more testing required.
 - Conditions for HCCI combustion testing are not clear.
 - Trying to use one test to correlate with cold starting under normal diesel combustion conditions (not premixed) and HCCI, which is premixed.
 - Need to translate fundamental fuel properties into sources and how to produce future fuel candidates.
 - Need to review use of ether-oxygenates from other-than-chemistry view (e.g., environmental, safety).
 - The tool is poorly suited to address the problem as is.
 - Need more data on real engines, need to include fuel properties beyond those evaluated. Also, need to include some discussion of cost, availability, etc. of the compounds investigated such as DPGME and whether they are practical.
 - Not correlated to engine tests of HCCI or low-temperature combustion.
 - So far, work doesn’t seem to directly link to HCCI. Maybe initial work is just setting the stage for future, more relevant research that would more directly measure performance under HCCI conditions.
 - Lack of coordination with the fuel industry, lack of more complete theoretical understanding and development of theoretical modeling and understanding of important combustion properties as they relate to fuel composition and structure and HCCI, but this is the reason for doing the work. More work is needed to determine if the fuels being tested have a real shot at commercial reality and therefore getting to the replacement goals. Perhaps some of this is there, but it didn’t come out in the review.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 16 reviewers)

- Would including some chemical kinetic modeling of the combustion of the fuels help to increase our understanding?
- The future work outlined is right on track.
- Develop other combustion tools for additional characterization more closely associated with real-world combustion.
- Correlate Ignition Quality Test results to ignition delay or ignition performance of gasoline and/or diesel engines operating in HCCI mode; correlate cold start estimates with real engine startability; include low compression ratio non-production engines in this study; correlate results with kinetic modeling of auto-oxidation at HCCI conditions.
- Needs to coordinate with engine development activities for cross-fertilization.
- Look for peroxides in fuel with use of oxygenates, could be the source of cetane boost!
- There are a number of experimental approaches for measuring ignition delay. The primary benefit of the IQT is that it permits rapid measurements for a variety of fuels, and with a minimum of sample. The major weakness, however, is that it does not appear to give results consistent with other approaches (e.g., RCM, shock tube) whose validity for understanding ignition kinetics has been established. Other major issues limiting its utility for screening HCCI fuels include the fact that the mixture is not even close to homogeneous and the equivalence ratio is too high ($\phi=0.8$). This technique also doesn’t address the fact that HCCI ignition for a given fuel mixture depends on three variables: pressure, temperature, and time - all play a major role. The goal of ranking fuels for HCCI begs the question - under what conditions? The ON and CN tests have a well-specified area where fuel rankings are required - what about HCCI? Will it rank at high load or low?
- Broaden the scope of combustion modes. Even if fully theoretical technique is not possible, perhaps a bench technique can be developed.
- Expand scope beyond just ignition delay effects, include consideration of real engines, include some judgment of practicality of fuels considered, and further develop chemical explanation and modeling to explain effects.
- Might also include more inexpensive, non-biodiesel, non-oxygenate fuel components in future work.



- Continue with existing recommendations, especially the biodiesel. Need to do pure compounds to get info for the model, but need to expand the testing to include realistic blends of these components with diesel fuel. More work needed with the fuel industry to determine what realistic oxygenates or other components could or might be produced if this work proves successful.



Fuels Technologies Program

Testing of Biodiesel and Biodiesel Blends in a Modern Production Medium-Duty Engine, Bob Hayes of the National Renewable Energy Laboratory

Brief Summary of Project

This project is designed to learn about the effects of biodiesel use in a modern production heavy-duty diesel engine to improve the understanding of the fundamental mechanisms causing observed emissions effects. A proof-of-concept strategy to mitigate NOx increases while retaining other emissions benefits will be developed.

Question 1: Relevance to overall DOE Objectives (Written responses from 12 of 16 reviewers)

Reviewers were very positive in stating that this project was relevant to meeting part of DOE's fuel displacement goal. One said that there is little information on biodiesel and biodiesel blend impacts on post-2000 engine technologies. This project addresses a real need, and biodiesel does have the potential to hit the 5% replacement fuel goals of FCVT. Nearly 1 billion gallons of petroleum displacement annually is possible with a national B5 level. Petroleum fuel displacements at substantially higher levels than B5 were investigated. One reviewer commented that understanding the emissions tradeoffs in modern diesel engines is valuable as the results are different than for previously tested, older technology engines. Another reviewer stressed the need to understand why the results were different and to compensate if possible through adjustment of engine parameters. A final reviewer said that his lower numeric rating was only due to the fact that the project explores "one" modern engine, while the objective and the conclusions refer to "modern engines."

Question 2: Approach to performing the research and development (Written responses from 9 of 16 reviewers)

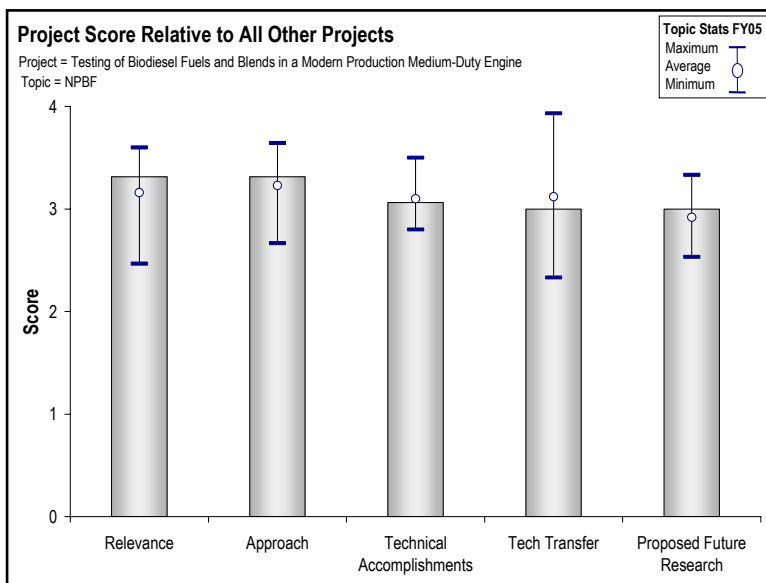
Reviewers were satisfied with the approach used, stating that it had industry involvement, was similar to other work done in this area, was well thought out and designed, and had a good basic approach for looking at the effects of different biodiesel levels. The method of understanding combustion, NOx and soot was considered adequate. In-cylinder condition measurements (temperature, pressure, mixedness of EGR) would help evaluate why the tradeoffs for a modern engine are different from EGR, perhaps mechanically controlled, engines. One reviewer said that the results of the tests are most likely engine-specific; can we draw general conclusions?

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

Again, reviewers were positive about the accomplishments of the project. While one reviewer felt that the increase in knowledge was modest, another felt that the work led to more questions, which was a good thing in that it identified additional research areas. Curiosity was expressed about the understanding the "root cause of the NOx increase." A reviewer said that the lack of impact of feedstocks and cetane improvers with newer EGR engines is truly groundbreaking and an important finding, and leads to other solutions than fuel modification for biodiesel in these new technologies or means that modification of the fuel for cold flow improvements will most likely not substantively affect NOx emissions. A reviewer said that the project needs to continue investigating why the engine behaves this way (injection, EGR, combustion geometry, spray are all interconnected to affect emissions). Finally, a reviewer commented about the interesting near-term conclusion but also felt that tests from only one new Cummins engine cannot support a wide statement about all new engines.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 9 of 16 reviewers)

Responses on this question were diverse. Some found good involvement but others clearly want to see more



involvement with an energy company, a light-duty diesel engine OEM, other medium-duty OEMs and collaboration with other national labs. That would assure an appropriate focus on the issues and wider technology transfer. One reviewer said that the team had good collaboration with the engine and fuel industries, but the team needs to do a little more to get the word out about this really good project to the OEM industry in general. A reviewer said that these results were for one engine only, and we should not infer behavior of all modern combustion systems will be similar.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 12 of 16 reviewers)

Responses on this question were also diverse and numerous. One said that future plans are reasonable, but the team should avoid generalizations, unless they are proven. One reviewer thought the work was right on target but others felt that more insight would be needed on how to meet emissions reduction goals and on how to evaluate the economics of the fuel use. In addition, while there is good work toward more chassis testing, there is a need to address fuel quality as well as blending stability issues. Another reviewer felt that including 2007-targeted PM and NOx aftertreatment is important. While future work seems to indicate that this will be included, advanced PM measurement technology will be required. Current EPA gravimetric methods planned for 2007 are inadequate for DPF research, stated one reviewer. Another reviewer suggested in-cylinder conditions and fuel properties be taken into consideration in future work. Also suggested were tests to see how the loss in energy efficiency could be mitigated. Other comments focused on better understanding and eliminating the increase in NOx emissions with biodiesel use, both at engine-out and chassis levels. Finally, a reviewer said that the future work plan is solid, but suggested that the team have more engine companies' input into parameters to be studied so they can take advantage of the information.

Specific Strengths and Weaknesses (Written responses from 13 of 16 reviewers)

- Specific Strengths
 - Good logical approach.
 - Excellent match with DOE objectives.
 - Good start in exploring biodiesel emissions and fuel economy performance in modern engines.
 - Relevance for one modern combustion system.
 - Addresses true barrier of lack of data on new engines with B20.
 - Experiment with different types of biodiesel to understand fuel properties effects on emissions.
 - Attempts to understand reason for biodiesel NOx increase.
 - Fits well with the DOE's objective of removing impediments and encouraging use of biodiesel in the future.
 - Fits well with Bob McCormick's project - this project should also benefit from the detailed fuel property considerations in that program.
 - Understanding the difference between engine-out and chassis NOx emissions results needs to be understood.
 - Working on a timely issue with increasing emergence of biodiesel in market.
 - Biodiesel potential for imported energy replacement. Interesting exploration of combustion effects.
- Specific Weaknesses
 - Need to include non-road applications.
 - Needs to be oriented toward more fundamental understanding.
 - Correlate the results to in-cylinder conditions (spray characteristics, timing, pressures, temperatures, air fuel ratio) and fundamental fuel property effects (boiling point, fuel evaporation).
 - Need to expand the research well beyond what has been reported.
 - Just a minor comment regarding the presentation: properties of the fuels used for the bus testing were not detailed. Biodiesel effect seems too pronounced.
 - Do not yet understand mechanism of increased NOx with biodiesel. Also, work seems somewhat more focused on selling benefits of biodiesel than on fundamental understanding of why these benefits are evident.
 - Based on one engine, concluding that later engine technology is more sensitive to biodiesel, even though the results are within the range of what has been seen below.
 - Compares one modern system against several typical older engines.
 - Not clear how this breaks down barriers to more biodiesel use.
 - No energy partner to guide fuel insights. Only one engine under test.



- Biodiesel should not be limited to SME; other feedstocks may improve benefits.
- Only potential weakness would be getting a little more input from other OEMs and getting data out in a general sense, but all in all a very strong program.
- Must explain combustion effects observed. Collaboration within and outside NREL needed.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 10 of 16 reviewers)

- Long-term evaluation of biodiesel: engine durability, material compatibility, etc.
- Keep up the good work.
- Work plan should continue, and potentially be expanded to other engine or in-cylinder technologies which will be used.
- Demonstrate economics of biodiesel to show incentives for use; demonstrate how high altitude testing relates to low altitude applications.
- Explain the real-world NOx reduction in the chassis tests.
- Describe strategy to reduce NOx increase with biodiesel.
- I would phase out this work using the current approach and combine it with other studies of the fundamentals of fuel properties on diesel combustion over various combustion modes that include low-temperature combustion and HCCI. Understanding of the emissions effects of biodiesel should be part of a broader understanding of fuel properties effects on combustion.
- Looking at biodiesel impacts on one specific engine does not do much for removing barriers to increased biodiesel use.
- Future technologies (post-2007 engines) are expected to use diesel particulate filters. How might biodiesel affect this subsystem, impact of fuel properties on injection characteristics and factors that might reduce the fuel economy penalty?
- Recommend collaborating with Mueller at Sandia to generalize results from both engine systems.
- Engage other DOE expertise in engines and combustion.
- Proposed ongoing work will be good additions. In engine optimization for biodiesel, should add further work to understand molecular mechanisms for why biodiesel optimums are reached and if other non-biodiesel blending agents could provide similar or better results at lower cost.



Fuels Technologies Program

Weekday/Weekend Ozone Study, Doug Lawson of the National Renewable Energy Laboratory

Brief Summary of Project

The main purpose of this project is to study the phenomenon of weekend ozone levels being higher than on weekdays for many urban locations, despite lower ozone precursor production (i.e. hydrocarbons, carbon monoxide, and NO_x). Activities under this project included analysis of existing ambient air quality data, development of emissions inventories, and air quality simulation modeling.

Question 1: Relevance to overall DOE Objectives (Written responses from 12 of 14 reviewers)

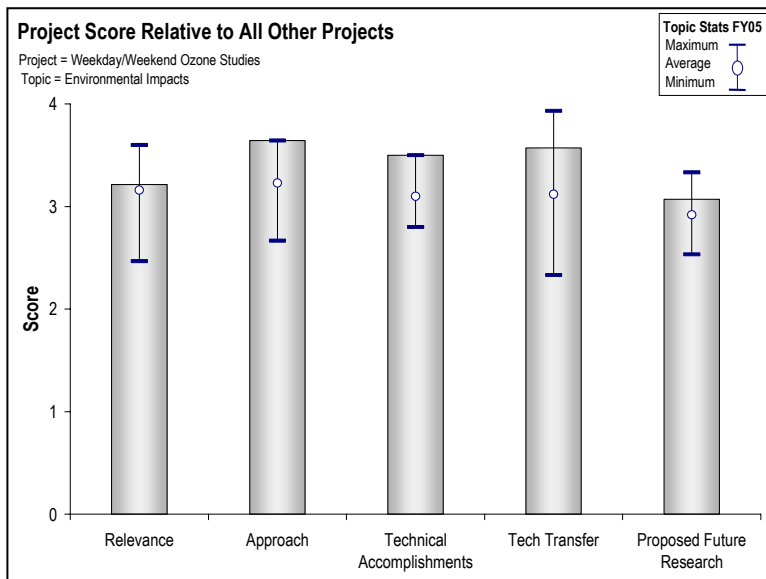
One reviewer commented that this project is a perfect fit into the New Technology Impact Research activity. Another added that this kind of work has been long needed; instead of ignoring the effect it is good to attempt to explain it. A reviewer said that it was highly relevant to understand ambient emissions, their origin and appropriate control measures. Another reviewer commented that the benefits to DOE policy would be a change of NO_x emissions regulations to enable high fuel economy engines/vehicles. Another person stated that while the study provides an understanding of the unintended consequences if no changes in emission patterns are made, future control strategies must recognize this impact and be developed accordingly. Others questioned the validity of the project in addressing DOE objectives. One reviewer stated that this air quality work seems out of the scope of the DOE objectives. Another continued that this is not a good connection with DOE objectives on future fuel technologies, other than perhaps establishing a current baseline for today's fuels. Another added that he cannot see the relevance to DOE's mission. Shouldn't this be an EPA effort? Another reviewer felt that the project is very relevant, though not sure whether this is more of an EPA issue. Another reviewer had a similar comment, stating that this research is interesting and is one area that could easily be overlooked and the responsibility is placed on another agency. DOE should continue this work to understand the air quality effects of advanced vehicles and fuels. A reviewer had extensive comments, noting that his immediate reaction was that it should rate low in this category: what in the world is the FreedomCAR program doing with ambient air quality measurement and interpretation? After sitting through the presentation and spending a considerable amount of time subsequent to this review studying the area and the results, it was clear to this reviewer that this project may have more impact in helping to promote DOE goals and objectives on the whole, as well as the Freedom Car program objectives, than any other presentation provided. This reviewer guessed DOE was just saving the best for last. The final comment was that this was a good study and pointed out that reducing NO_x will not eliminate ozone increase, but in fact the opposite occurs.

Question 2: Approach to performing the research and development (Written responses from 8 of 14 reviewers)

Several reviewers had similar comments that this was a good, well-thought-out, well-executed, and well-documented scientific approach. Others were concerned that the sample size will not produce statistically significant results, so the researchers need to analyze more areas. The final reviewer added that the collection of additional ambient VOC data would have been nice, but would have required equipment not currently installed. One simply said "wow."

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 14 reviewers)

In general comments were positive. One simply said "double wow." Several reviewers noted the good results that were generated. Another added that these preliminary results call for more detailed studies and analysis. Another added that results such as these are very useful during the consideration of appropriate control strategies. Yet



another felt that the results are extremely interesting; hopefully policy makers will consider these results as they propose new guidelines and revise current requirements. The final reviewer was not sure how this study would provide input to overcoming technical barriers.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 14 reviewers)

Reactions to this question were mixed. One reviewer felt that it appears stakeholders and policy makers are very well engaged. Another agreed that there was good coordination with CARB and SCAQMD. Another reviewer agreed that there was good transfer, but perhaps better direct collaboration on analysis of the results was necessary. One reviewer questioned why the EPA was not involved. A reviewer said the tool is important in assessing the effect of emission strategies in total emission inventories. One reviewer had difficulty in choosing a score, saying that the project is a 4 from the standpoint that the collaboration and involvement of others is first rate, but it was a 2 from the standpoint that this information is so groundbreaking (and so important) that it will take a significant amount of time and effort to share this information with regulators and others who have made a career out of trying to reduce NO_x. So much effort is being spent right now on reducing NO_x, and it was clear (in this reviewer's opinion) that EPA and other regulators have their blinders on about the weekend ozone effect implications—that NO_x is not what we need to be focusing on for reducing ground-level ozone—it is hydrocarbons. This can have dramatic effects on the applicability of higher fuel economy diesel engines in general, as well as the replacement fuels like biodiesel—all of which have “NO_x issues” of some sort. The final reviewer commented that he was not sure how amenable this program is to industrial (OEM) participation.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 14 reviewers)

One reviewer noted that while study provides valuable insights on control strategy development, it is not clear how this would apply to engine technology development. Another reviewer commented that it seems as though the fundamentals are known now; he was unsure how extension to other cities should be balanced. Another reviewer noted that the need for VOC reduction was identified. One commented that the need for future work was not certain. Finally, a reviewer said that it wasn't entirely clear from the presentation what the next steps or proposed research should be. In subsequent discussions this reviewer had with Doug Lawson, it was agreed that a significant and sustained effort is needed to share this information around the country and see that it is used to create appropriate policies as they relate to NO_x in general—and as that relates to DOE as well as USDA goals for our country—and this must be done.

Specific Strengths and Weaknesses (Written responses from 10 of 14 reviewers)

- Specific Strengths
 - Work is beyond reproach.
 - Interesting study.
 - Good scientific study.
 - Excellent study.
 - Liked everything. Very interesting.
 - Fundamental study addressing key issue for understanding ozone formation and policy question.
 - Construction of emissions inventory and air quality modeling.
 - Extensive field data.
 - Excellent work on a critical and basic issue.
 - The conclusions of this work are significant. These conclusions should be considered when policies regarding air quality are considered.
- Specific Weaknesses
 - None.
 - Application to DOE goals on advanced fuels and other advanced technologies.
 - How are VOC reductions going to be achieved?
 - If the hydrocarbon limited argument is accepted, how can improved control of poorly maintained gasoline cars be achieved to further reduce HC levels?
 - Not sure there's an answer, but how do we solve the problem?



Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 9 of 14 reviewers)

- Work toward future technology impacts and work beyond a baseline situation for future technologies.
- Not clear that much more work needs to be done; the question is what does this mean to policy?
- Results and conclusions should be compared to other studies. Disparate conclusions and opinions should be reconciled whenever possible. Findings could have a profound effect upon state and national air quality control strategies, if a consensus emerges among researchers.
- This is a very important area but the connection to DOE's goals (in particular for the next stage) needs to be there.
- It is important to remember that the purpose of ozone attainment is the reduction of health effects caused by air characterized by ozone levels. Is the activity shown for HD vehicles in Long Beach related to port activity, and how recent is this data?
- Try to get as wide a visibility for this information as possible so that future legislation can be fact-based instead of opinion-based.
- More follow-on characterizing VOC emissions seems to be worthwhile.
- [Provide] defined ways to reduce VOCs.
- Fund the sharing of this information, and the follow-up work planned, at as high a level as needed to get the word out—AND ACCEPTED—among what is admittedly not going to be a willing audience (regulators and environmentalists) and the effort must be funded for a multi-year effort (5 to 10 years) because this will not be accepted overnight.



Fuels Technologies Program

Effect of Fuel Sulfur & Engine Operating Parameters on Corrosivity Associated with EGR in Heavy-Duty Diesel Engines, Mike Kass of Oak Ridge National Laboratory

Brief Summary of Project

This investigation centers on use of a corrosion probe to monitor corrosion induced by diesel engine exhaust. Investigators are also examining the effect of engine parameters on EGR-induced corrosion. Corrosion rates have been determined to be highly dependent on fuel sulfur level (higher sulfur levels cause more corrosion).

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 14 reviewers)

One reviewer felt that this is a good durability project, and another agreed, adding that the project addresses a real problem. A reviewer said that the project achieved in-situ measurement of corrosion caused by sulfur. Another went on to say that the impact of sulfur on engines as development moves forward to meet 2007 and 2010 emissions standards is important.

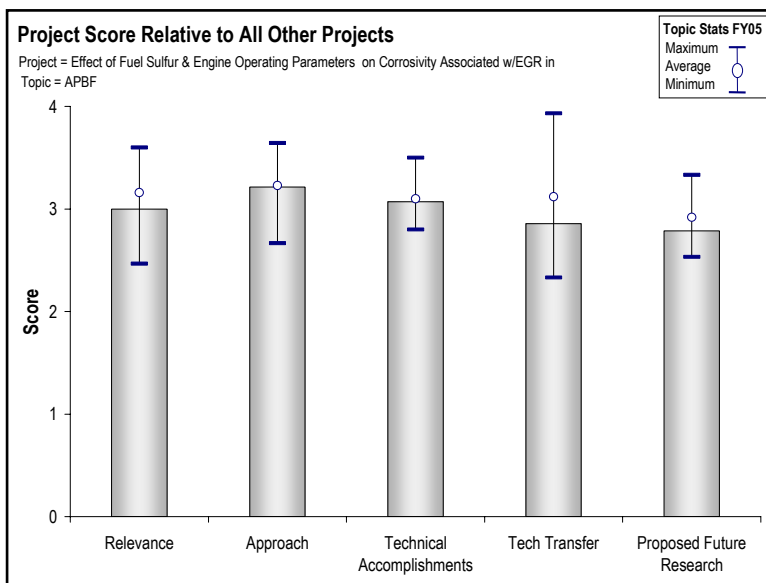
One person agreed that this work is relevant to the Fuels Technology objectives within FCVT, but another said that this is excellent work but is again focused on conventional fuel rather than the 5% replacement fuel goals. The focus of this work is durability and life of engine subsystems and provides an understanding of corrosive nature of fuel. If the probe works, then the instrument will be useful for future studies, although cost may be an issue. However, another reviewer noted that the sulfur level in fuel is coming down drastically, and that high-sulfur fuel has been used for many years and no significant corrosion problem in vehicle exhaust systems was observed. The final reviewer felt that the work does not seem to be an issue demanding DOE's attention.

Question 2: Approach to performing the research and development (Written responses from 9 of 14 reviewers)

Two reviewers noted that the in-situ use of a commercially available corrosion probe is an innovative approach, and a third said that this was an excellent transfer of technology from a different industry. A reviewer felt that this approach may work for low- and ultra-low sulfur fuels, but sulfur effect is more than on intake manifolds, especially with high-sulfur fuels (military and aviation fuels, or in other countries); how does one measure effects in such cases? Another reviewer felt the work was okay, but that it does not address source of sulfur, i.e., whether it's fuel or lubricant. They suggested that the researchers also look at fuel sulfur levels for the global market. Another reviewer thought that the work was good for the sulfur issues, but would like to have seen an in-depth analysis of the nitric acid situation, also. The final reviewer felt that the study could have included non-road fuels sulfur levels.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 14 reviewers)

One reviewer commented that the performance was good given the low level of funding. Another said that the results and implications of this project are outstanding and large. Others cited the development of corrosion probe as significant, with immediate, real-world application potential, and that the results demonstrate the needs for lower-sulfur fuel. Several reviewers stated that the program data provides a better firsthand understanding and valuable insight into conditions leading to, and processes of, corrosion. The final group of reviewers felt that the findings confirm what one would expect before conducting the study, however, the use of a probe in this fashion seems to be the innovative result from this effort. Another agreed, stating that the corrosion related to fuel sulfur level and onset of moisture condensation is not unexpected.



Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 14 reviewers)

One reviewer noted that two diesel engine manufacturers were involved, but others felt that there was room for improvement here. Another person added that even though there was not much outside involvement, the results are very useful and transferable. One reviewer felt that technology transfer is not obviously happening. The work is being done at ORNL on behalf of the engine companies. The final reviewer commented that it is hard to rate this area, as the industry field results were not reported due to a confidentiality agreement. This was echoed in the comment of a reviewer who said the proprietary data results with the two diesel engine companies should be repeated with government funds and made available to all with the unit already purchased.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 14 reviewers)

One reviewer felt that the researchers need a clear pathway forward, while another added that the efforts should be better focused on key barriers. One reviewer said the team should continue EGR system analyses. A reviewer suggested that further use of the probe would be worthwhile, but the researchers need to also address source of sulfur (whether from the fuel or lubricant) and in what percentages. Another person agreed, adding that studies with closed crankcase vent systems would be a benefit (which another reviewer said was an excellent idea). Another reviewer commented that future sulfur levels are expected to be low: is there a problem anticipated with such level of fuel sulfur? One said that the proprietary work should be made public, and it would also be interesting to do more sulfur levels between 15 and 350 ppm to verify the linear effects of sulfur concentration on corrosion, as well as some points with higher sulfur levels. One of these samples could be a 20% biodiesel blend as a way to reduce sulfur with 350 ppm fuel and with off road 3000 ppm fuel to quantify beneficial corrosion impacts. The final reviewer called for more in-depth of nitric acid's corrosion contribution.

Specific Strengths and Weaknesses (Written responses from 9 of 14 reviewers)

- Specific Strengths
 - This is one of the best projects I have seen in a while. Absolutely excellent.
 - Good work and good analysis.
 - Good application to durability research.
 - Quick and cost effective test method.
 - Fundamental study of key durability issue for future diesel system.
 - Identification of a tool or methodology for the industry to do its work.
 - Broad application. Scientific approach.
- Specific Weaknesses
 - Data analysis and firsthand understanding of the researchers.
 - Not all fuels were evaluated.
 - Should have also measured and correlated with pH of the condensate; not all sulfate will be sulfuric acid.
 - Need better science on condensation, 150°C is not the condensation point of dilute sulfuric acid in engine exhaust.
 - Not a strong case for future studies, at least until non-traditional combustion becomes more developed.
 - It is not clear that sulfur corrosion will be a problem with post-2007 engines considering that engine manufacturers have largely dealt with corrosion problems with <500 ppm S.
 - Not enough NOx contribution analysis.
 - Might want to look at nitrate level impacts on corrosion with ultra-low NOx technologies or high-NOx technologies (i.e., older equipment) to split out the corrosion impacts of nitrates vs. sulfates. Although, based on the data it probably doesn't make sense to do this with 350 ppm sulfur fuels or higher, since the sulfate levels will dominate.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 14 reviewers)

- Strengthen the analysis of the results for real-world applications.
- Need to look at non-road fuel sulfur levels.
- Analysis of hydrocarbons condensed at more reasonable cooled EGR levels.
- Analysis of pH of condensate.
- Use multi-component vapor-liquid analysis to explore dew point of exhaust mixture and expected composition

of condensed gases.

- Continue to work with OEMs to investigate sulfur-induced corrosion issues related to 2007/2010 targeted technologies.
- Not enough NO_x contribution analysis.
- Proposed future work seems appropriate. Might add how to avoid corrosion in intake system with high-sulfur fuels. Including biofuels is good, might possibly also consider oxygenates.



Fuels Technologies Program

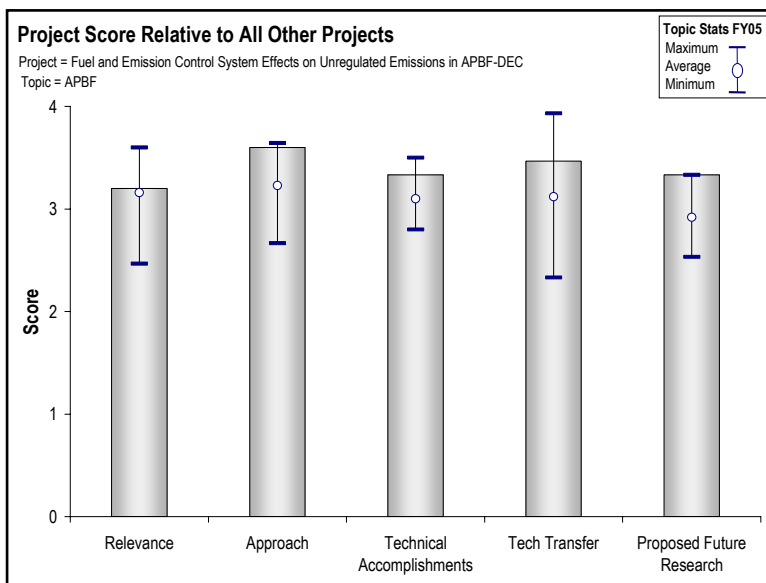
Fuel and Emission Control System Effects on Unregulated Emissions in APBF-DEC, John Storey of Oak Ridge National Laboratory

Brief Summary of Project

The goal of this project is to determine the effect of 2006 fuels reformulation on unregulated emissions and air toxics with and without advanced emission control systems. Three teams were working on unregulated emissions for urea-SCR, NO_x adsorbers, and lubricants. The teams developed analytical methods for measurement of any unusual compounds formed in urea-SCR systems and NO_x adsorber systems.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 15 reviewers)

All of the reviewer comments were very positive. A mention was made that this is a good problem to examine. Another stated that the researchers have looked beyond the DOE objectives. One person felt that this project is a good complement to the DOE program. Another commented that this is good technical work on understanding exhaust toxics. Another agreed and added that this is a good activity for due diligence of exploring new technologies. A reviewer said that given the use of novel aftertreatment systems to meet emissions requirements, it is prudent to investigate any undesired side effects of these systems. A final reviewer said that it is largely thought that new NO_x/PM systems will reduce overall air toxics compared to engines without such systems, so in that respect this project is just confirming what most believe to be true and thus isn't addressing what is viewed to be a "major barrier."



Question 2: Approach to performing the research and development (Written responses from 6 of 15 reviewers)

Most of the comments about the research approach were positive. A reviewer stated that this is a good program for a limited budget. Another added that it is comprehensive and thorough, and that these are the two key areas for emissions reductions being considered. Another thought that the APBF has a great work plan. One person liked the methodology development and added that this project was sorely needed. He also liked the attempts to answer some of the questions that came up during this research. To another reviewer the accomplishments seemed impressive, but he wondered whether there was a way to get the same data with less pain. The last reviewer said that the approach is good, especially as it relates to measuring urea decomposition products and development of measurement tools. This reviewer noted one major issue that was not covered: what happens to the urea by-products if the NO_x catalyst has been de-sulfated? In addition, this reviewer said that varying PAH levels in the incoming diesel fuel were not designed in when looking at exhaust PAH, although with DOC and DPF it probably doesn't matter. One group deemed missing in the development of the approach, however, was US EPA. This is a major weakness of this program (in this reviewer's opinion), as it will be CARB and EPA that set the technological constraints for unregulated emissions.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 15 reviewers)

All of the comments regarding this question were very positive. One person commented that very good progress has been made considering limited resources that were available. Another added that very interesting technical results on toxics were presented. A comment was made that the methodology contribution was excellent. A reviewer stated that there was good progress and solid conclusions were found. It did not seem clear to him what level of confidence (precision, accuracy) to place on the data, however. He added that for slide 16, one wonders if nitromethane is a problem.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 6 of 15 reviewers)

Reviewer's comments were positive regarding the technology transfer and outside collaboration. One person mentioned that there is a good collaboration with key stakeholders. Another agreed and added that he was impressed with the collaboration. One reviewer acknowledged that papers about this research are being published. Someone suggested that expertise with other labs and industry will probably have to be shared as we move forward and some or all of the methods become more universal. Another thought that perhaps larger industry participation would strengthen the study. A final reviewer said that EPA was not involved in developing the project, which was seen to be a major oversight. Other collaboration is good, in this reviewer's opinion.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 7 of 15 reviewers)

Reviewers acknowledged that the program is ending in 2005. Comments were made that a list of papers would have been useful and that papers are a very good way of spreading data. One person stated that tie-in to ACES is important. Another said that this project is a good match to future technologies. One reviewer felt that there is a need to move analysis into the mainstream.

Specific Strengths and Weaknesses (Written responses from 12 of 15 reviewers)

- Specific Strengths
 - Identify potential issues with new emissions control devices.
 - Doing the research now as opposed to later.
 - Developed techniques applicable to future research.
 - Good development of measurement techniques.
 - Relevance.
 - Useful work to look for unregulated by-products.
 - Very extensive list of compounds examined.
 - Connected to DEC engine/fuel studies.
 - Like the methodology development.
 - Methods developed for many compounds.
 - Looking at urea decomposition with both poor and good quality injection systems.
 - Good in-depth study of urea system.
 - Including regeneration during testing is beneficial to achieving relevant conclusions.
 - Great cooperative work on toxics.
- Specific Weaknesses
 - None identified.
 - Characterization of all the technologies is probably not being done; but a plan should be developed to take any developing technology through this process.
 - Did not include measurement of emissions during forced DPF regenerations and LNT desulfation.
 - Program is ending.
 - Simplifying the techniques for more mainstream use as routine measurements.
 - Appears to consider only normal operating conditions. What happens during common failure modes when things are not normal?
 - Not including desulfation effects reduces real-world benefits of test results; finding urea decomposition products pooling implies immature injection system design.
 - EPA not involved—this is a must. Desulfation of catalysts not studied, and impact of fuel PAH on exhaust PAHs not taken into account. Nitromethane was increased regardless—impact of this was not thoroughly discussed.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 15 reviewers)

- Find a way to bring new technologies to a single test lab location for evaluation at a pre-determined development point or set up a test protocol that can be duplicated in other labs to test for unregulated emissions in a consistent manner.
- Perhaps outside the scope of this project., but:
 - Need to consider the effect of secondary PM formation from ammonia slip.



- Environmental effect of leakage of urea/water solution prior to injection?
- Could nanoparticles and PM number be considered unregulated emissions? Application of advanced, real-time PM measurement techniques would have been interesting.
- We need to continue forums where OEMs, energy companies, national labs, universities, and other stakeholders cooperate on projects.
- I think this type of work is very important - we know that undesirable compounds (H_2S , N_2O) can be formed in aftertreatment systems and this should be well understood.
- A good follow-on would be low-temperature combustion artifacts.
- Look for other unintended by-products and under a wide range of operating conditions, including abnormal but plausible failure modes.
- Project is closing down, so publishing results the only thing left. Analysis of unregulated emissions (aldehydes, formaldehyde, urea degradation, PAH) should be incorporated as one component in future engine and aftertreatment studies, but only as a confirming analysis rather than something that needs to be done up front. This effort should be thoroughly reviewed with CARB and EPA regulatory bodies who will likely be making the determination for future regulations of air toxics to determine any additional recommendations in this area, especially CARB as it relates to multi-media testing for new engine technologies.



Fuels Technologies Program

Fuel Effects on Gasoline-Based HCCI Performance and Emissions, Bruce Bunting of Oak Ridge National Laboratory

Brief Summary of Project

This project team is evaluating fuel chemistry and property effects on gasoline HCCI combustion, performance, and emissions. The team extended previous studies to an engine with negative valve overlap, fully variable hydraulic valve actuation, and spark assisted ignition. An added activity is to learn about HCCI combustion control and stability through spark augmentation.

Question 1: Relevance to overall DOE Objectives (Written responses from 8 of 17 reviewers)

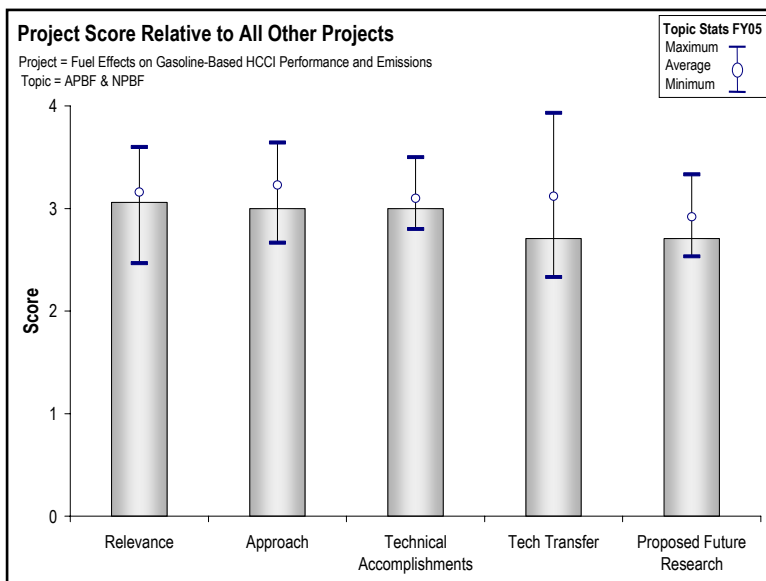
Reviewers recognized the significance of the project and generally agreed that it is very relevant to the DOE objectives. One reviewer made a comment that HCCI is a technology that can limit the cost impact of meeting future emissions regulations, and understanding how fuel can impact HCCI operation is of great importance. Another added that the overall objective is to understand fuel chemistry effects. He also stated that the fuel matrix is too complex for this objective right now. It was mentioned that the research has made a couple of modifications based on previous input. Reviewers agreed that this technology has a great potential for emissions reductions. They also emphasized that the fuel effects have to be understood. A reviewer commented that this is the type of fundamental research that should be conducted by DOE and that it is very relevant. Someone mentioned that it's hard to grade this one as "sharply focused" because there are so many aspects, but that "we'll be a whole lot smarter when it's done." To one reviewer it was not clear what conclusion should be drawn from this work. Another asked why or how was 50 percent of mass fraction burned (MFB50) selected as a fuel property for correlation? This seemed arbitrary to this reviewer. Another added that HCCI is interesting science, but the relevance to DOE goals is tangential. One reviewer thought that more specifics (quantitative) are needed on this application.

Question 2: Approach to performing the research and development (Written responses from 10 of 17 reviewers)

The reviewers had generally positive comments regarding the approach of this project. Some of the positive comments included: "great fundamental research," "good engine for this type of work and DEER presentation was also good," and "very good technical program and in-depth understanding." One reviewer commented that the ORNL engine uses fixed engine valve control while most other HCCI researchers are using variable valve timing to optimize HCCI operation. Another said that this is a complex project and that the complete results using statistical analysis are needed to properly rate this area. Another thought that a clear connection is needed with the experimental research and final application. A reviewer stated that an incomplete picture is presented when focusing only on fuels. Another felt that the research could use a precise technical question to be addressed and that it comes off as "learning along the way." To one it did not appear to have a clear emphasis on understanding why fuels behave differently. He was not convinced that differences are not due to engine not being well matched to the fuel. Another understood that the goal is to understand fuel effects, but asked "under what conditions and with what end?" Another said that a more in-depth analysis to determine the reasons for some of the effects observed is required and that more of a systems approach between engine technologies and fuel would be beneficial. A reviewer said that the approach of not inventing a new fuel, but assessing volatile fuels characteristics, is very realistic.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 11 of 17 reviewers)

Reviewers mentioned that this project has provided good data on fuels that may become good HCCI and LTC candidates. This project was viewed as an important addition to the HCCI knowledge base. One reviewer felt that



evaluating ten fuels was a major accomplishment. Another said that this was a very solid technical analysis. One commented that quite a bit of experimental work has been accomplished. One thought that the focus on fuels that are in the marketplace or could be distributed in the marketplace is critical for this project. Another mentioned that this is an important topic, but improvements could be made in the approach. A reviewer thought that complex interactions between multiple variables will be difficult to determine without a larger sample of data. A reviewer commented that producing and distributing a unique fuel may lead to poor acceptance and integration. A reviewer commented that there seem to be lots of data—he would like to see more key conclusions from it. He added that it is important to know that data point variations are due to fuel versus experimental conditions and hopefully Battelle statistical analysis will help. Another agreed that more in-depth theoretical analysis is required. It was also mentioned that a summary of accomplishments toward the program goals is needed. One said that results should be shared with the public faster, and that lots of interpretations have yet to be done, but this may just be a factor of where the program is in its life.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 17 reviewers)

Comments on the technology transfer and outside collaboration were somewhat mixed. A reviewer made a comment that HCCI operations are very dependent on the specific design and configuration of the engine and it may be difficult to apply the information from this program to other engines. One reviewer said that this project is very good and that he is curious what the OEMs' thoughts are on impact of this research on their projects. Another reviewer liked the broad industry involvement, whereas another commented that broader industry collaboration might be helpful. Someone mentioned that having engine/auto industry involvement would be good if it could be kept relevant and pre-competitive. One felt that there is limited collaboration, with no fuel supplier or OEM involvement for technology critique/transfer. Another asked where the industry interest and support for this effort is and how industry will take the results from this effort to develop products to meet 2007, 2010 standards. One reviewer stated that Asian OEMs (e.g., Honda) would welcome a dialog on this issue. He added that Honda developed and produced an HCCI-like engine several years ago for a racing motorcycle, and work continues. A reviewer stated that he did not hear much about technology transfer. Another suggested engaging Sandia, with their knowledge of low-temperature combustion.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 17 reviewers)

Several suggestions were made by the reviewers in regard to future research. A comment was made that the statistical analysis is needed to drive the direction for future research. A reviewer states that there is a need to define where the research is going and what the expected outcome will be. He went on to say that a variety of new projects are proposed, but it is not clear how these efforts will contribute to the final program goals. Another agreed that the forward path needs to be more clearly defined rather than just discussing and reviewing data with various groups for input and ideas. He asked, "Where is the industry input and interest?" A reviewer highly supported the stated objectives, but was not sure this project is a great start on getting there. One reviewer thought that the description of future work was slightly vague but the direction of the project seemed good. Another added that SAE paper(s) should be planned, if this is not already in the works. Someone said that there were not enough details presented to judge future plans. He wondered what is expected from continued work. To him, future plans of test/analysis and publishing are vague. One thought that future planned work will help complete the research that has been done. He added that the data help provide a better understanding of this technology. Someone stated that there is a need to understand what the spark is doing: is there a relationship between fuels that need a spark and those that don't? Another suggested bringing in as much outside expertise as possible to answer the questions regarding the results.

Specific Strengths and Weaknesses (Written responses from 14 of 17 reviewers)

- Specific Strengths
 - Evaluating a wide variety of fuels.
 - Good look at a wide range of fuel and engine variables.
 - Excellent approach.
 - Good experimental program.
 - Goal of project to understand fundamentals of fuel chemistry on combustion.
 - Use of existing engine a good idea, collaboration with fuel company good and necessary, use of Battelle for



- statistical analysis a good idea.
- Good science and understanding of engine effects.
- A useful engine parametric study.
- It is important to understand effects of fuels and new combustion regimes. Project takes comprehensive look at multi-parametric operating regimes and fuel combinations.
- Bruce has done a good job reaching out to industry; great fuel matrix.
- Well designed fuel set. Engagement of fuel supplier.
- While the experimental approach is sound, HCCI technology must be further developed. Experiments may be needed as HCCI technology is further along.
- HCCI and LTC are relevant topics for the future low-emissions, high-efficiency IC engines.
- Specific Weaknesses
 - The fuel matrix is too complex for the state of engine development.
 - A common fuel matrix should be used for all DOE gasoline HCCI projects.
 - How /why are these fuels selected - rationale, crisp understanding /learning, very high UHC, low BMEP tests.
 - How will results translate into direction for future engine development?
 - Overall direction and application toward program goals (what is the real-world application of the technology toward energy reduction and economics).
 - Too many abbreviations used with this audience. Tangential research to DOE goals, but very interesting work.
 - Lack of sufficient in-depth analysis. Engaging of all combustion expertise available at the other national labs.
 - Need more useful correlations with fuel properties, though perhaps this is part of a future study.
 - Need to see if the statistical analysis points out any weakness.
 - I would increase focus on HCCI conditions and what can be done to expand focus on pure HCCI.
 - It is hard to tell yet—still in the middle of the research. There is a ton of data here—and it seems other interesting data—operating outside of the chosen points—have to be overlooked at this point, otherwise they would be buried in data.
 - Need to expand the collaboration of other fuel companies to confirm data is valid for broad range of “real” fuels, need to publish results and make available sooner than waiting on presentation at SAE or other industry groups, need more collaboration with auto and OEMs.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 13 of 17 reviewers)

- Need to investigate effects of engine design (valve timing, EGR rates, compression ratios ...) on combustion in addition to fuel effects.
- As stated above, need to see the results from the statistical analysis to drive the next steps.
- Need to summarize the impacts of the fuels and the potential commercial applications of the data collected to date.
- Rather than measure combustion phasing as a function of fuel properties, combustion needs to be optimum no matter what fuel is used. Change the approach of the project to adjust engine controls, including valve timing, to optimize combustion on each fuel. Correlate resulting optimum valve timings with fuel composition.
- Tie the results to kinetic modeling to provide better understanding of results; start with simpler fuel structures for which auto-oxidation chemistry can be better modeled.
- Spend more time improving engine system to enable better pure HCCI combustion.
- I disagree with proposals to go away from fully flexible valves; pre-competitive research should not worry about added hardware but should use systems that have the most flexibility.
- Fuel compatibility with future conventional SI engines should be considered, (but not as a limiting factor).
- More emphasis on understanding results & conclusions. Need for acceptable UHC vs. NOx, formaldehyde measurements.
- Can this program identify the advantages and disadvantages of SI and CI approaches to the engine(s) of the future?
- Statistical analysis is a good next step to see what is real vs. noise in the data.
- Recommend evaluating fuel effects at constant conditions (valve timing) etc. to help differentiate fuel vs. hardware effects; there is a tremendous amount of data here - it should be milked thoroughly.
- Use ALL of DOE resources.



- More on fuel molecular effects would be useful. Work to date does not really answer the stated objective to “Evaluate fuel chemistry and property effects on gasoline HCCI combustion, performance, and emissions” (slide 2).
- On the objectives slide—seemed to reverse engineer the tie to the FreedomCAR plan.
- Complete the outlined follow-up. No change in work scope.



Fuels Technologies Program

Fuel Property Effects on Diesel High-Efficiency Clean Combustion, Scott Sluder of Oak Ridge National Laboratory

Brief Summary of Project

The focus of this project is to examine fuel property effects on advanced combustion regimes. The approach to this project is to perform engine-based evaluations of the performance of relevant fuels in a 1.7-liter diesel engine operating in a high-efficiency clean combustion mode achieved through EGR dilution and fuel parameter adjustments.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 15 reviewers)

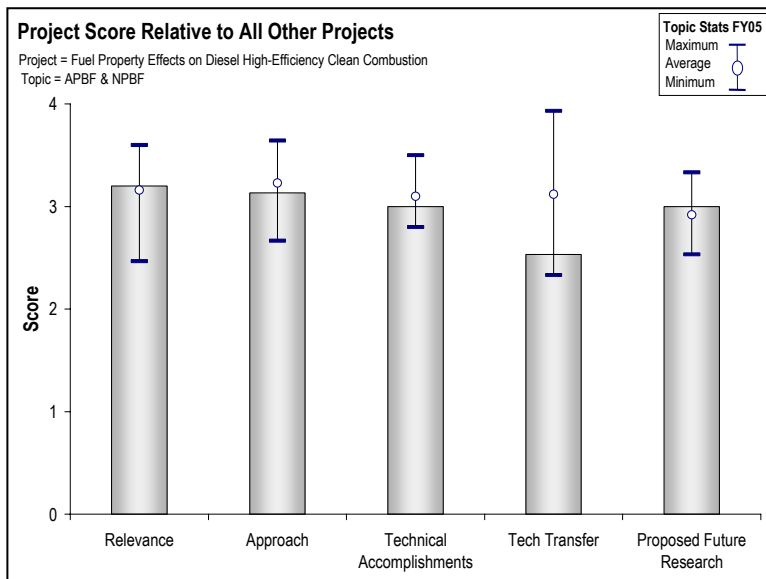
In general, reviewers felt that this research was relevant to the DOE objectives. One reviewer noted that understanding of the fuel properties is one key to enabling clean combustion. A reviewer said that this project is a good start to point out the need for a comprehensive fuel program for clean combustion. To another reviewer this project appeared relevant in general terms. One person commented that the fuel designed needs to be improved to allow fundamental understanding of its fuel properties. Another liked the combination of combustion modes and fuels. However, he added, oxygenates are unlikely to be commercially available in sufficient quantities to have a significant impact. To one reviewer this project seemed like conventional diesel work that would be appropriate for OEMs to do. To a final reviewer, the use of biodiesel (especially blends) certainly fits in with program goals, but testing of ECD-1, CARB diesel and certification diesel doesn't replace petroleum, although they are needed for baseline.

Question 2: Approach to performing the research and development (Written responses from 10 of 15 reviewers)

Several comments were made about how the approach of this research could be improved. One reviewer said that this is a good start, and another said that the approach is very good. Another added that good hardware is in place. One person stated that statistical analysis of the data is required. He also mentioned that in addition to cetane differences in the current fuel set, there are other differences (aromatics, oxygen, sulfur...) that could cause the differences in performance. Someone asked if generalization to other engines beyond the Mercedes 1.7 liter can be made. He also asked how different engine geometry affects the results as well as the range of variations that could be tested and evaluated. He was not sure if all of the key variables were accounted for. One person felt that when using different fuels, attributing results entirely to cetane differences may not be correct. Another added that differences in other fuel properties may be the cause. A point was made that this research needs a coherent focus. A reviewer stated that a broad scope of combustion modes helps increase with understanding of LTC. Another said that the work scope needs to be broadened.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 15 reviewers)

Comments about technical accomplishments and progress were mixed. To one person, the matrix approach seemed sound. He asked if this is leading to a better fundamental understanding of how these different fuel formulations will combust under different conditions in different advanced-combustion engines. Another person noted that the fuel-specific properties that help enable HECC need to be understood. One reviewer thought that this was a reasonable technical program. Another pointed out that so far only five fuels have been examined and there are still others to come. One felt that limited fuel sets were studied and that the researchers need to condense the meaning of current research. Another mentioned that the project does broaden understanding, but he did not see any "barriers" coming down—the project has accomplished what it was intended to at this point. A final reviewer agreed that the project has accomplished what it was intended to at this point.



Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 11 of 15 reviewers)

Reviewers in general thought that guidance/participation of OEMs was noticeably absent. One reviewer noted that a full-blown fuel program should have all the stakeholders involved. Contrarily, one reviewer did not see low outside collaboration as a problem. He felt that some projects are better run in one lab. Another person thought that broader collaboration with industry would be helpful before instead of after the work is done. A comment was made that there was a lack of industry participation and it was not clear if there is coordination across labs on all of these fuels projects. Another commented that collaboration with industry thus far has not been too good, but planned collaboration with the fuel industry is excellent and needed, and that publications in technical societies were good and should continue. Someone added that this review should just be one aspect, while there should be much greater coordination and collaboration on a routine basis. Another person thought that the combustion MOU meeting should be incorporated as part of this broad effort for industry input. To one person, the extent of auto OEM involvement was unclear. He thought that automaker feedback would be an important reality check. One person acknowledged that technology transfer is included in the plans. To one reviewer, it appeared that most of this work has been done by ORNL alone. He added that developing a basic understanding of fuel properties for HECC builds a good basis for a cooperative program among fuel producers, engine manufacturers and other stakeholders. A mention was made of good citation of published work. One person acknowledged the public reporting and discussions, but suggested in-depth collaboration in analysis with industry and the other national labs where a lot of combustion expertise exists.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 9 of 15 reviewers)

Comments regarding the approach and relevance of proposed future research were generally positive, with a few suggestions. A comment was made that the direction seems good, including industry collaboration. One person stated that there is a good plan for future work. Another liked the “fuel set” approach very much. He suggested working with Josh Taylor (NREL) regarding more relevant measures of autoignition. He also suggested looking at injection system and air motion variables to improve mixing (recommendations could come from within DOE or outside). One person thought that this project has good potential but needs to be developed more. Another would like to see a ramp-up of work to show the promise of commercialization. Someone mentioned that the working group concept is good, but needs to address proprietary information and competitive aspects of the work. A mention was made of how development of a fuel set with industry cooperation and research commitment could provide valuable information regarding HECC technologies. If Fischer-Tropsch fuels are going to make it, said one reviewer, those fuels should probably be included in the mix, along with ULSD since all fuel will be ULSD in the future. This reviewer said that the fuel matrix working group, with heavy representation from the fuel industry (diesel, F-T, biodiesel), should determine the fuels.

Specific Strengths and Weaknesses (Written responses from 13 of 15 reviewers)

- Specific Strengths
 - This project makes the point for a comprehensive fuel effects program to achieve 2010 emissions: such a program is highly needed.
 - Good approach.
 - Technologically very sound.
 - Excellent presentation of the project; good momentum established.
 - Good project; helps fill knowledge gaps, and reveals areas that merit more study.
 - Inclusion of measurement of PM precursor and related species.
 - Understanding fuel properties that can lead to high efficiency and/or reduced emissions is critical. This understanding will help determine what fuels are needed for HECC technologies.
 - More near-term commercial relevance and clear opportunity to reduce petroleum dependence than other projects.
 - Good engine approach to work.
 - Nice engine setup.
 - Wide variety of combustion modes. Exhaust speciation.
 - Good initial overview of HECC fuel requirements.
- Specific Weaknesses
 - Need to link results with commercialized products by identifying the benefits and applications.

- Based on the GC-MS results, the CARB fuel doesn't look like a "real" market fuel. Appears to have been augmented by specific chemicals, as opposed to true refinery streams.
- Was EHN or another cetane booster used in any of the fuels? This could be a confounding parameter.
- Test engine was not optimized for cetane number, thereby "penalizing" some of the fuels.
- Very little industry involvement at this time, and investigation of only one combustion regime; this is handled in the future plans.
- Presentation does not identify pertinent test variables.
- Collaboration with fuel industry thus far.
- Working on technology that OEMs should be doing.
- Possibility of oxygenate availability in any quantity [is] nil.
- More resolution on molecule effects and combustion mechanisms as opposed to whole fuel effects would be helpful.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 15 reviewers)

- Fuel set design is very important in this kind of experiments.
- Review results with industry once finalized.
- The advantages of fuel are not clear from the current data. The HECC seemed to be more important than fuel differences. The future fuel matrix did not include oxygen in the proposed parameter set.
- Add a 40 cetane fuel.
- Include experiments and analysis to investigate how robust clean combustion at specific EGR levels is to changing fuel properties or explore ways for closed-loop control of combustion to adjust for changing fuel properties.
- Include a wider variety of fuels, especially those that allow a fundamental understanding of fuel chemistry on clean combustion.
- Lots of collaboration with combustion experts within DOE rather than "after the fact" discussions. Work is good, but could be excellent if all the available brainpower could be brought together going forward.
- More off-cycle (cold start, etc.) effects and a wider range of fuels for testing would be useful.
- Proposed work is good, but I would place less emphasis on designer fuels and more on fuels that are likely to be available (i.e., ULSD, biodiesel, F-T)



Fuels Technologies Program

HC-SCR with Fuel-Borne Reductants, John Thomas of Oak Ridge National Laboratory

Brief Summary of Project

This project team is examining the potential of fuel-borne substances as reductants for lean-NO_x catalyst systems (specifically alumina-supported silver catalysts). This project was focusing on ethanol added to diesel fuel to determine emissions performance in full-scale systems, to evaluate methods for separating ethanol from diesel fuel onboard a vehicle, and to potentially identify other promising reductants.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 15 reviewers)

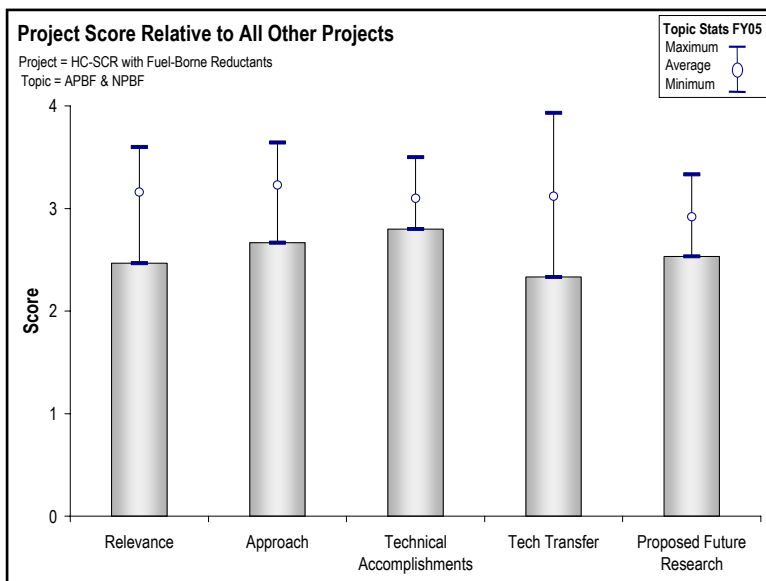
Several comments on this work were positive. One reviewer felt that the work seems relevant, while another felt the project was an interesting concept. One person commented that the researchers have pointed out that issues with ethanol mixtures are not a showstopper. Others were more critical of the project. One person said that the project is academically interesting, but is in itself not a practical solution. Another added that although the need for a fuel-borne reductant is real, developing a fuel mix which may not be practical is a significant concern. One reviewer questioned whether the focus on ethanol and alcohols is appropriate given the issues associated with alcohol and diesel blend. Another commented that using ethanol as part of emissions control system is an infrastructure issue. Another noted that fuel-borne alcohols may provide good reductants, but significant technical and safety hurdles need to be overcome for E-diesel (or other light alcohol/diesel blends as fuels for diesel engines in general) before this concept could provide substantial contribution to the replacement fuel goals. The last person stated that SCR works with urea, which is cheap and available, and wondered what the motivation for this research is.

Question 2: Approach to performing the research and development (Written responses from 7 of 15 reviewers)

Several reviewers felt that the experimental and technical approach was well thought through. Another person added that the project looks to be a novel approach to reducing emissions. Another person thought that the approach was interesting, but would be better if copper-zeolite catalyst formulations had been included. One reviewer suggested that the researchers need to reconsider the commercial feasibility of blending ethanol in diesel fuel (which is thought to be unsafe) and perhaps consider a separate reductant application strategy. The distillation is an extreme separation technique. They added that the researchers should assume separate reductant storage systems, and that they need to consider the commercial application of the reductant system. The final reviewer commented that there was no energy company participating to add a fuel perspective, e.g., no mention of any safety aspects of blending ethanol with diesel causing a potentially explosive mixture. There was also no mention of special expensive additives needed to dissolve ethanol in diesel.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 15 reviewers)

One reviewer felt that this was a good first step, but that there is still a long way to go. Another person noted that hardware has been developed and applied. One reviewer did not understand the benefits of blending ethanol into fuel, and then expending energy to distill ethanol out of the fuel onboard the vehicle. Another wondered why certain alcohols are active while others are not. The final reviewer said that this work clearly differentiates which of the selected oxygenates may work, but this reviewer was not familiar with the FY04 "Systematic Evaluation of Reductant Functional Groups" so it was not clear why these were the chosen ones and how involved the fuel industry was in their selection. Work on ammonia production and acetaldehyde slip is important (in this reviewer's opinion) but seemed to be downplayed for some reason: this seems to be a bigger issue than presented.



Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 15 reviewers)

One reviewer felt that there was excellent collaboration, however many other reviewers felt industry collaboration on the approach was limited, but necessary. One reviewer said that the work is valuable as investigative research, but that further technology transfer is complicated by the need to use an onboard reformer, which makes the SCR even more complex and riddled with issues. The Caterpillar involvement was seen as positive; but one reviewer asked where other collaborations were. Another added that collaboration with LD and HD OEMs is critical, since heavy resistance to this approach will likely be encountered. One reviewer commented that the proposed fuel cocktail/composition has significant operational and practical barriers. Others stated that they do not see how this program technology could be useful, and that at this point it is difficult to project this technique into the mainstream. Lastly, a reviewer said that there was good collaboration with Caterpillar and Exxon, but to communicate this and get buy-in with the fuel industry in general would be a really big task.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 6 of 15 reviewers)

Several comments were positive. Several reviewers said that they consider the onboard reforming of diesel a step in the right direction. Another felt that the project is on target, but there is a need to understand the impact with each type of aftertreatment. One reviewer felt that the need for future work was not clear. Another said that the path of the follow-up proposed and how that work will get to commercialization and provide payouts in the proposed FCVT program timelines and volume levels is not clear, or at least did not come across (if it is there). The last reviewer commented that HC-SCR has promise, but not if a fuel-borne additive is required.

Specific Strengths and Weaknesses (Written responses from 12 of 15 reviewers)

- Specific Strengths
 - Good documentation with several SAE papers plus patent pending.
 - Good experimental program.
 - Examination of non-noble metal, lean NO_x aftertreatment solutions.
 - Looking at fundamental issues relating to favorable reductants for HC SCR, relating the results to fuel structure.
 - Innovative approach.
 - May be beneficial use of EtOH [ethanol] for both petroleum reduction and renewable benefits.
 - Good differentiation from the oxygenates tested and some clear trends were developed.
 - Expanded knowledge of HC-SCR.
 - Good work as an initial proof of concept.
- Specific Weaknesses
 - Ethanol/diesel mixture has safety risks. Why add ethanol to diesel fuel and then separate it later as reductant? Why not put ethanol in separate container as in the case of urea?
 - A new fuel is not practical? Diesel /alcohol mix causes a potential safety hazard. The flash point within vehicle fuel tank can create a flammable air/fuel ratio in the fuel tank. Diesel & alcohols do not mix well. A surfactant is normally used to keep these in mixed state. How does this impact onboard distillation?
 - Concept of blending ethanol into diesel and then distilling it out on-board vehicle makes little sense.
 - Need to consider from big-picture standpoint, for example, what would be the effect upon vehicles not equipped with the HC-SCR system? Alcohols in diesel fuel are problematic for many reasons, not the least of which would be the safety issues associated with the low flashpoint. Cetane would also be adversely affected, as would lubricity and stability.
 - Alcohols form azeotropic mixtures, and would be difficult to separate cleanly outside of the lab.
 - Needs to show practical means to accomplish goals. What are combustion effects of the emulsifier? Myths of methanol hazards should not be allowed to influence technical progress.
 - Need more work on real-world issues of ethanol in diesel; need to further consider cost and availability of reductants.
 - Need better commercial application of the study design and performance.
 - OEMs would oppose from the standpoint of added cost and complexity.
 - Requiring ethanol to be added to the fuel does not “enable” non-petroleum fuels, *it requires them*, therefore creating infrastructure issues.
 - Unclear that continued work would significantly contribute to commercial use of replacement fuels to meet



- program replacement goals in the timeframe of the program.
- Screening of reductants could have been done through bench testing. No “why” as to the reason some species enhanced low-temperature activity while others did not. Copper-zeolite formulations not included.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 8 of 15 reviewers)

- Do a real-world design and application of the technology to determine commercial potential.
- HC-SCR focus is OK, but drop the fuel-borne reductant concept. Consider market acceptance of any approach before proceeding.
- Combine HC SCR with low-temperature/HCCI combustion strategies to look for synergism.
- Investigation of the potential for combustion as source for reductants.
- Could hydrogen be generated on-board to enhance combustion and aftertreatment? Since polar light primary alcohols performed well, why was methanol not included?
- Cease project.
- Add additional formulations/reductants and do bench screening.
- Inclusion of non-alcohol options is a good inclusion in scope.
- Need to identify the potential issues and practical aspects on the transportation, blending and use of the reductant compounds, their economics, and their likelihood of making a significant contribution to the replacement goals before a whole lot more lab testing of their ability as a reductant is worthy of further investment. Perhaps some of this information is available and was just not presented.



Fuels Technologies Program

Rapid Aging of Lean NO_x Traps for Diesel Applications, Todd Toops of Oak Ridge National Laboratory

Brief Summary of Project

This team was investigating how lean NO_x traps are deactivated, and exploring the establishment of a protocol for rapid aging of lean NO_x traps. Researchers are examining the fundamental mechanisms for deactivation, monitoring deactivation as a function of temperature and time, and potentially modeling the thermal deactivation of the catalyst.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 15 reviewers)

One reviewer noted the good alignment with DOE objectives, establishing control systems that are durable and understanding the deactivation mechanism will ensure these systems function properly. Another agreed, adding that this is excellent, timely work in an area with significant knowledge gaps. Another felt that the project provides understanding of aging effects. One reviewer commented that lean NO_x traps (LNT) are a new technique to reduce NO_x emissions, and that their efficiency and life have a major impact on engine system efficiency and robustness. Others added that LNTs are required for 2010 emissions standards. The results are in an early stage of research. Others were not as complimentary, stating that this is a good durability project, but they were not sure how it applies to fuels. While this is mainly focused on existing diesel engines, said a reviewer, this information is needed also to study the effects the new replacement fuels will have on this same phenomenon and set up a protocol for these fuels to be tested as well. The final reviewer commented that this project seems to be product development for catalyst suppliers.

Question 2: Approach to performing the research and development (Written responses from 7 of 15 reviewers)

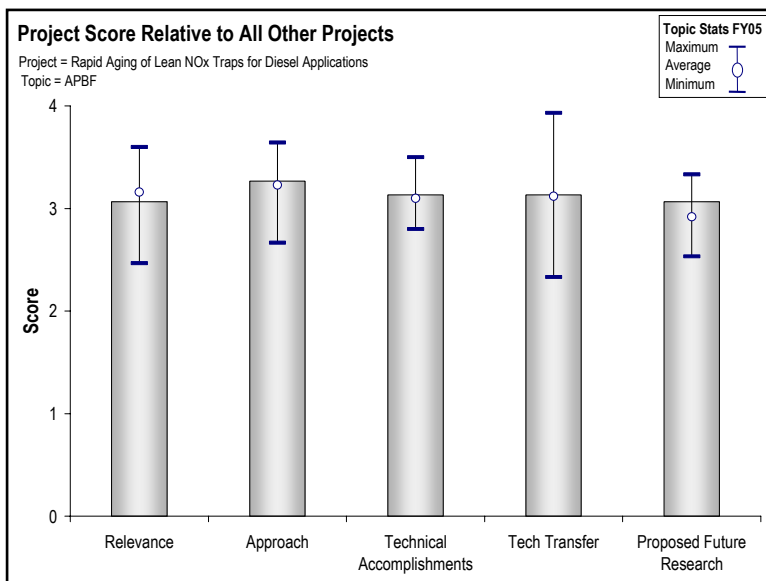
Several reviewers noted that the researchers have taken a good, technically sound approach, with a good experimental program. One reviewer noted that the focus on learning the failure mechanism is good. The correlation of bench testing with field results is right approach. Characterization studies are good. Another agreed, adding that aging the catalyst on an engine provides a practical deactivation path. The bench reactor studies can be an effective tool for catalyst deactivation models. The final reviewer felt that the results would be better if temperature profile data across the catalyst were available.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 7 of 15 reviewers)

Several researchers felt that there was good progress to date and that there have been reasonable results for the effort. Another added that the progress so far is in line with previous learning (e.g., deactivation due to activated surface area loss, precious metal sintering, etc.). One person commented that a lot more testing needs to be done. Another said that the information from this project will be key in identifying the data that should be investigated with new replacement fuels. The final reviewer cautioned that while this is important to understand, parallel work is needed to determine if there are ways to reduce the effect.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 15 reviewers)

Several reviewers noted the good coordination and collaboration with industry and the University of Tennessee, however another felt that they could improve on the technology transfer. One reviewer acknowledged that the monolith/catalyst supplier involvement, CLEERS focus group, and HTML lab capabilities are good. One reviewer noted the initial direction was based on industry input, while another suggested considering soliciting feedback on



experimental design from auto and truck OEMs. The final reviewer felt that the project has the potential to be very valuable once field correlation is established.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 10 of 15 reviewers)

Two reviewers noted that the direction seems very good and that the comparison to field-aged catalysts, as noted, will be important. A reviewer said that this is a very useful research tool to investigate LNT behavior and performance. Another added that the project appears to build on current findings and expand work on deactivation mechanisms. Another person added further to this, stating that the work continues to correlate bench testing and field results as well as evaluating deterioration mechanisms. Two reviewers had similar comments that deterioration modeling should also be a major focus to further understanding of mechanisms. Another reviewer simply stated that future needs and research should be sharpened. Another suggested that temperature and flow profiles might be informative. One offered that the future research is good, but the team needs a wider range of temperatures for the rapid aging, and to look at temperature variation within the catalyst structure. The final reviewer suggested that catalyst suppliers should be doing this work instead of a national lab.

Specific Strengths and Weaknesses (Written responses from 9 of 15 reviewers)

- Specific Strengths
 - Good experimental program.
 - Fundamental investigation of aging, the key issue for lean NO_x traps.
 - Solid theoretical and practical work.
 - Good initial look at some catalyst deactivation mechanisms.
 - Potential applicability. Identification of mechanisms.
 - Establishment of test method.
 - Correlation of engine and bench results.
 - Excellent use of tools to understand the problem.
 - Broad list of industrial collaborators.
- Specific Weaknesses
 - None.
 - Need better application.
 - Practical ways to overcome the barriers.
 - Need to see more analysis of the data.
 - Apparently the aged catalysts were evaluated at only one condition/temperature.
 - Flow and temperature profiles lacking.
 - Does the project measure actual temperature variations throughout the catalyst brick? Don't larger diameter bricks experience higher temperature variations across the cross-section, reaching higher peak temperatures in order to achieve a minimum desulfation temperature?
 - Suggest looking at a wider range of aging conditions.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 15 reviewers)

- Demonstrate application by getting review from the catalyst industry.
- More data analysis. Future work defined is on target.
- Add lean gasoline to the study.
- Initiate study to correlate to actual engine tests, specifically one or more of the DEC studies.
- Evaluate aged catalysts at a range of engine conditions and temperatures to answer the question: Is aging effect the same at all temperatures and space velocities? Do different aging mechanisms have different effects at low/high temperature and high/low space velocity?
- It is important to verify that simulated environment correctly models actual catalyst operating conditions.
- Flow and temperature profiles lacking. Also, it might be instructive to try to get some collaboration from any automotive companies regarding what they consider to be representative duty cycles (if they are willing to share).
- Proposed work scope looks good; verify that other deterioration mechanisms are not being missed.
- Really solid future work plan, should look at a wider range of temperatures for the rapid aging, and look at temperature variation within the catalyst structure.

Fuels Technologies Program

Transportation, Fate, and Impact of Lube Oil Phosphorus, Bruce Bunting of Oak Ridge National Laboratory

Brief Summary of Project

This project is focused on phosphorus poisoning of catalysts and phosphorus exhaust chemistry to understand the mechanisms by which catalysts are poisoned by lube oil additives. The team used a variety of methods for introducing lube oil phosphorus into the catalyst in order to simulate the various ways in which lube oil might reach the exhaust stream.

Question 1: Relevance to overall DOE Objectives (Written responses from 9 of 16 reviewers)

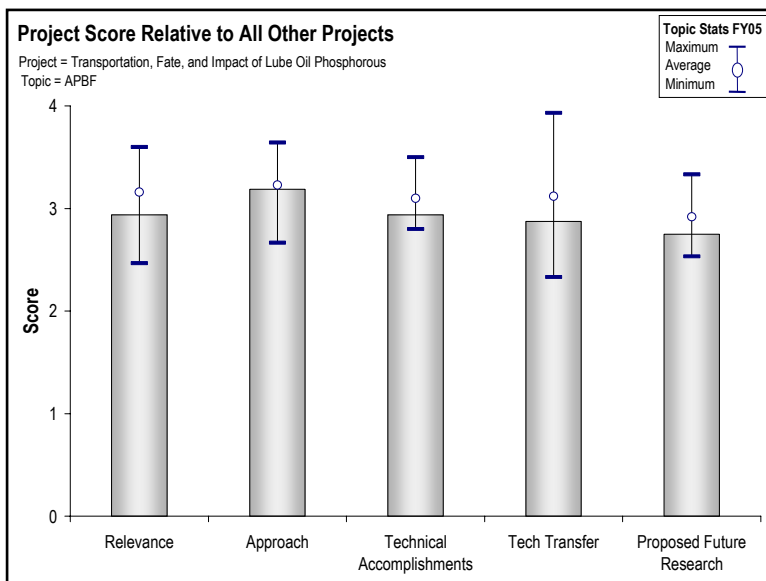
Most reviewers had positive comments about the project. One felt that there is good alignment with DOE goals, adding that the research is a good example of examining “all” potential contaminants to advanced catalytic systems. Another agreed that the project is a good fit for DOE’s objectives, and that this is an important and timely issue. Others stated that the project adds to the understanding of the lube oil impact on catalysts and that the work is a step toward showing that there is a potential issue. Another reviewer said that the replacement of ZDDP in engine lubes with stricter emissions limits is coming; this work will add insight toward that replacement. Another reviewer felt that there is a potential application to both gasoline and diesel, and that accelerated bench techniques to shorten cycle times and engine testing requirements should be followed. One of the reviewers agreed that the work is relevant, but felt that there should be a focus on quantitative contribution potential. Others questioned whether the project fits DOE’s goals. One person stated that this sounds like an air quality or engine emission issue. The final reviewer wondered whether the project might not be better addressed by lube additive/catalyst companies.

Question 2: Approach to performing the research and development (Written responses from 7 of 16 reviewers)

All of the reviewer comments to this question were positive. Several complimented the approach for examining different lube oil poisoning regimes, while another liked the accelerated testing method. One person felt that the comparison to field-aged samples is critical, and was pleased to see it included. They added that the researchers have used an interesting matrix of differentiating location of introduction and have made good use of imaging diagnostics. One person felt that more data on real-world poisoned catalysts would be helpful. Several reviewers cautioned the researchers must make sure that the accelerated test method is representative of the real-world situation. One reviewer noted that slide 18 seems to indicate OEM catalyst is different from the model. One person added that decades of research on the phosphorus poisoning effect on passenger car three-way catalysts is still inconclusive, suggesting that the effort might look at the reasons for this and avoid similar failure to reach a usable outcome. The final reviewer commented that there is no substitute for testing with a full-scale engine under real-world conditions, but this approach is often impractical due to time and budget constraints. Therefore, testing with a scaled-down system and a spiked lubricant is acceptable, and allows rapid screening. Use of an actual engine with various ZDDP introduction techniques (as was done in this project) is far superior to approaches that attempt to use surrogates to simulate pre-catalyst oil combustion.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 4 of 16 reviewers)

Several reviewers noted that the team has made some good progress with initial project in detecting barriers, but not in solving the problem. Another stated that the researchers have showed differences in how sulfur and phosphorus form deposits on the catalyst. The last reviewer felt that the results do not conclusively show there is a problem, because the chemistry (i.e., no zinc on the catalyst) is inconsistent with analysis of real diesel catalyst.



Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 8 of 16 reviewers)

Replies to this question varied significantly. Several reviewers felt that there appears to be a solid team assembled, and that presentations of results at two conferences are effective ways to obtain industry support/feedback. Most comments from the remaining reviewers acknowledged the work with University of Tennessee, but suggested that the team could improve here, and that the lack of industry partner involvement, especially an engine OEM, is a miss. Another suggested collaborating with both light- and heavy-duty engine manufacturers for representative fleets and “wish lists.” A reviewer added that, as noted in the presentation, comparing results with field samples is probably the most important next step for this project, and that the search for field samples should be broadened to include multiple OEMs. This was reflected in the comments of the final reviewer, who said the team has tried to get more involvement of catalysts from field but it is proving difficult. This is a critical link, so the team needs to keep at it and get the field catalysts.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 8 of 16 reviewers)

Several comments were positive, including one reviewer who felt that the team has developed a reasonable future work plan. Another agreed saying that if the objective is test development, this approach should get the researchers there. Several stated that the comparison to actual field-aged sample data important and is included. One reviewer added that the highest priority should be a “reality check” involving catalysts retrieved from the market. It might be best to focus on fleets, due to the availability of maintenance and repair histories. Other reviewers felt that the project needs better definition of the future work plans. The final reviewer added that the project retains a very generic scope of work. The project needs to identify key barriers.

Specific Strengths and Weaknesses (Written responses from 11 of 16 reviewers)

- Specific Strengths
 - Good approach for investigating the problem.
 - Good look at a timely issue.
 - Good for test development.
 - Bench set-up for accelerated test methods.
 - Good test methods.
 - Valuable work for a relevant topic in new lubricant formulations.
 - Investigation of contaminant distribution on the catalyst with different doping methods.
 - Technically very strong, impressive.
 - Very relevant to upcoming challenges. Good characterization and in-depth evaluation of phosphorus and sulfur poisoning.
- Specific Weaknesses
 - No quantification of the effect of recommendations for a solution.
 - Interesting work, but in the end the solutions will probably be to reduce phosphorus in the oil and/or reduce oil consumption; it’s not clear what the benefit of understanding the mechanism will be.
 - Identification of the problem.
 - Needs to describe relevant effects on catalysts likely to be used with advanced diesel engines with any desulfation effects.
 - Need more real in-use poisoned catalysts to study deposition, and to verify if lab method reproduces field experience.
 - Lack of ability to get field catalyst samples.
 - Use of technique to solve problem.
 - Follow-on work at a wider range of catalyst temperatures would be worthwhile.

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 6 of 16 reviewers)

- None: continue efforts.
- Find where the Zn is going.
- Need to see more details on future work before I can provide input.
- As diesel emissions approach zero, lubricant effects become more important. Program may need to include sulfur reduction in lube oil as a confounding issue.

- Incorporate ways to solve/reduce the problem.
- List for future work looks realistic; more detail [on what] would be done would be helpful.



Fuels Technologies Program

Optical Engine Studies of Fuel Effects on Low-Temperature and CIDI Combustion Processes, Charles Mueller of Sandia National Laboratories

Brief Summary of Project

This project uses the Sandia optical one-cylinder research engine to study the in-cylinder fuel combustion processes using advanced diagnostic techniques. These results were compared to engine-out emissions, simulations, and other sources of combustion information. Study focuses included the ability of dilute clean diesel combustion processes to meet 2010 emissions levels without aftertreatment devices and the underlying causes of increased NO_x emissions with use of biodiesel.

Question 1: Relevance to overall DOE Objectives (Written responses from 10 of 16 reviewers)

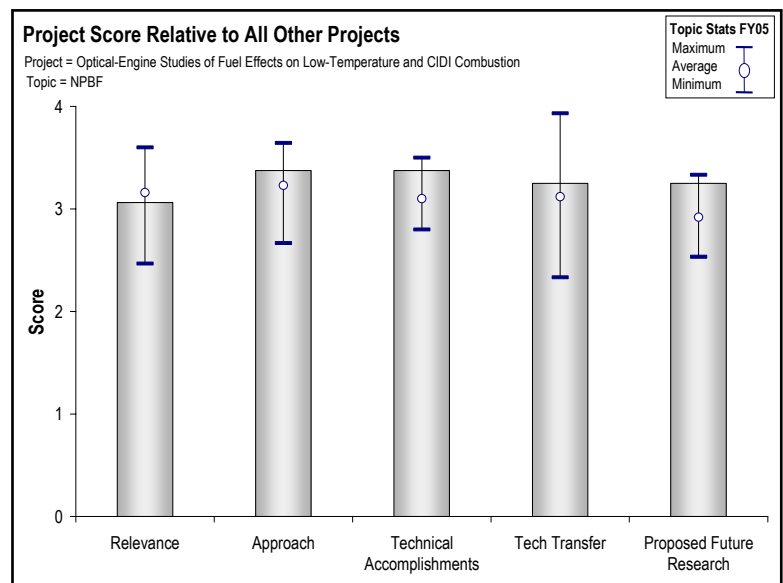
Several reviewers stated that this project exhibits excellent fundamental research and focus with good alignment with DOE goals. Others noted that the project attempts to answer some basic questions with a clear focus on leveraging oxygenated fuels for low-temperature direct injection combustion. One reviewer added that the better understanding of diesel combustion fundamentals enables advances in lower emissions and better fuel efficiency. One person suggested that the researchers need more work on real diesel fuels and fuel components. One reviewer was not clear how basic research will apply to DOE objectives. The final comment was that the higher NO_x with biodiesel is a key rate limiter. This was echoed by a reviewer who said NO_x is a major barrier to biodiesel introduction in ozone non-attainment areas, and understanding the causes of biodiesel NO_x and how to reduce it will serve to assist biodiesel penetration into the ozone non-attainment areas and increase the amount of petroleum it replaces—a definite fit with the FCVT program goals.

Question 2: Approach to performing the research and development (Written responses from 9 of 16 reviewers)

Comments were positive; including one reviewer who thought the team had developed a good work plan. Another person commented approvingly on the attempts to answer the “whys.” Several comments were favorable toward Sandia’s experimental capabilities. One reviewer stated that Sandia’s experience with optical engines is very valuable, and that the DCDC research should segue from research fuels to market fuels. Another felt that the experimental work was well planned and carefully conducted. Another added that the optical engine system is a unique and powerful tool to study combustion. One person complimented the researchers on the “fabulous” experimental capabilities, good control of conditions, and well-posed experiments. Another reviewer noted that the researchers used suggestions from review panelists. One person felt that the lab had developed a good tool, but felt that they needed to better present how the tool will lead to the goals. The last reviewer was not clear if diethyl ether is representative of feasible fuels.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 8 of 16 reviewers)

One of the reviewers felt the team had very good combustion insights. Another felt that there has been impressive progress with very difficult experiments. Another felt that there has been good progress, and looked forward to future results. He suggested that more complete emissions, including formaldehyde is a must, adding that radiative heat transfer is an angle on understanding biodiesel NO_x problem which requires more research. One reviewer noted that the presentation addressed comments from the 2004 review, adding that DCDC is a good find. One reviewer questioned how the results compare to means by which diesel engine manufacturers plan to meet 2010. Another commented that the earlier combustion with biodiesel is not the sole cause of higher NO_x. Another person felt that the researchers need to focus on a more commercially viable fuel. A reviewer offered that he would



rate the project somewhat higher if the particulate radiative heat transfer could be further pinned down as the mechanism, and the way to reduce it identified. This reviewer continued by noting the work done to eliminate combustion phasing appears to be in conflict with work by Van Gerpen where timing was retarded to match the pressure rise curve with B20 and diesel fuel and showed a slight NO_x reduction. The last reviewer commented that he is not a strong proponent of fuel as an emissions control device (it can be an enabler) because of the great reluctance of the “Energy Companies” to make the necessary investments. He concluded by complimenting the researchers, saying that they have, however, “made us smarter.”

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 10 of 16 reviewers)

Several reviewers noted the good level of collaboration with industry and universities team members. Another liked the fact that there were “a lot of folks” involved. One said that increased industry collaboration with OEMs and biodiesel industry is good, but projects always can use more, especially in helping to get the results more widely reported in the mainstream. One reviewer felt that the researchers had effectively used the review panels. Others were more critical, including one person who acknowledged the several outside contacts, but said that the collaboration appears to need more focus. One person felt that the light-duty auto OEMs should be included. The final reviewer stated that the collaboration and technology transfer should be improved with future work.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 7 of 16 reviewers)

One reviewer felt there was a good future work plan. Another said the future research was excellent and that the team should make it happen sooner rather than later. Another suggested that the team keep pursuing low-temperature combustion enablers, agreeing that the expansion of measurements is a good step, and that the team should keep asking “why?” Others felt that there was a weak statement of future research, especially why more measurement tools are needed, and what they will do. However, another reviewer’s expectation is future work will similarly be of high quality.

Specific Strengths and Weaknesses (Written responses from 13 of 16 reviewers)

- Specific Strengths
 - Adapted research to previous reviewer comments.
 - Capabilities without peer.
 - Good understanding of engine combustion is essential to improve engine efficiency.
 - Good analysis. Attempts to explain results.
 - Technologically strong – I’m encouraged to see our national labs do such good, theoretical work that has real meaning for real-world problems.
 - Looking at diesel engine combustion fundamentals.
 - Good tool.
 - Effective use of a single-cylinder engine.
 - Fundamental studies of compression ignition to understand the processes involved.
 - Fundamental understanding of biodiesel NO_x effect.
 - Good experimental techniques - optical diagnostics and correlation with engine-out emissions. Good approach to studying biodiesel NO_x increase question.
 - Important to discover reasons for biodiesel NO_x increase and ways to mitigate.
 - Good summary, useful work for understanding mechanisms. Info on NO_x from biodiesel is helpful.
- Specific Weaknesses
 - Making the connection between basic research measurements and addressing the DOE goals.
 - DGE DCDC results are interesting but it is not clear how it could be implemented.
 - Lack of modeling, discussion of DGE as a practical fuel, formaldehyde emissions.
 - The chosen fuel for DCDC really stacked the deck by being intrinsically low PM. Use of real fuels would be a big plus. Not clear that this will be addressed in next step.
 - Fuel as an emissions control device.
 - Need to further define effects of low-oxygen fuels and higher inlet temperatures.
 - Just need to drive the understanding of NO_x with existing engines--and the fixes--to completion and verify the impact of biodiesel blends on the new combustion regimes under study (HCCI, DCDC)



Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 11 of 16 reviewers)

- None. Execute proposed plans as quickly as possible.
- The presentation does not really describe the DCDC process (how is it different from HCCI? The test fuel, DGE, is not a realistic fuel for 2010 engines.
- Improve communicating how the tools have a connection to problem solving DOE goals.
- Expand industry involvement.
- How can we take the learning from DGE and apply them to a commercial solution?
- Stronger connection between this work and other related DOE projects.
- Add work to explore range of fuels and fuel components to understand barriers to combustion.
- Coordinate work with real, high technology engine.
- When evaluating IMEP include cycle simulation modeling to estimate BMEP. Industry partners should be able to help here!
- Understanding the NOx issue with biodiesel is important to this fuel's integration in the marketplace.
- Keep going.
- I would strongly recommend that the radiative heat transfer argument be pursued theoretically and experimentally. It may be of academic interest, since the difference is only 10%, but it is important nonetheless.
- Injection system & air motion as "mixing" variables. Could shift clean combustion region.
- Looking at more conventional fuels is a key need; glad it's in the next steps.



Fuels Technologies Program

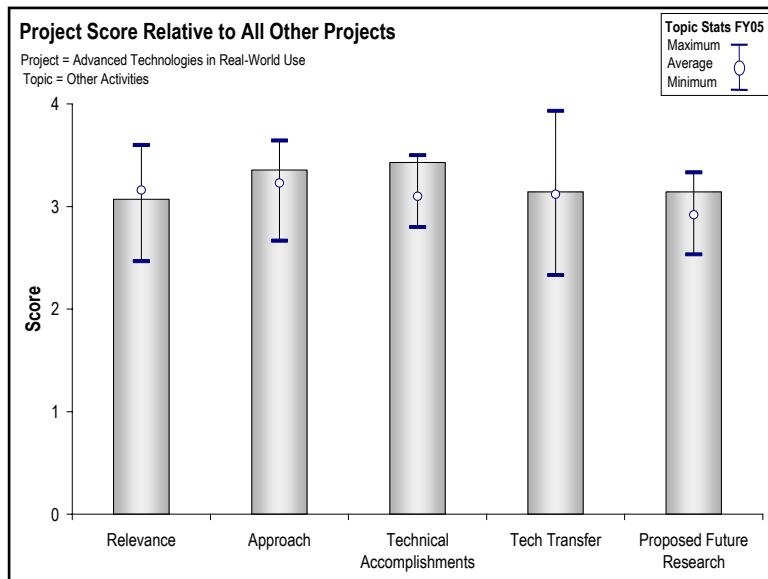
Advanced Technologies in Real-World Use, Nigel Clark of West Virginia University

Brief Summary of Project

The overall objective of this project is to measure regulated and unregulated emissions from advanced technologies in service. Projects included NO_x reduction technologies for marine applications, examination of ultra-low-sulfur diesel effects on particulate emission, and emissions from use of Fischer-Tropsch diesel fuel.

Question 1: Relevance to overall DOE Objectives (Written responses from 7 of 14 reviewers)

Reviewers were aware that emissions reduction is not a direct DOE goal but, rather, a necessity to also be achieved along with fuel economy improvements. One reviewer called it “back-casting” to provide a foundation for determining actual benefits of developed systems in real-world operation. Actual differences in fuel economy were not always mentioned in the presented data. A reviewer said that the project provides important real-life information on emissions, due to reliable experimental capability. One reviewer commented extensively on the project, saying that it is a good project in a general sense, and Nigel and his crew certainly know that they are doing, but the testing of particulate filters with ULSD does not appear relevant to the FCVT program goals of 5% replacement of ULSD, nor does the water injection testing. The work with F-T in these technologies is potentially relevant in this reviewer’s opinion, but only if F-T is a viable domestic industry, which needs further study (as reported in comments on other FCVT project reviews). This reviewer liked the results and other aspects of the project and felt it was good information, but most of the work just doesn’t appear to be a good fit for 5% petroleum replacement.



Question 2: Approach to performing the research and development (Written responses from 7 of 14 reviewers)

Reviewers were clearly familiar with the body of work previously published by WVU. They respected the sound field evaluation, the use of the chassis dynamometer, the very good and thorough experimental plan, and the impressive facilities. The absence of a discussion of fuel economy differences was lamented. A reviewer said that the approach to work completed is good on the whole, but longer durability time than 6 months or one year is needed. Chassis dynamometer data is not well accepted by EPA and some other regulatory agencies, noted this reviewer, so more effort comparing chassis dynamometer to accepted EPA data would be useful, especially for HD vehicles, as the engine testing currently used is difficult and expensive.

Question 3: Technical Accomplishments and Progress toward project and DOE goals (Written responses from 5 of 14 reviewers)

Reviewers felt this project addressed several current high-priority issues, among them: in-use performance of DPFs; marine emissions; gravimetric PM measurement uncertainty; and evaluation of alternative PM measurement techniques. While there were lots of data, the conclusions were not “earth shattering.” Rather, they were good technical accomplishments which tended to back up the claims of the component manufacturers. Confirming F-T impact on trap PM and NO_x emissions is good, said a reviewer, and is needed as part of the prove-out on F-T. The slight reduction in NO_x and the change in NO/NO₂ split were a bit of a surprise to this reviewer. Other accomplishments are also good, and related to project title, but not really related to FCVT program goals, in this reviewer’s opinion. A reviewer said that the team has made achievements in a multitude of relevant projects.

Question 4: Technology Transfer/Collaborations with Industry/Universities/Other Labs (Written responses from 7 of 14 reviewers)

Reviewers gave mixed comments. While the test team is known for being very communicative of results, one

thought there was limited industry involvement, while others felt there was excellent collaboration from industry partners and very good participation across industry and academia. One reviewer said that the nature of the work implies collaboration.

Question 5: Approach to and Relevance of Proposed Future Research (Written responses from 5 of 14 reviewers)

Reviewer comments were focused on the PM measurement question going forward. Measurement techniques should be investigated from both a mass- and size-distribution perspective. Improving PM measurement at low levels and during transients is needed by the EPA, but was not thought to be easily translatable into the DOE goal of reduction of imported petroleum. The proposed work demonstrating low PM measurement techniques and improving standardized PM number is something needed for diesel emissions in general, but does not get the FCVT program any closer to fuel replacement goals. It is good, valid work and needs to be done, just not with FCVT funds unless there is no other good place to fund this type of work. Measuring regulated and unregulated emission from the field is a good FCVT fit, but only if it is done on fuels that can replace ULSD.

Specific Strengths and Weaknesses (Written responses from 10 of 14 reviewers)

- Specific Strengths
 - Sound and detailed approach. Well documented.
 - Work is technically solid.
 - Good experimental capability, maturity of research staff that is conducive to high-quality work.
 - Measurement of heavy-duty vehicle emissions.
 - It is good to see graduate, post-graduate students and professors having an opportunity to work on research that is directly related [to] future fuels and vehicle technology.
 - Very good research on an important topic to transportation in USA.
 - Advancement of testing techniques - good.
 - Good description of making real-world emissions measurements and results.
 - Excellent management of wide variety of vehicles and test conditions to obtain relevant results.
- Specific Weaknesses
 - Not clear how it is relevant to DOE goals of petroleum reduction; too much emissions work on older vehicles.
 - Does not appear to fit in with FCVT goals very well, except for F-T work but that only fits if F-T is really a viable DOMESTIC fuel option. General lack of acceptance of chassis dynamometer work by EPA and other local and regional groups is a big weakness as well
 - GTL results don't provide significant new knowledge.
 - Fischer-Tropsch is a PROCESS, NOT A FUEL! Better characterization of that specific fuel would be helpful.
 - If the cycles used are truly felt to represent "real world" why not use them for fuel economy estimates?

Specific Recommendations/Additions to or Deletions from the work scope (Written responses from 7 of 14 reviewers)

- Complete future work and expand to non-road applications.
- EPA and CRC are also conducting studies to improve the procedure for measuring very low level PM emissions (CRC Project E-66)
- Continue work.
- Why not expand field work to include fuel economy?
- Future work will be useful. Besides size and count, might also characterize exhaust particle composition and structure in more detail. Also more detail on what regulated and unregulated emissions planned to be measured on advanced fuels / technologies would be helpful.
- I would recommend phasing out this work unless it can be shown to overcome a specific barrier to implementation of petroleum reduction technologies.
- From a strict FCVT standpoint, the development of accurate low PM measurement hardware and improving and standardizing PM number measurement do not appear to be barriers to replacement fuel goals so should be deleted, as should work on ULSD unless it is needed as a baseline for comparison purposes with other replacement fuels. Emissions testing costs and the requirement for engine dyno FTP emissions ARE major barriers to proving out these new replacement fuels technologies, as is emissions data that can be generated from the field to relate real-world emissions deterioration of the replacement fuels in both existing and new



technologies. My recommendation for this program is to almost completely re-focus it on work needed to allow the use of chassis dynamometer data for official EPA certification and certifications by other bodies so that much less expensive chassis dynamometer emissions can be used for the emissions prove-out for these replacement fuels. This would be important for a lot of other diesel programs in general, and should be co-funded if not majority funded by EPA.





At the end of the merit review meeting, the advisory held a luncheon meeting to discuss the projects and the sessions in general. The following summarizes these comments for the meeting. DOE responses are shown in italics.

March 9, 2005: Comments from Review Committee Lunch

1. Project Presentations
 - *James Eberhardt: Some of the best work presented at the meeting was the hydrogen extraction work, and its implications for HCCI. The lines between gasoline and diesel are blurring with HCCI, so will fuel properties.*
 - *The question is how can we better collaborate with industry to accelerate commercialization of technologies and products?*
 - In general, the research presented was good and would not ordinarily be done by industry, therefore, we support the research presented in general.
 - The program ran very well! The projects were on time and presenters held to their time slots.
2. Reviewer Panel Format
 - *Steve Goguen: request the project evaluators to review the multi-year program plan (MYPP) goals as part of their evaluation of the projects and not identify themselves on the evaluation forms.*
 - From an overall merit review process, it would help for reviewers to have five minutes between projects to be able to write down comments.
 - *Kevin Stork: For the annual ACE review we develop a mix of reviewers with emission control or combustion expertise; we then generally assign these reviewers to their respective areas of expertise. Since project presentations alternate between emission control and combustion, the reviewers have up to half an hour to write down notes or take a break before the next assigned project. For next year's Fuels meeting, we can better distribute reviewers among projects to allow more time between projects.*
 - It would be helpful to the reviewers to have the multi-year program plan ahead of time.
 - *Kevin Stork: We will try to distribute the multi-year program plan a week before the meeting next year.*
 - *Steve Goguen: Along those lines, please give DOE any comments on the multi-year program plan as part of your overall review.*
3. DOE Programmatic Comments
 - Program Elements
 - *Steve Goguen: June workshop at Argonne – met with industry and lab stakeholders to formulate the basis of the FreedomCAR multi-year program plan.*
 - Clean Cities should have a goal of petroleum fuel reduction and filling the need for technology transfer and promotion. “Hand-holding” projects are important, but should not necessarily be part of this (Fuels) Program.
 - *Steve Goguen: All of DOE EERE should be out selling energy efficiency and alternative fuels, but this has never really been done.*
 - *Kevin Stork: Question becomes what is the extent or absence of coherence among the projects of the Program. In hearing all of the presentations, it was clear that there are several good individual projects, but that better cohesion is necessary to show how they fit together under the Program. Also, a number of projects seemed to lack “theoretical backbone.”*
 - There were some misplaced projects. From an industry perspective, the Program should not waste funding on non-competitive research. Some projects are very broad and not fundamental in nature, and thus, should be eliminated.
 - *Steve Goguen: The Program has struggled some since 2001. Funding was dramatically cut, but several projects were still ongoing and had to be shut down. Through a lot of industry support, the Program is coming back and is in the process of being realigned. We still have sulfur projects such as the ORNL (corrosion) and Honeywell (sulfur filter) work. These projects also parallel the Combustion Program research.*
 - *Steve Goguen: The DOE budget now must be appropriated through the Energy and Water Committee exclusively. The process is much more defined by program areas such that nuclear programs are in one column, and all energy programs are in another. Under this Committee, DOE programs may be facing an earmarking process rather than a process based on program planning needs as was done in the past. Industry should talk to this Committee to ensure that planning remains an integral part of the budget process.*



- *Kevin Stork: DOE is very interested in working with industry on this planning process to ensure that we do not become an earmarked program.*
- *James Eberhardt: Earmarks can be very damaging to programs. As an example, the Hydrogen Program is now 60% earmarked and the Biomass Program is now 110% earmarked.*
- How does industry address earmark needs versus discretionary spending dollars?
 - *Steve Goguen: Work directly with DOE to get your needs into the multiyear program plan.*
 - Hopefully, through a proper planning process, DOE will come up with a livable plan for all industry concerns.
- Laboratory/Industry Communications
 - Futuristic and fundamental studies and models are being cut within industry for budget reasons, yet these studies are still needed in order to keep pace with markets. Model development is key to enable these projections. Industry needs to be able to forecast to remain competitive!
 - *Kevin Stork: Program research should be balanced between short- and long-term needs with overall weighting towards the long-term. There still needs to be basis for striking this balance, however.*
 - Industry needs computer models. Field testing is too expensive. Modeling is critical for developing new fuel formulations.
- DOE Program Collaboration
 - *Steve Goguen: Referring to an industry comment from the earlier Wrap-Up session concerning the parallelism of projects between the DOE Fuels and Combustion Programs, DOE has considered combining these two programs. However, this could result in loss of overall funding for these programs since Congress will not likely just combine their budgets. Thus, DOE is considering simply combining planning exercises between the two programs for purposes of developing the multi-year program plan, but leaving the programs separate in terms of the budget request process.*
 - *James Eberhardt: Industry comments were well-taken concerning the need for the creation of a DEC-type program involving the collaboration of national laboratories and industry for both combustion and fuels issues. Collaboration should be a vital part of both programs.*
 - *Steve Goguen: Agreed. It would be interesting to see how such a program would be structured. One thought would be to have some organization like the CRC facilitate and manage it. However, this type of program may be very difficult to fund given the current budget environment. Usually, budget approval is difficult if the request does not stipulate that it is competitive and has defined start and stop dates. If 21st Century Truck Partnership and FreedomCAR Initiative support the development of such a program, this may make it easier to get funded.*
 - *James Eberhardt: Research typically takes a long time to complete. Sometimes so long for it to get to commercial market that it is difficult to remember when it started. However, Congress always wants to know what they have gotten for the dollars spent. Yet there is a disconnect in terms of research milestones and annual budgets. This is often why the DOE budget languishes in terms of growth and expansion.*
 - There appeared to be considerable scatter presented in the projects which sometimes made it difficult to see how they fit into the overall direction of the DOE Program. Also, should there be Centers of Excellence for the laboratories in terms of their research strengths?
 - *Kevin Stork: It is very clear that Sandia is a Center of Excellence. Some of the other laboratories do not have as clear a distinction of excellence.*
 - Agreed. The national laboratories are competing with each other. However, it would be useful for DOE to put together a plan to align the laboratories with certain areas of excellence. The laboratories may be resistant to choosing their own areas of excellence so as not to preclude certain bodies of research work. The idea would be to stretch the laboratories more towards basic science in general.
 - *Steve Goguen: DOE is being pushed in this direction as well. Requests for proposals (RFPs) now primarily go out through NETL. Individual laboratories must put in proposals to do R&D. I agree that we should go back to the laboratories and ask them which areas of excellence they would like to be associated with. For example, NREL should be renewable fuels (biodiesel), ORNL should be synthetic fuels (oil sands), and Sandia should be fuels chemistry.*
 - *Kevin Stork: We are also working towards having the laboratories work more with one another in certain research areas, but it will take time to get them to work in this manner.*
 - More emphasis should be placed on the multi-year program plan and parallel work with the Combustion Program. The underlying research for many of the projects presented is combustion



related. It would be helpful to have a short synopsis of DOE combustion-related work at the start of the meeting.

- *Steve Goguen: Agreed. We have considered doing a joint laboratory merit review meeting with the Combustion Program due to the parallel research. However, it is important that these Programs stay separate at DOE so that budget levels can be maintained. In terms of next year's meeting, we can give a program-level review of the DOE Combustion Program and show project relationships between the two Programs.*





TOPIC: _____

PRESENTER: _____

REVIEWER NAME: _____

Using the following criteria, please rate the **work** presented in the context of the program objectives. Please provide **specific** comments to support your evaluation.

1. Relevance to overall DOE objectives.

Numeric rating (circle one below)

- 4 = Outstanding, the project is sharply focused on one or more key technical barriers to development of advanced fuels technologies.
- 3 = Good, most aspects of the project will contribute to significant progress in overcoming these barriers.
- 2 = Fair, some aspects of the project may lead to progress in overcoming some barriers.
- 1 = Poor, the project is very unlikely to make significant contributions to overcoming the barriers.

Specific comments

2. Approach to performing the research and development

Numeric rating (circle one below)

- 4 = Outstanding, it is difficult for the approach to be improved significantly.
- 3 = Good, the approach is generally well thought out and effective, but could be improved in a few areas.
- 2 = Fair, the approach has significant weaknesses.
- 1 = Poor, the approach is not responsive to the project objectives.

Specific comments

3. Technical Accomplishments and Progress toward project and DOE goals

Numeric rating (circle one below)

- 4 = Outstanding, the project has made excellent progress toward overcoming one or more key fuels program technical barriers; progress to date suggests that the barrier(s) will be overcome.
- 3 = Good, the project has shown significant progress toward overcoming barriers.
- 2 = Fair, the project has shown a modest amount of progress in overcoming barriers, and the overall rate of progress has been slow.
- 1 = Poor, the project has demonstrated little or no progress toward overcoming the barriers.

Specific comments

4. Technology Transfer/Collaborations with industry, universities, and other laboratories

Numeric rating (circle one below)

- 4 = Outstanding, close coordination with other institutions is in place; industrial partners are full participants.
- 3 = Good, some coordination exists; full coordination could be accomplished fairly quickly.
- 2 = Fair, some coordination exists; full coordination would take significant time and effort to initiate.
- 1 = Poor, most or all of the work is done at the Lab with little outside interaction.

Specific comments

5. Approach to and Relevance of Proposed Future Research

Numeric rating (circle one below)

- 4 = Outstanding, future work plan builds on past progress and is sharply focused on one or more key fuels program technical barriers.
- 3 = Good, future work plan builds on past progress and generally addresses removing or diminishing barriers in a reasonable timeframe.
- 2 = Fair, future work plan may lead to improvements, but should be better focused on removing or diminishing key barriers within a reasonable time period.
- 1 = Poor, future work plan has little relevance or benefit toward eliminating barriers.

Specific comments

6. Specific Strengths of This Research

7. Specific Weaknesses of This Research

8. Specific Recommendations or Additions/Deletions to Work Scope

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Appendix D: List of Abbreviations and Acronyms Used in This Report

<i>Acronym</i>	<i>Definition</i>
ACE	Advanced Combustion and Emission Control (program)
APBF	Advanced Petroleum-Based Fuels
APBF-DEC	Advanced Petroleum-Based Fuels-Diesel Emission Control
ASTM	American Society for Testing and Materials
B100	100% biodiesel
B20	Blend of 20% biodiesel and 80% petroleum diesel
B5	Blend of 5% biodiesel and 95% petroleum diesel
BMEP	Brake Mean Effective Pressure
BTL	Biomass-to-Liquid
CA50	Crank angle at which 50% of combustion has taken place
CARB	California Air Resources Board
CCRT	Catalyzed Continuously Regenerating Technology
CI	Compression ignition
CIDI	Compression Ignition Direct Injection
CLEERS	Crosscut Lean Exhaust Emission Reduction Simulation
CN	Cetane Number
CNG	Compressed Natural Gas
CO	Carbon monoxide
CRC	Coordinating Research Council
DCDC	Dilute Clean Diesel Combustion
DEC	Diesel Emission Control
DEER	Diesel Engine Emission Reduction (Conference)
DGE	Diethylene glycol diethyl ether
DOC	Diesel oxidation catalyst
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
DPGME	Dipropylene glycol monomethyl ether
ECD-1	BPChevron test diesel fuel
EERE	(DOE) Office of Energy Efficiency and Renewable Energy
EGR	Exhaust Gas Recirculation
EHN	EthylhexylNitrate (commercial cetane improver)
EPA	U.S. Environmental Protection Agency
FCVT	FreedomCAR and Vehicle Technologies Program (DOE)
FEMA	Federal Emergency Management Agency
F-T	Fischer-Tropsch
FY	Fiscal year
GTL	Gas-to-liquids
HC	Hydrocarbons
HCCI	Homogeneous Charge Compression Ignition
HCNG	Hydrogen-compressed natural gas blend
HC-SCR	Hydrocarbon selective catalytic reduction
HD	Heavy-duty
HDD	Heavy-duty Diesel
HECC	High-Efficiency Clean Combustion
HTML	High-Temperature Materials Laboratory (Oak Ridge National Laboratory)
ICE	Internal Combustion Engine



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<i>Acronym</i>	<i>Definition</i>
ICTC	Interstate Clean Transportation Corridor
IMEP	Indicated Mean Effective Pressure
IQT	Ignition Quality Tester
LDD	Light-Duty Diesel
LFG	Landfill gas
LNG	Liquefied Natural Gas
LNT	Lean NOx Trap
LTC	Low-Temperature Combustion
MOU	Memorandum of Understanding
NBB	National Biodiesel Board
NETL	National Energy Technology Laboratory
NGNGV	Next Generation Natural Gas Vehicle
NGV	Natural Gas Vehicle
NOx	Oxides of nitrogen
NPBF	Non-Petroleum-Based Fuels
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
ON	Octane Number
ORNL	Oak Ridge National Laboratory
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate matter
PPM	Parts per million
R&D	Research and Development
RCM	Rapid Compression Machine
SAE	Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SCR	Selective Catalytic Reduction
SI	Spark ignition
SwRI	Southwest Research Institute
TPGME	Tripropylene glycol monomethyl ether
UHC	Unburned Hydrocarbons
ULSD	Ultra-Low-Sulfur Diesel
ULSF	Ultra-Low-Sulfur Fuel
USDA	U.S. Department of Agriculture
VOC	Volatile Organic Compounds
VVT	Variable Valve Timing
WVU	West Virginia University
ZDDP	Zinc dialkyldithiophosphate



A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. By investing in technology breakthroughs today, our nation can look forward to a more resilient economy and secure future.

Far-reaching technology changes will be essential to America's energy future. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a portfolio of energy technologies that will:

- Conserve energy in the residential, commercial, industrial, government, and transportation sectors
- Increase and diversify energy supply, with a focus on renewable domestic sources
- Upgrade our national energy infrastructure
- Facilitate the emergence of hydrogen technologies as vital new "energy carriers."

The Opportunities

Biomass Program

Using domestic, plant-derived resources to meet our fuel, power, and chemical needs

Building Technologies Program

Homes, schools, and businesses that use less energy, cost less to operate, and ultimately, generate as much power as they use

Distributed Energy & Electric Reliability Program

A more reliable energy infrastructure and reduced need for new power plants

Federal Energy Management Program

Leading by example, saving energy and taxpayer dollars in federal facilities

FreedomCAR & Vehicle Technologies Program

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle

Geothermal Technologies Program

Tapping the Earth's energy to meet our heat and power needs

Hydrogen, Fuel Cells & Infrastructure Technologies Program

Paving the way toward a hydrogen economy and net-zero carbon energy future

Industrial Technologies Program

Boosting the productivity and competitiveness of U.S. industry through improvements in energy and environmental performance

Solar Energy Technology Program

Utilizing the sun's natural energy to generate electricity and provide water and space heating

Weatherization & Intergovernmental Program

Accelerating the use of today's best energy-efficient and renewable technologies in homes, communities, and businesses

Wind & Hydropower Technologies Program

Harnessing America's abundant natural resources for clean power generation

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